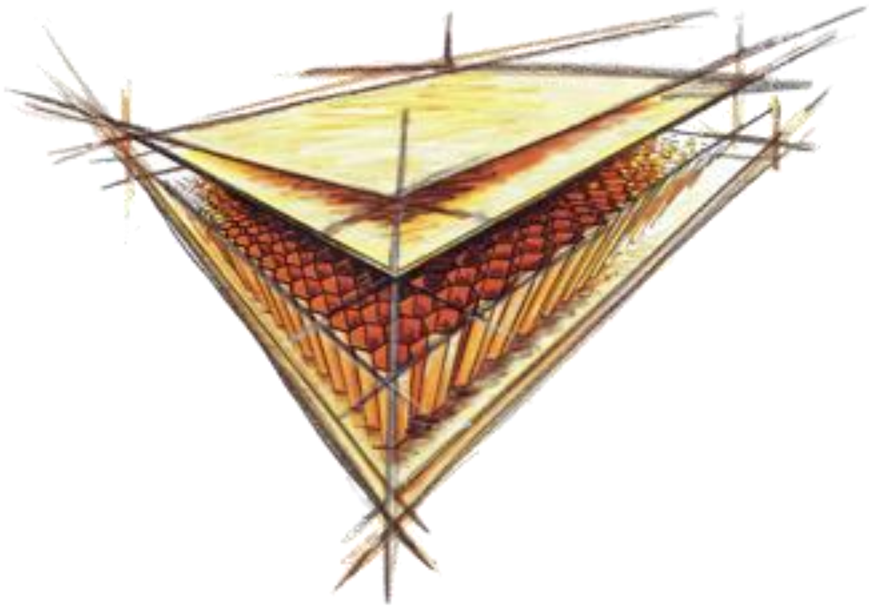

Martin Pütz

Digital unterschrieben von Martin Pütz
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3D Honeycomb for Curved Structure Manufacturing

3D Honeycomb

Agenda:

1. Introduction
2. Goal
3. 3D h/c applications, manufacturing, properties
4. Case studies
5. Demonstrator
6. Conclusion

Introduction

Project Participants:

EURO-COMPOSITES:	Martin Pütz Marco Wittlich
ESTEC:	Hermann Fischer Ugo Lafont Alexander Ihle
HPS:	Paolo Zolla

Goal

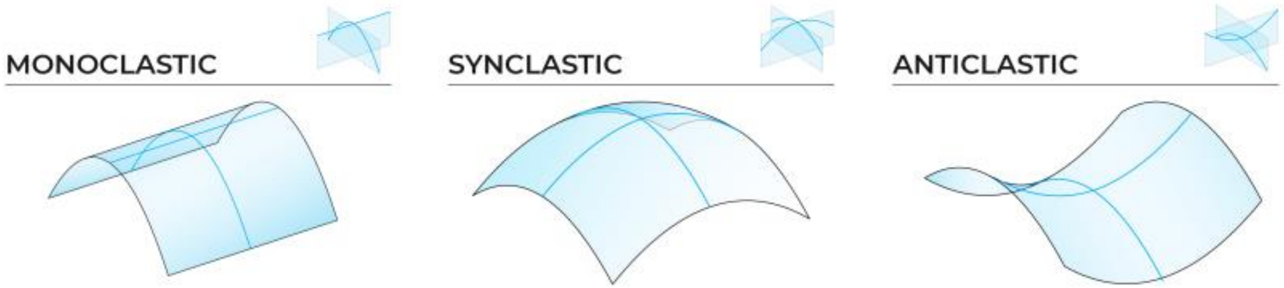
The objective of this activity is to:

- Demonstrate the added technological and manufacturing values using 3D honeycomb for curved composite structures
- Demonstrate the manufacturing process with tests on samples, breadboards and a (subscale) demonstrator
- Demonstrate the suitability for space applications

EC Claim:

- Ease of manufacturing of double curved structures
  - No/Less splicing or milling process
  - Lower risk, better surface quality and easier lay-up

3D honeycomb trade-off



		K1				
		++	+	0	-	--
K2	++	sc	sc	mc	ac	ac
	+	sc	sc	mc	ac	ac
	0	mc	mc	flat	mc	mc
	-	ac	ac	mc	sc	sc
	--	ac	ac	mc	sc	sc

sc	synclastic
mc	monoclastic
ac	anticlastic
++	high pos. Curvature
+	low pos. Curvature
0	no Curvature
-	low neg. Curvature
--	high neg Curvature

3D	3D or Hex	Hex

Possible 3D honeycomb applications

Business class seats

Radome

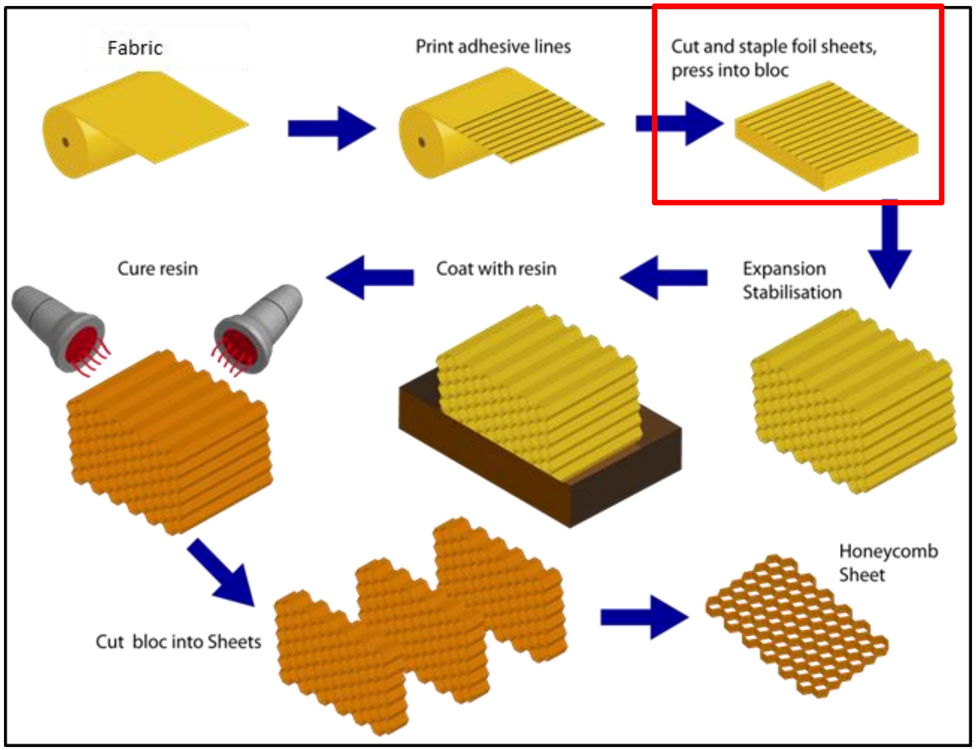
Ground antenna

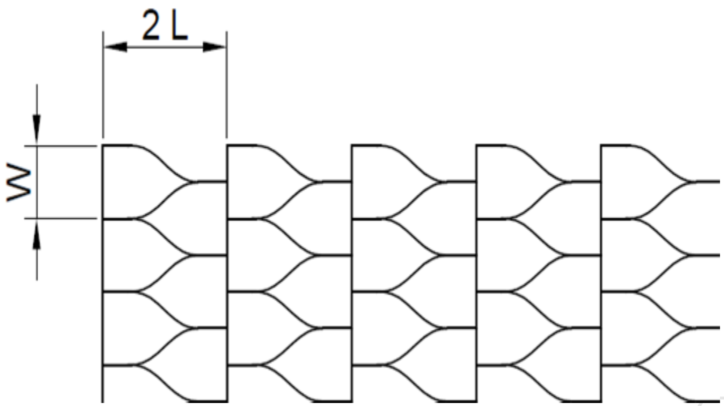
Payload fairing

Launch vehicle adapter cone

Antenna reflector

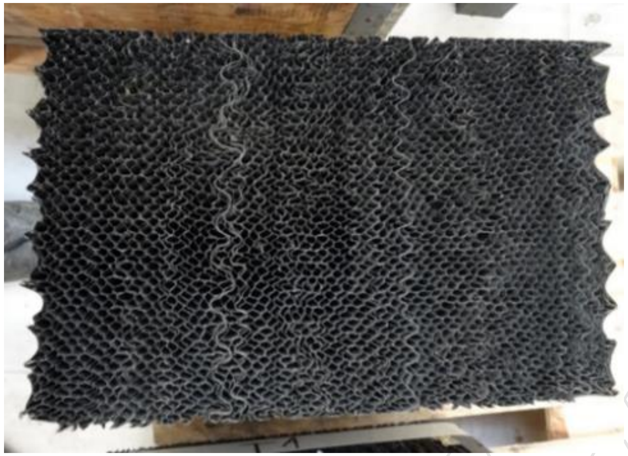
3D honeycomb manufacturing





3D honeycomb manufacturing trials

Basic material	E-Glass	Quartz-Glass	carbon fibres	Al 3003	Al 5056	Al 5052
Fabric/ Foil	81/105 gsm	60 gsm	60/68 gsm	60 µm	33 µm	33 µm
Density [kg/m³]	64	-	-	160 / 105	65	72 / 36
Status	Successful	Failure (expanding)	Failure (expanding)	Successful	Successful	Successful



3D honeycomb mechanical properties

Product type*	Cell size (mm)	Density ($kg.m^{-3}$)	Compression ASTM C365		Plate Shear ASTM C273			
					L-Direction		W-Direction	
			Strength (MPa)	Modulus (MPa)	Strength (MPa)	Modulus (MPa)	Strength (MPa)	Modulus (MPa)
Al 5056	3.2	72	4.83	1276	3.10	483	1.79	262
3D Al 5056	3.0	70	3.80	1187	2.77	462	1.23	147
3D/Hex			-21.3%	-7.0%	-10.6%	-4.3%	-31.3%	-43.9%
E-Glass	4.8	64	4.15	315	1.8	100	1.10	50
3D E-Glass	5.0	64	3.70	374	2.00	123	1.10	48
3D/Hex			-10.8%	18.7%	11.1%	23.0%	0.0%	-4.0%

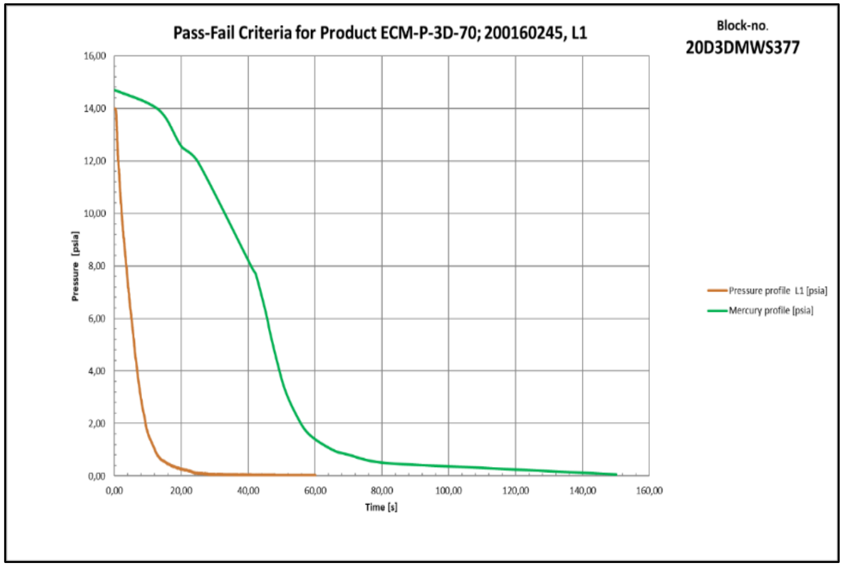
* All data presented are based on tests related to the development phase.

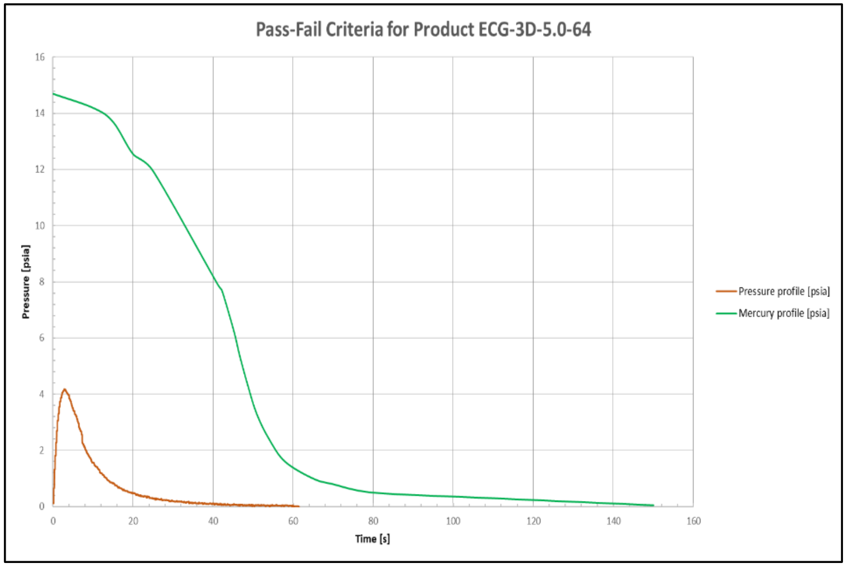
Better mechanical properties →

3D	3D or Hex	Hex

← **Less Splice/easier manufacturing/less manufacturing costs**

Venting / Outgassing

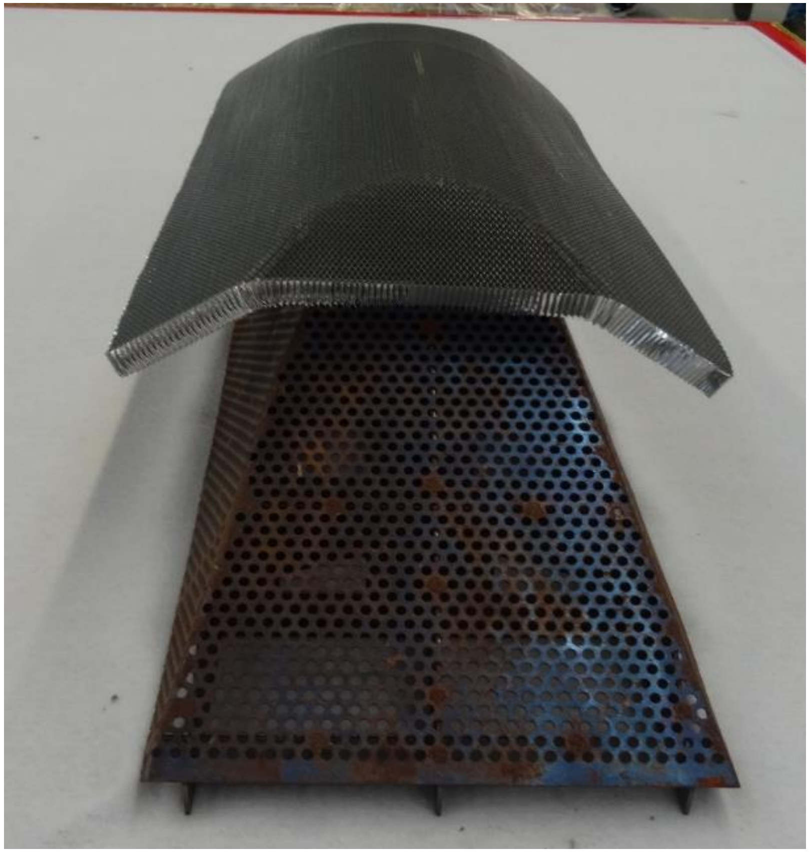




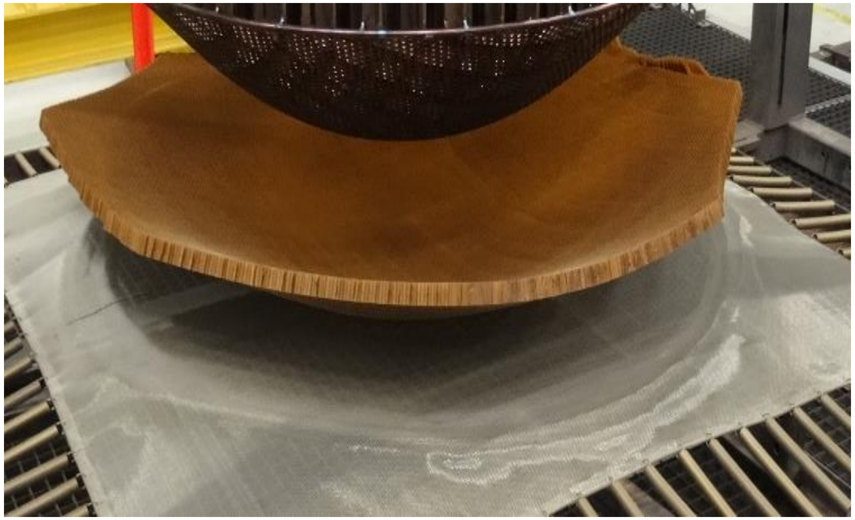
Honeycomb type	Actual results (mean value)	Acceptance Value *	Actual results (mean value)	Acceptance Value *	Actual results (mean value)	Acceptance Value *
	RML %	RML %	CVCM %	CVCM %	TML %	TML %
ECM-P-3D 3.0-70 (5056)	0,047	< 1,0	0,012	< 0,10	0,081	-
ECG 4.8-64	0,280	< 1,0	0,000	< 0,10	0,799	-

* In accordance to ECSS-Q-ST-70-02C

Preforming trials



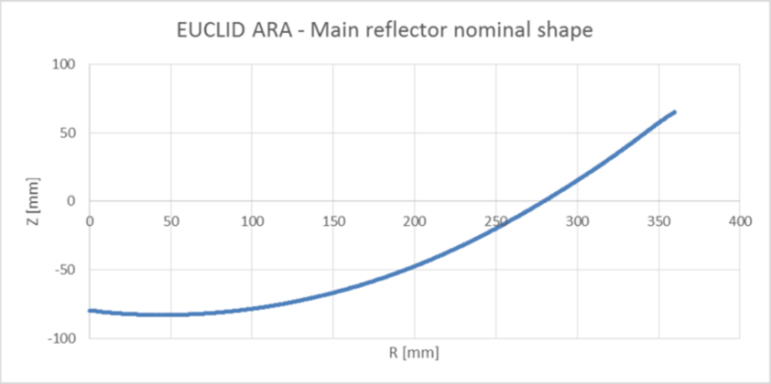
Deformation radius100mm
Sheet thickness: 16 mm

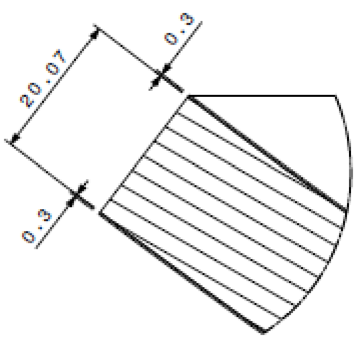


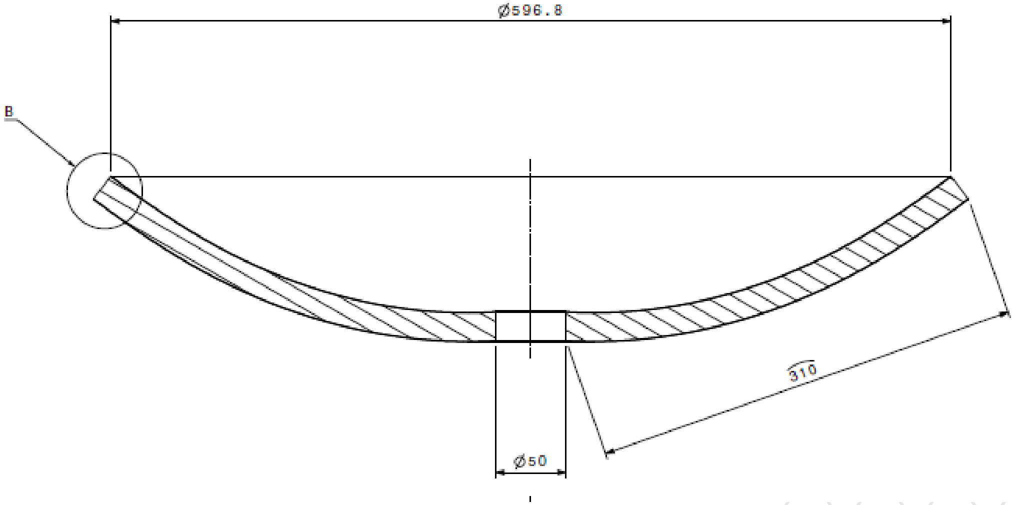
Antenna reflector shape
Sheet thickness: 19 mm

Case study 1 (antenna reflector) input

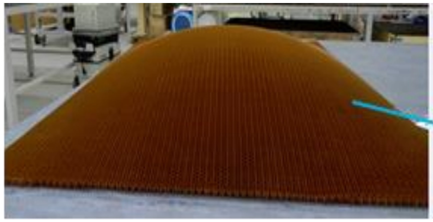
Input by HPS (Munich)



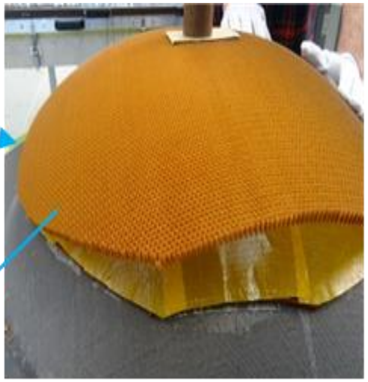




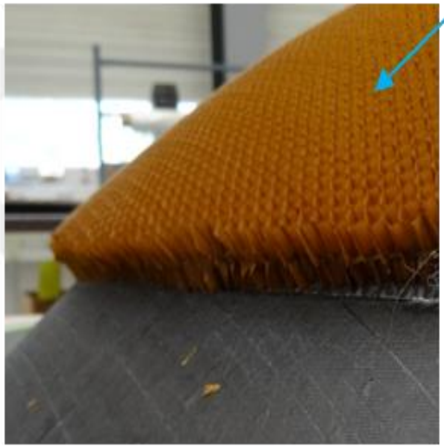
Case study 1 (Antenna reflector)



Heat formed core segment



Trimmed segment on the lay up tool



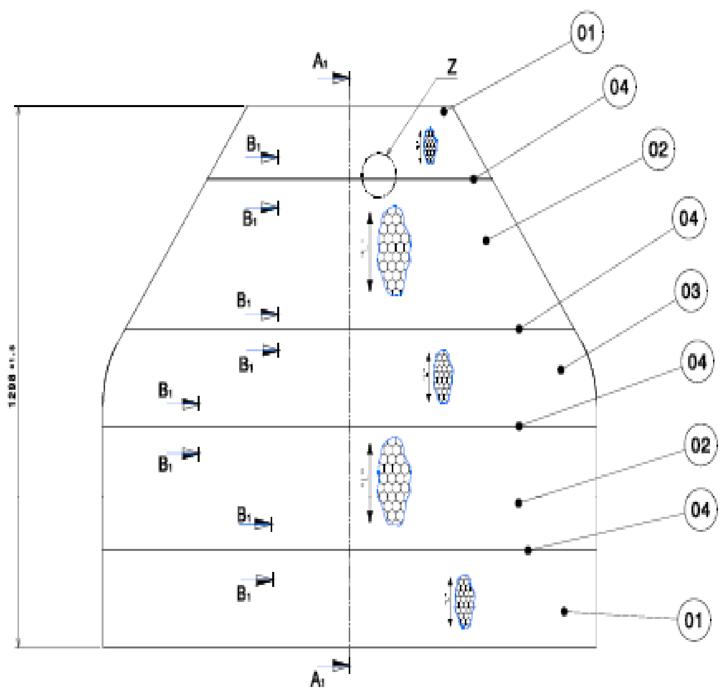
Formed core after bonding

Materials:

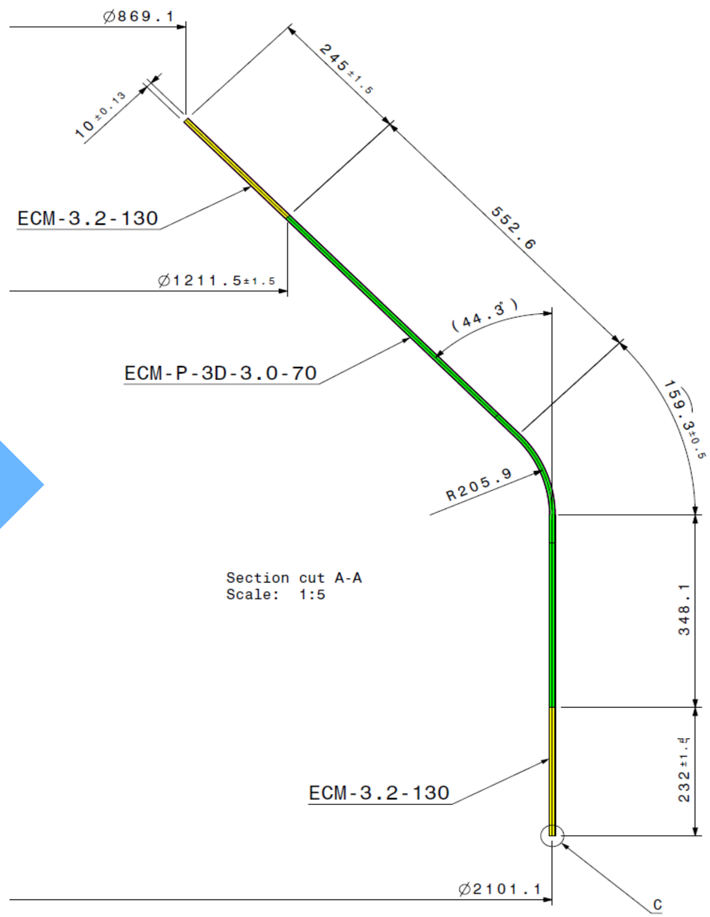
- ECG-3D 5.0-64, 3D honeycomb
- UD carbon prepregs
- Epoxy adhesive film

Case study 2 (VESPA) Input

Input by Airbus Madrid



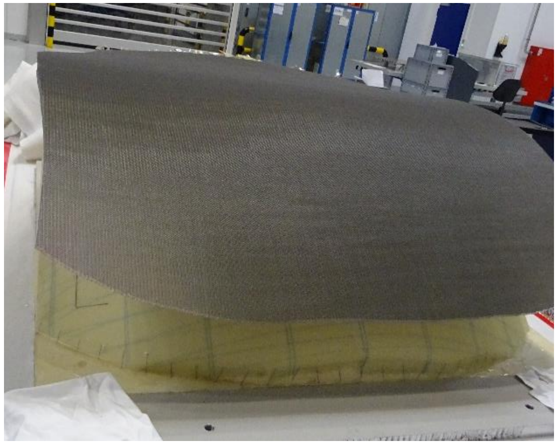
1: 130 kg/m³
2: 50 kg/m³
3: 104 kg/m³

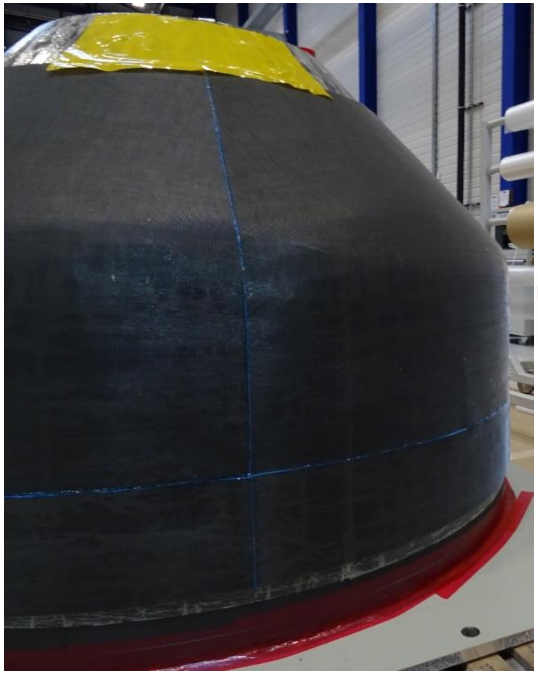


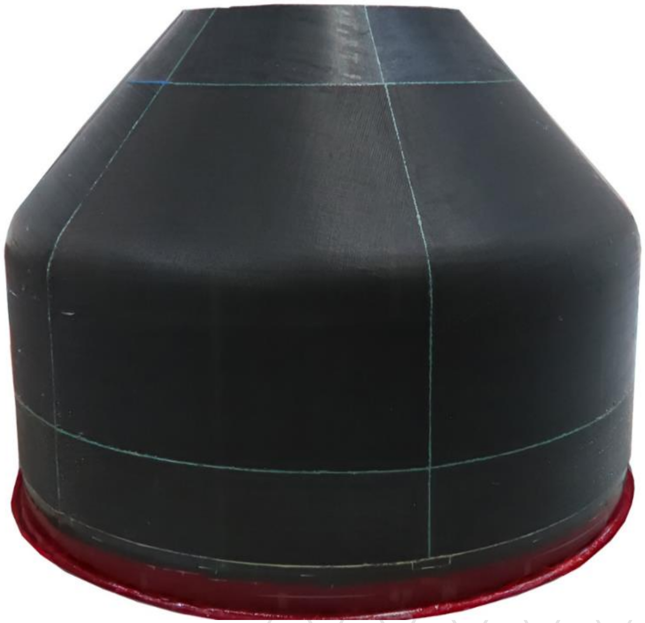
Case study 2 (VESPA)

Materials:

- ECM-P-3D 3.0-70 (5056) , 3D h/c
- UD carbon prepregs
- Epoxy adhesive film







Feedback on case studies

HPS on Antenna Reflector

- If machining can be avoided, this would be a big step to a more robust process
- Core density should be lower
- Splitting of the core introduces complexity
- Fabric prepregs should be used
- HPS using aluminium cores

Airbus on VESPA

- Applicability of 3D aluminium core is unlikely
- For Airbus it's not easy to introduce new material
  - High amount of tests and qualification efforts
- Double curved structure are rather the exception

Case study influences on demonstrator

Case Study 1 - Antenne reflector with Glass fibre 3D H/C-core

Case Study 2- VESPA structure with Aluminium 3D-H/C core

Demonstrator Antenna reflector with Aluminium 3D-H/C core

Prepreg:

- Fabric
- Higher resin content

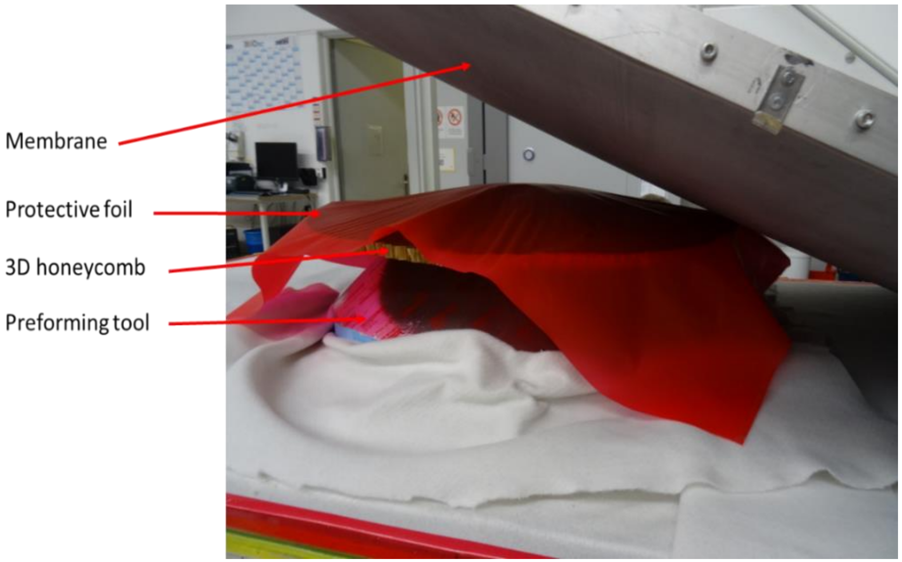
Curing:

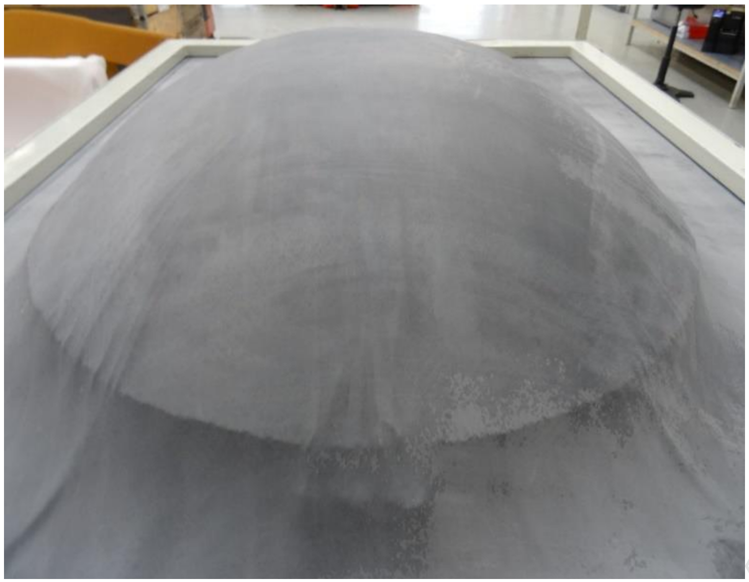
- Autoclave

Core:

- Aluminium core
- One 20 mm thick sheet
- Full size

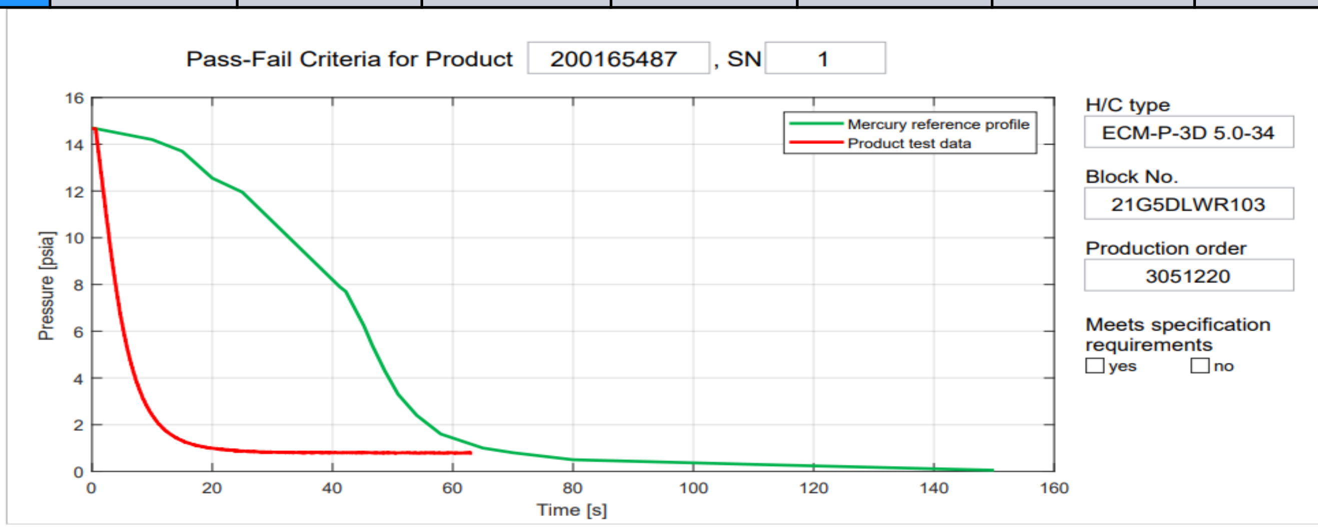
Preforming trial





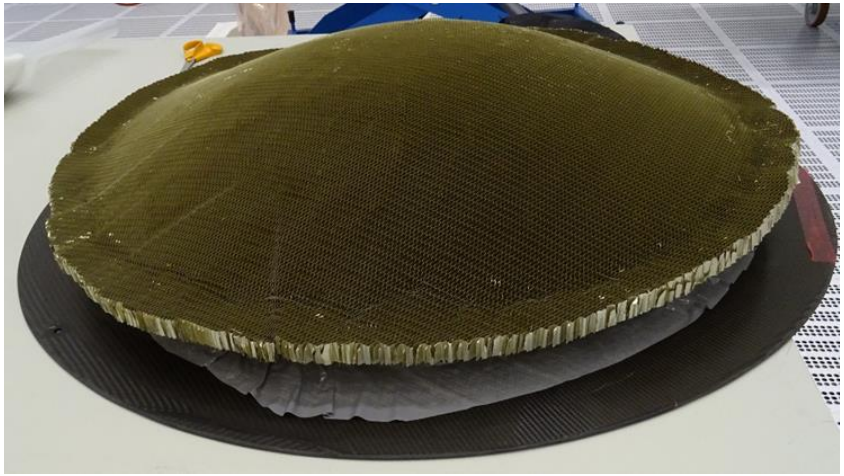
Mechanical properties / Venting

Product type*	Cell size (mm)	Density (kg.m^{-3})	Compression ASTM C365		Plate Shear ASTM C273			
					L-Direction		W-Direction	
			Strength (MPa)	Modulus (MPa)	Strength (MPa)	Modulus (MPa)	Strength (MPa)	Modulus (MPa)
ECM 4.8-32 5056 PAA-CP	4.8	32	0.93	208	0.92	266	0.52	126
ECM-P-3D 5.0-34 PAA-CP	5.0	34	0.86	164	0.58	195	0.38	80
3D/Hex			-7.5%	-21.2%	-37.0%	-26.7%	-26.9%	-36.5%



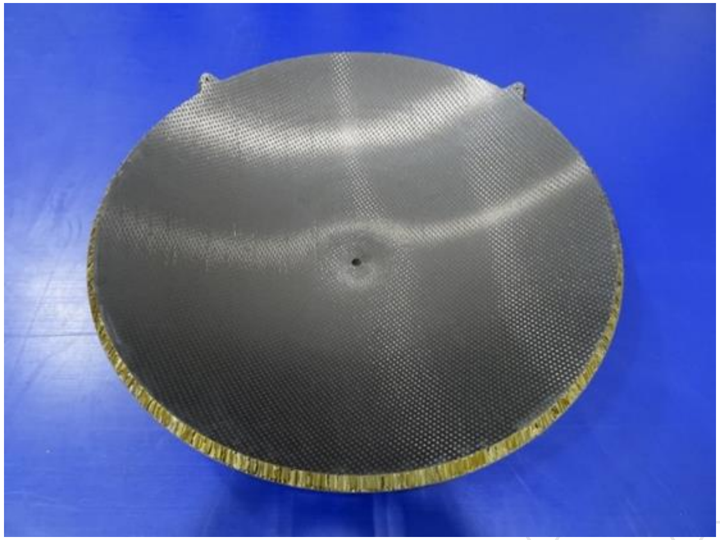
Venting test performed according PCD ECP204-00

Demonstrator (Antenna reflector)



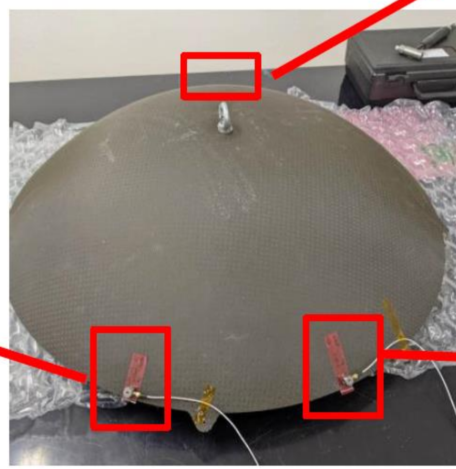
Materials:

- ECM-P-3D 5.0-34 5056 PAA-CP, 3D h/c
- Twill carbon prepregs (0,63mm/side)
- Epoxy adhesive film – Hexbond 319L

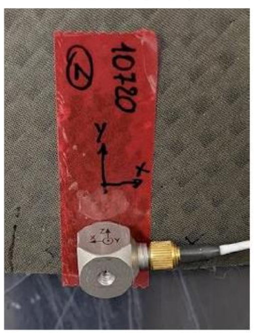


Modal measurement

Excitation point
Node 14151
(Not visible in the overall picture)



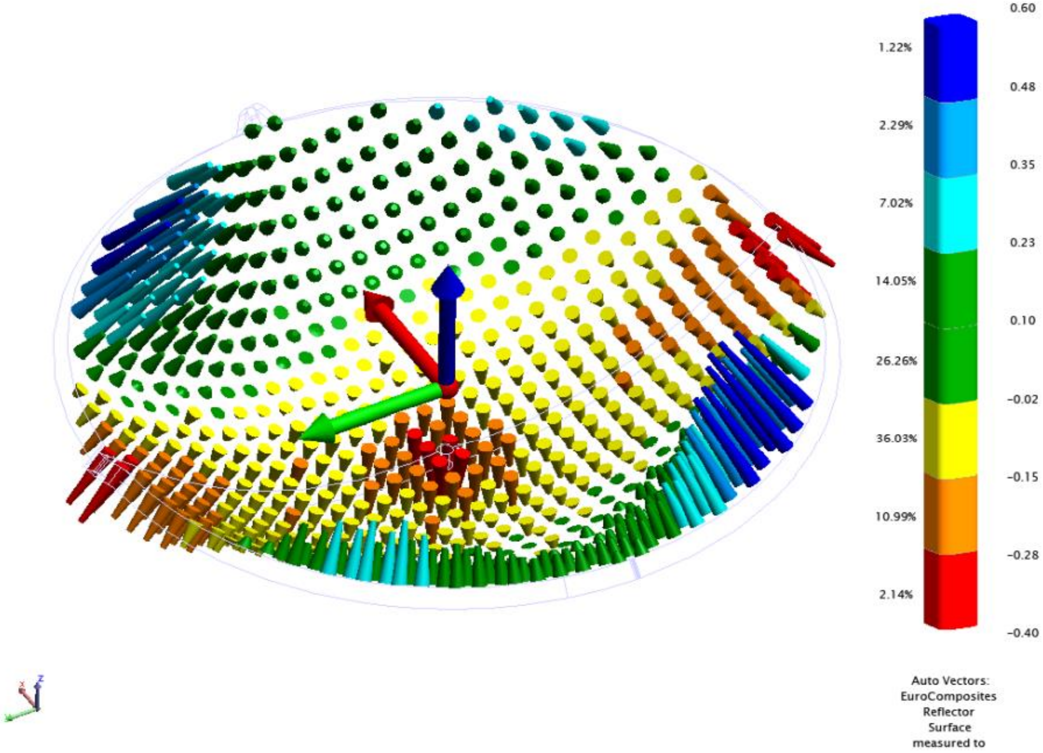
Accelerometer 1
Node 10720



Accelerometer 2
Node 12819

	Measured frequency [Hz]	Predicted frequency [Hz]	Difference
Mode 1	**168**	**158**	**+6%**
Mode 2	323	370	-13%
Mode 3	556	606	-8%
Mode 4	565	691	-18%

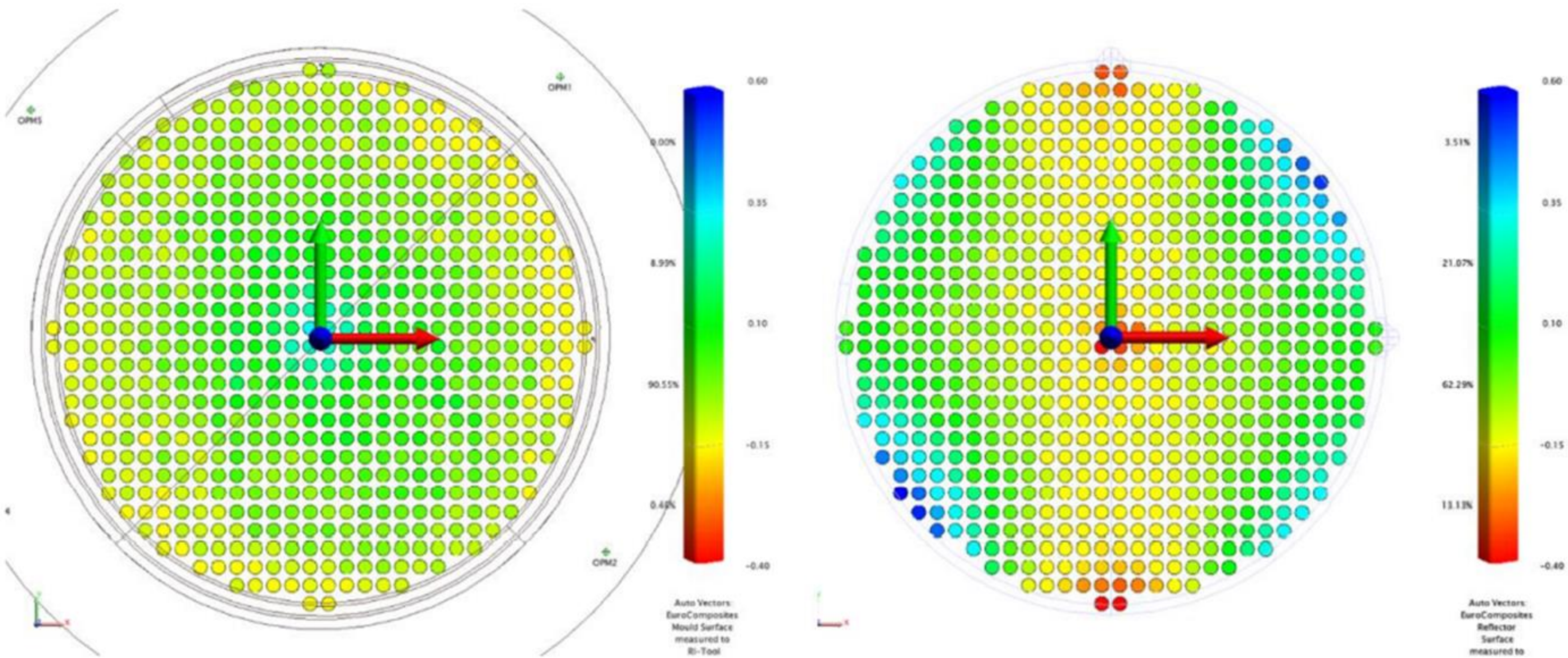
Surface accuracy measurement



	dX [mm]	dY [mm]	dZ [mm]	Mag [mm]
Min	-0.29	-0.26	-0.39	-0.40
Max	0.32	0.25	0.45	0.60
Average	-0.00	0.00	-0.00	0.01
StdDev from Avg	0.07	0.07	0.13	0.16
StdDev from Zero	0.07	0.07	0.13	0.16
RMS	0.07	0.07	0.13	0.16

Distance (in mm) between the measurement points and the CAD model of the reflector

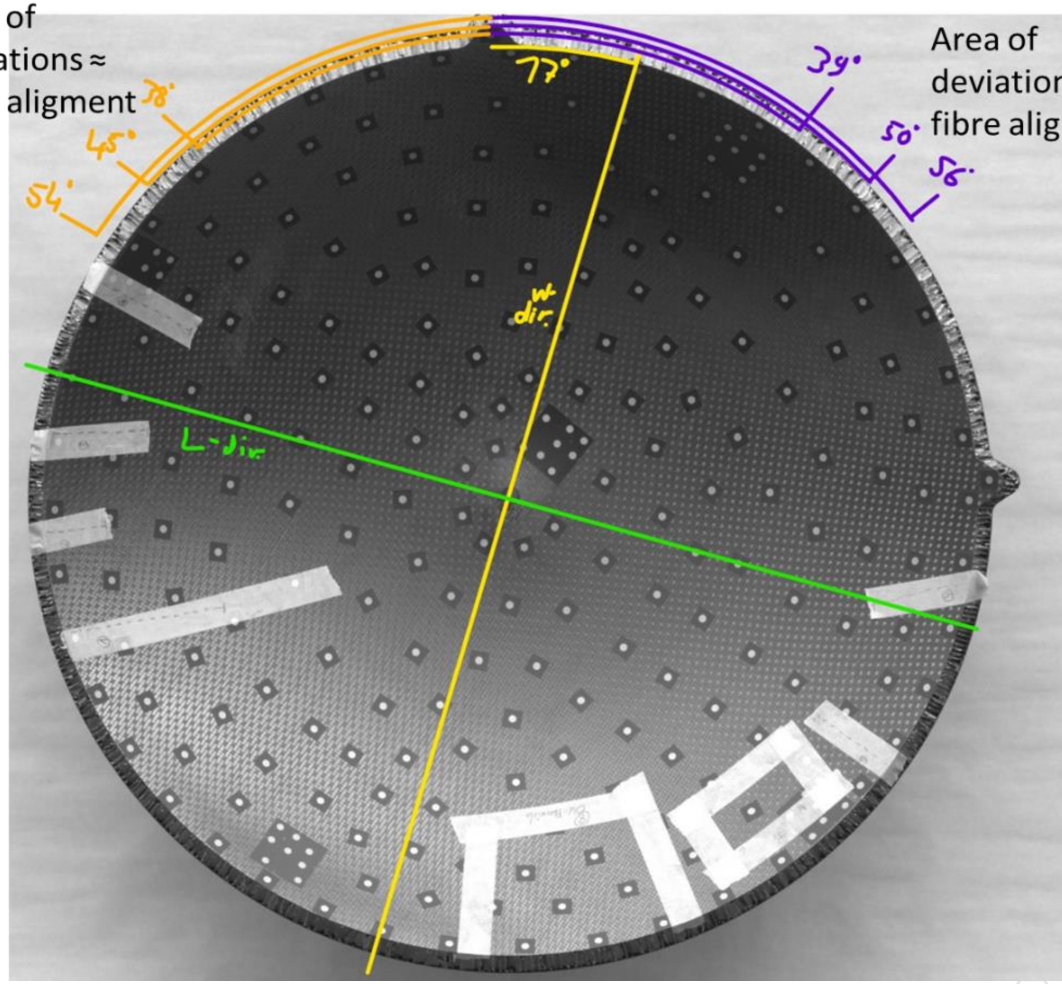
Comparison mould (Lay-up tool) vs Antenna refector



Distance (in mm) between the measurement points and the CAD model of the mould / reflector. The color scale is the same for the two plots

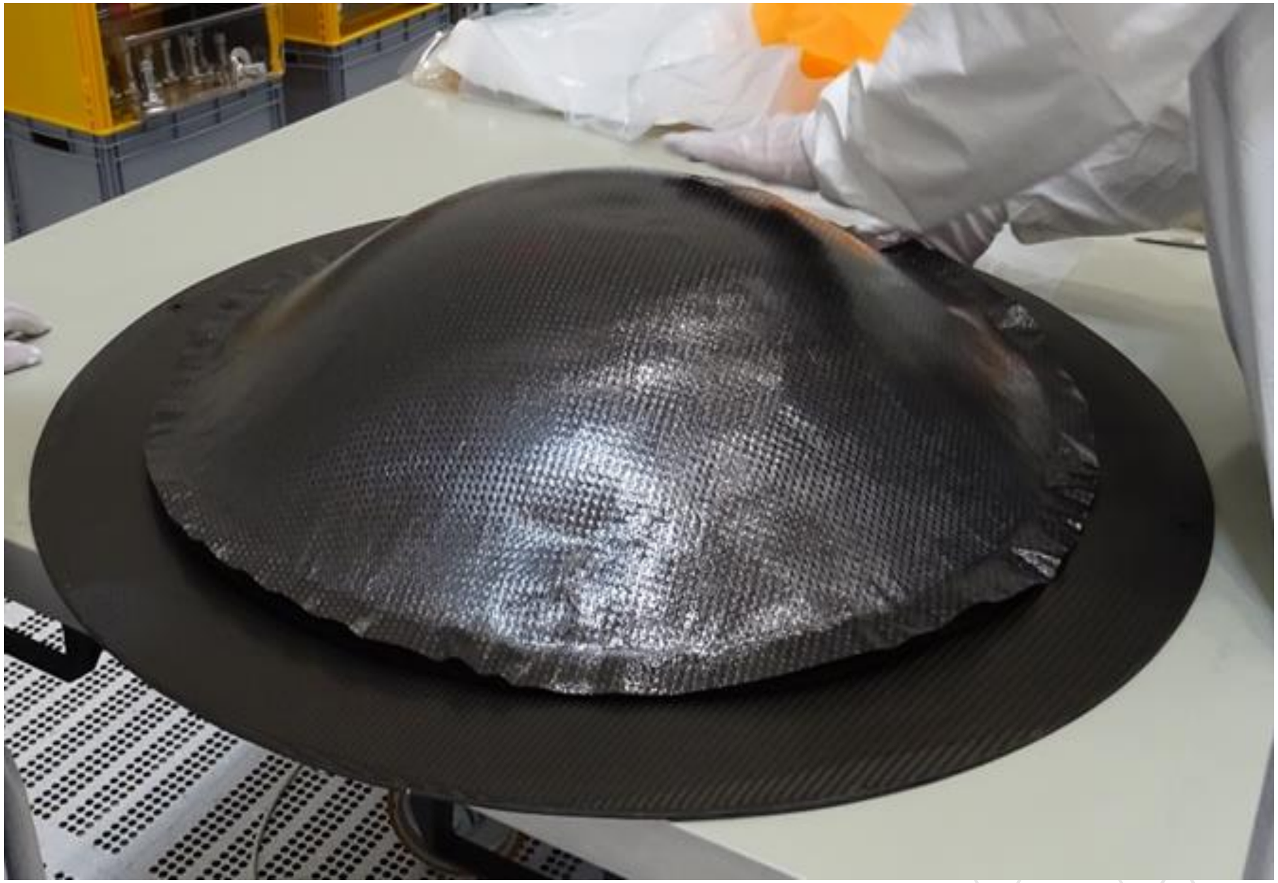
Fibre alignment surface accuracy

Area of deviations ≈ fibre aligment



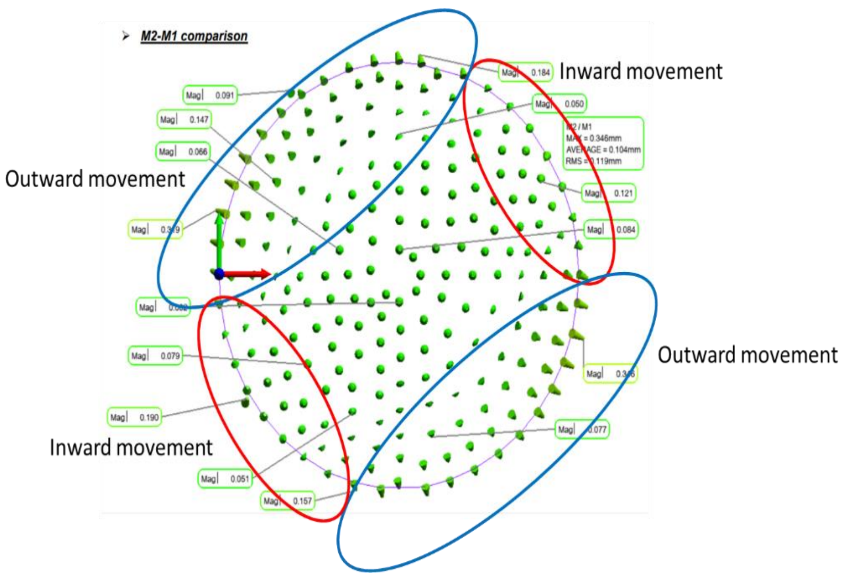
Area of deviations ≈ fibre aligment

Fibre alignment surface accuracy



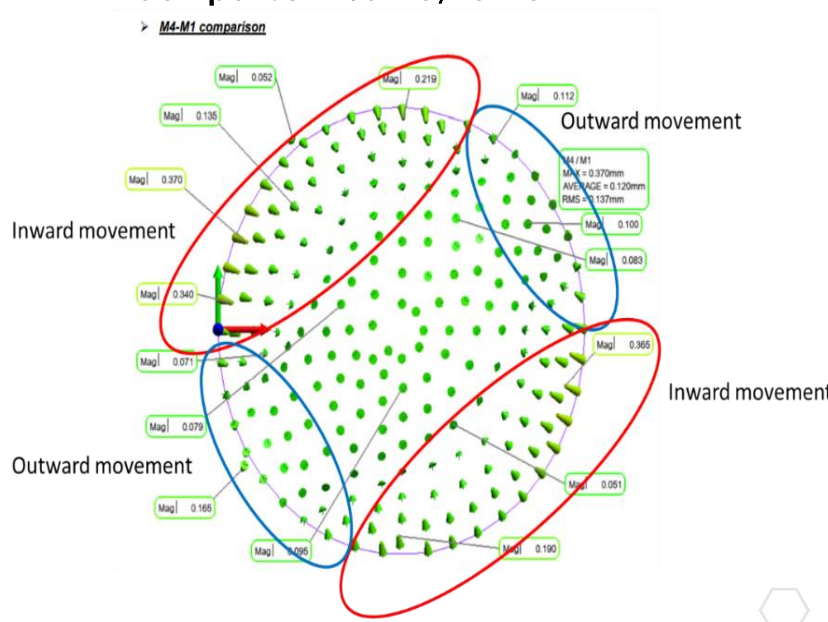
Thermal elastic distortion (TED) test

Comparison 100° C/20° C



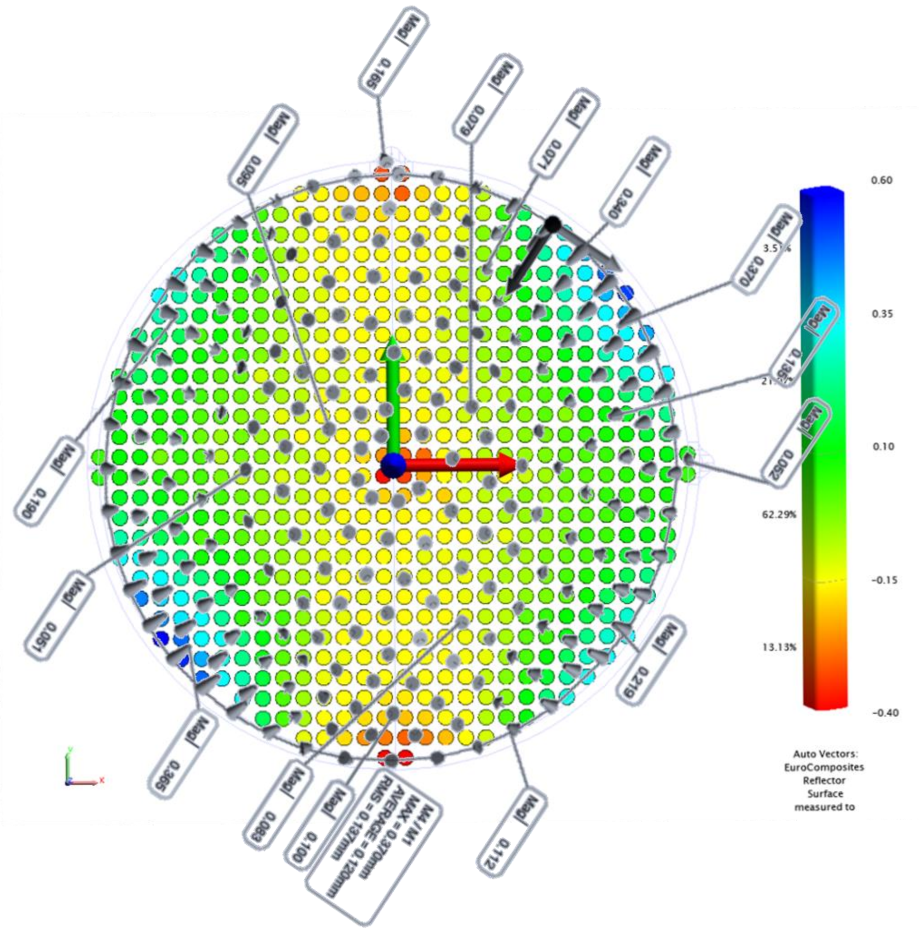
Max.: 0,346mm
Av.: 0,104mm
RMS: 0,119mm

Comparison -50° C/20° C



Max.: 0,370mm
Av.: 0,120mm
RMS: 0,137mm

Thermal elastic distortion (TED) test



Comparison Surface Accuracy and TED (-50° C/20° C) measurement

Conclusion 3D honeycombs

- Successful double curved structure manufacturing
- High potential to avoid extensive milling and splicing
  - Labor time and cost reduction
- Enables to build parts with:
  - Double curvatures
  - Smaller bending radii