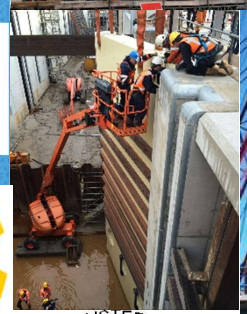
Technology Transfer Group: Infrastructure

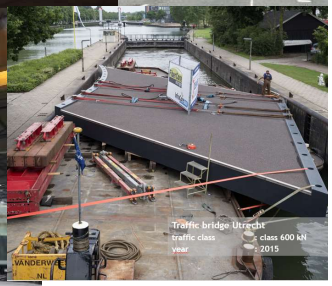
Structural health monitoring in thick-walled FRP structures

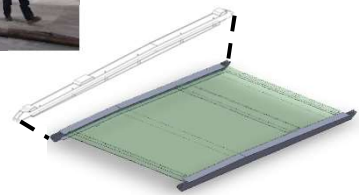
Bremen, 29-01-2020









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Structural health monitoring in thick-walled FRP structures

- Inspection techniques
  - Non-destructive evaluation (NDE)
  - Structural health monitoring (SHM)
  - Sensor mapping

InfraCore inside

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Non-destructive evaluation (NDE)

SSC-463

INSPECTION TECHNQIUES FOR
MARINE COMPOSITE
CONSTRUCTION AND NDE

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Distribution is unlimited

SHIP STRUCTURE COMMITTEE
2012

RAMSSES

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StrengthBond Offshore

CompositesNL

FiberCore europe

InfraCore inside

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Non-destructive evaluation (NDE)

- Description of potential defects
- Non-destructive evaluation techniques
- Aerospace Damage & Repair Inspection Procedures
- Wind Turbine Blades
- Test panels & Case studies
- Summary & conclusions

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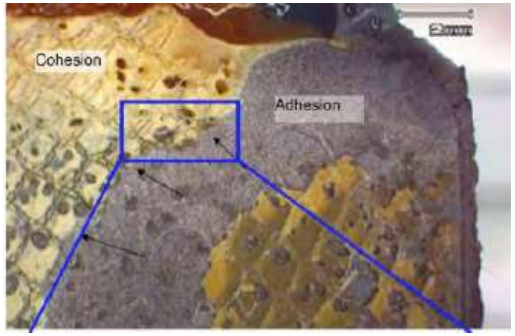
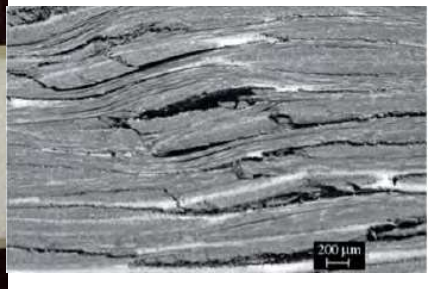
Non-destructive evaluation (NDE)

- Description of potential defects
  - Bonded joint failures (adhesive, cohesive, mixed)
  - Air bubbles
  - Blisters
  - Core crushing
  - Core shear failure
  - Crazing
  - Delaminations





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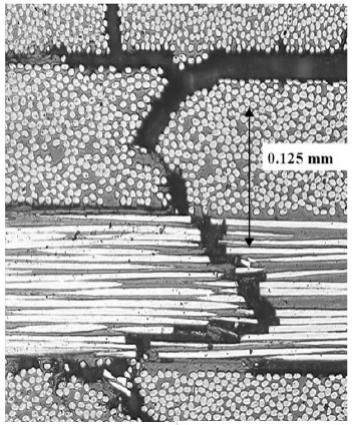
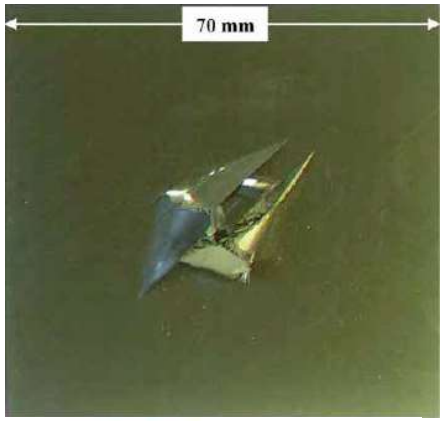
Non-destructive evaluation (NDE)

- Description of potential defects
  - Fibre failure
  - Kissing bond
  - Impact damage
  - Matrix cracking
  - Moisture ingress
  - Ply/fibre waviness
  - Resin rich/poor area





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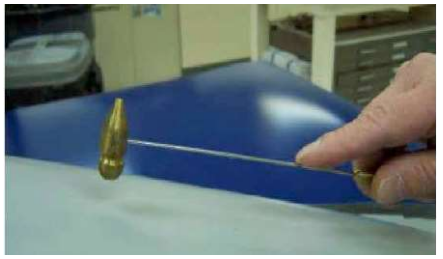
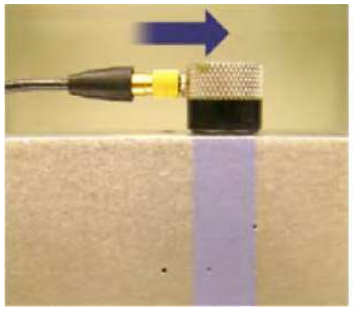
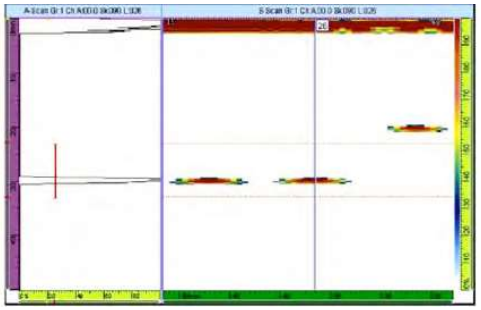
Non-destructive evaluation (NDE)

- Non-destructive evaluation techniques
  - Visual inspection
  - Tap testing
  - Ultrasonic inspection
  - X-radiography
  - Eddy current
  - Thermography
  - Moisture meters







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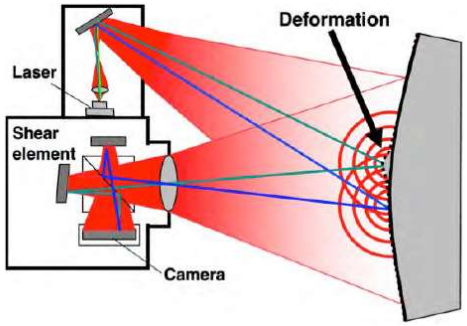
Non-destructive evaluation (NDE)

- Non-destructive evaluation techniques
  - Bond testers
  - Laser shearography
  - Modal methods
  - Structural Integrity and Damage Evaluation Routine (SIDER)
  - Acoustic emission



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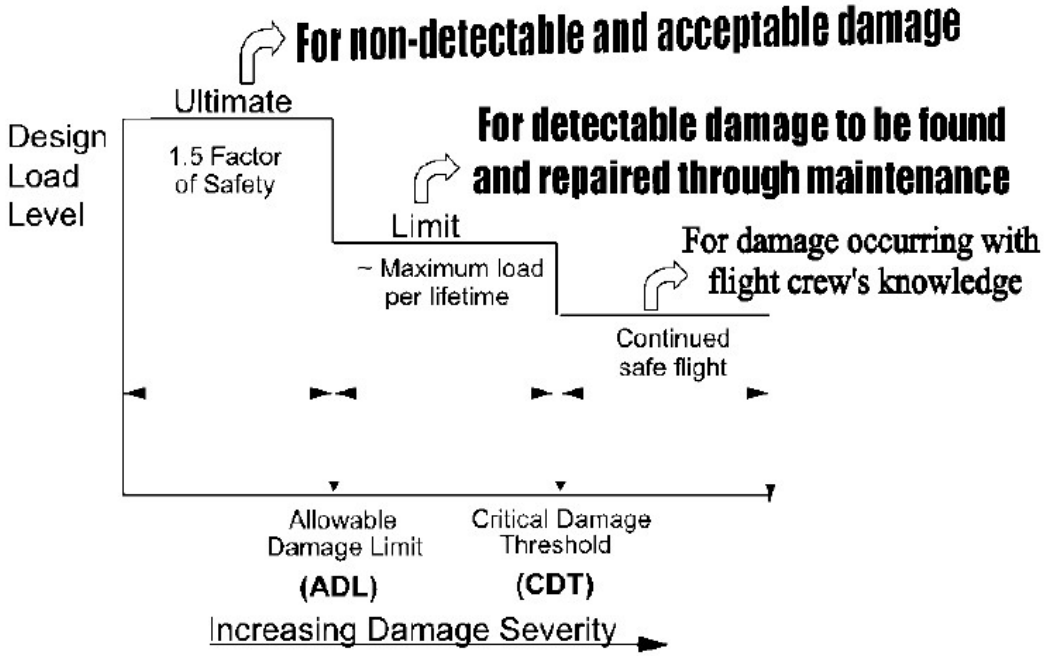
Non-destructive evaluation (NDE)

- Aerospace Damage & Repair Inspection Procedures



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Non-destructive evaluation (NDE)

- Aerospace Damage & Repair Inspection Procedures

	Test procedure	Outer skin Bonding	Inner Skin Bonding	Fluid	Estimated Insp. Time	Flaw size	Training	Remarks – Availability - Advantages – Constrains
FIT (field inspection technology)	Tap Test / Woodpecker				4h 3h	25 mm 50 mm	No	• High human factor!
	ELCH				2x4 h (2 Operators)	100mm	No / Introduction	• Simple, reliable, qualified • Development for improvement: OPTO-ELCH
	BONDMASTER	no procedure	no procedure		2x8h (2 Operators)	25mm	UT II + Special course	• Portable, reliable • Competing with UT
	Ultrasonic				48h	25mm	UT II +	• Procedure available • Equipment common • Not for large areas
	X-Ray				4-8h	1 cell	RT II	• Everywhere available • Safety?
	Thermography				4-h	1-3 cells	IRT Level I limited	• Relatively Cheap • Small and highly portable • Easy to use
Close to FIT	OptoELCH				2x4 h (2 Operators)	25mm	Introduction	• Simple, reliable, compact, cheap
	Shearography	missing threshold	too expensive		16h	25mm	SH II No course avail.	• Expensive/bulky • No quantitative deformation indication • Missing inspector certification scheme

Applicability Verified | In Development | With Adaptaion Possible | Potential | Not Applicable

Figure 69. Comparison of the effectiveness of NDE techniques for honeycomb sandwich structures by Airbus [Bisle 2010]

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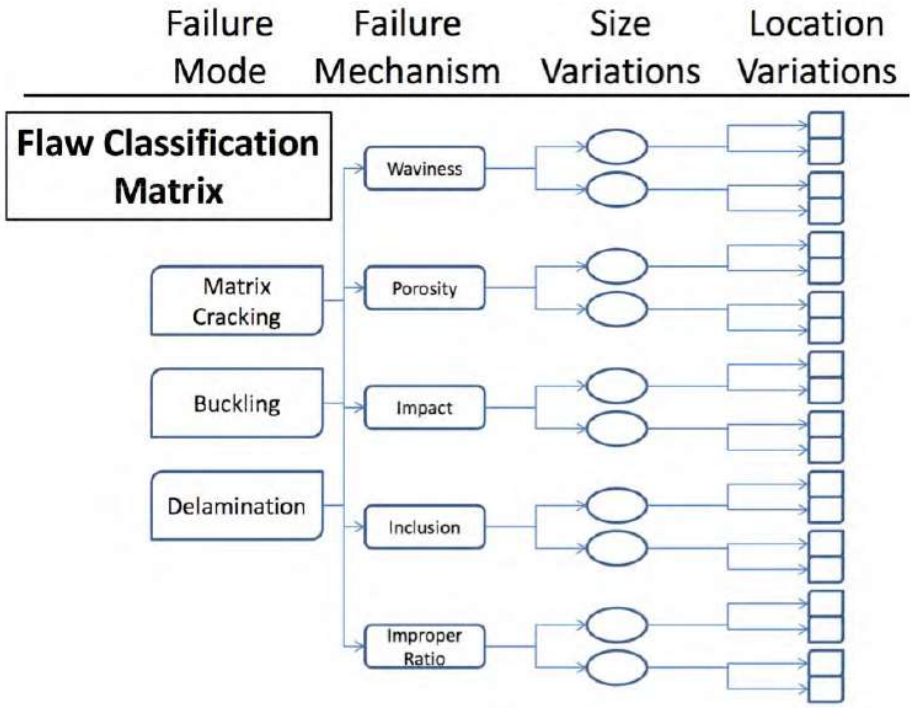
Non-destructive evaluation (NDE)

- Wind turbine blades
  - Visual
  - Ultrasonics
  - Shearography
  - SHM (FBG)



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Non-destructive evaluation (NDE)

- Test panels &
  Case studies

	Defect	Laser Shearography	Ultrasonic Inspection	Infrared Thermography	Digital Tap Hammer
Delamination	Min. Size Detected	2 inches	2 inches	3 inches	3 inches
	Max. Depth Detected	1- 2 plies	1 ply	2 – 3 plies	2 – 3 plies
	Overall Effectiveness	good esp. for kissing bonds	can't detect kissing bonds	can't detect kissing bonds	can't detect kissing bonds
Water Ingress	Min. Size Detected	2 inches	4 inches	2 inches	4 inches
	Max. Depth Detected	skin/core interface	skin/core interface	skin/core interface	skin/core interface
	Overall Effectiveness	good	use higher frequency transducer	very good	fair
Impact Damage	Min. Size Detected	1 inch	2 inches	1 inch	3 inches
	Max. Depth Detected	skin/core interface	1- 2 plies	skin/core interface	skin/core interface
	Overall Effectiveness	very good	good	good	only edge delaminations found
Void	Min. Size Detected	2 inches	2 inches	1 inch	defect not detected
	Max. Depth Detected	¼ inch	½ inch	¾ inch	
	Overall Effectiveness	fair with thick laminates	good for uniform laminates	very good	not effective
System limitations:		Requires good reflective surface – not good with matt finish black parts or clear gel coat; not good with thick or highly curved parts	Requires good calibration sample and uniform laminate; small probe area	Known good laminate required for baseline data; defect must produce a thermal gradient	Only effective with larger defects
Equipment cost:		≈ $100,000	≈ $40,000	≈ $10,000	≈ $1,500

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Non-destructive evaluation (NDE): conclusion

- By far the best NDE tool for marine composites is still the human eye. However, visual inspection cannot reveal the extent of damage with certainty.
- The initial assessment of NDE technologies revealed laser shearography, thermography, ultrasonic testing and digital tap hammers to be the most promising for marine composites inspection.

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Non-destructive evaluation (NDE): conclusion

from NDE Methods for Infrastructure Composites

Defects	Acoustic Emission	Acoustic Impact Testing	Eddy Current Testing	Modal Analysis	Optical Methods (Shearography)	Penetrant Testing	Radiographic Testing	Rapid Load Testing	Strain Measurement Techniques (Optical Fibers)	Thermographic Testing	Ultrasonics	Visual Testing
Delamination	C	A	0	?	A	0	A	?	C	A	A	C
Fiber Breakage	B	C	B	?	A	C	A	?	0	?	?	0
Fiber Waviness	0	C	B	0	A	0	A	?	C	?	?	C
Matrix Cracking	B	0	0	0	?	C	A	0	0	0	0	0
Moisture	0	0	?	?	?	0	C	?	0	C	C	0
Porosity	0	0	0	0	?	0	A	0	0	?	?	0
Resin Thickness Irregularities	0	0	0	0	?	0	A	0	C	?	?	0
Voids	0	C	0	?	A	0	A	?	0	C	C	0

A = High
(allows localization or accurate sizing)

B = Generally Detectable
(works generally well)

C = Limited Detectability
(may be used under certain conditions only)

0 = Not applicable
(will not detect the defect)

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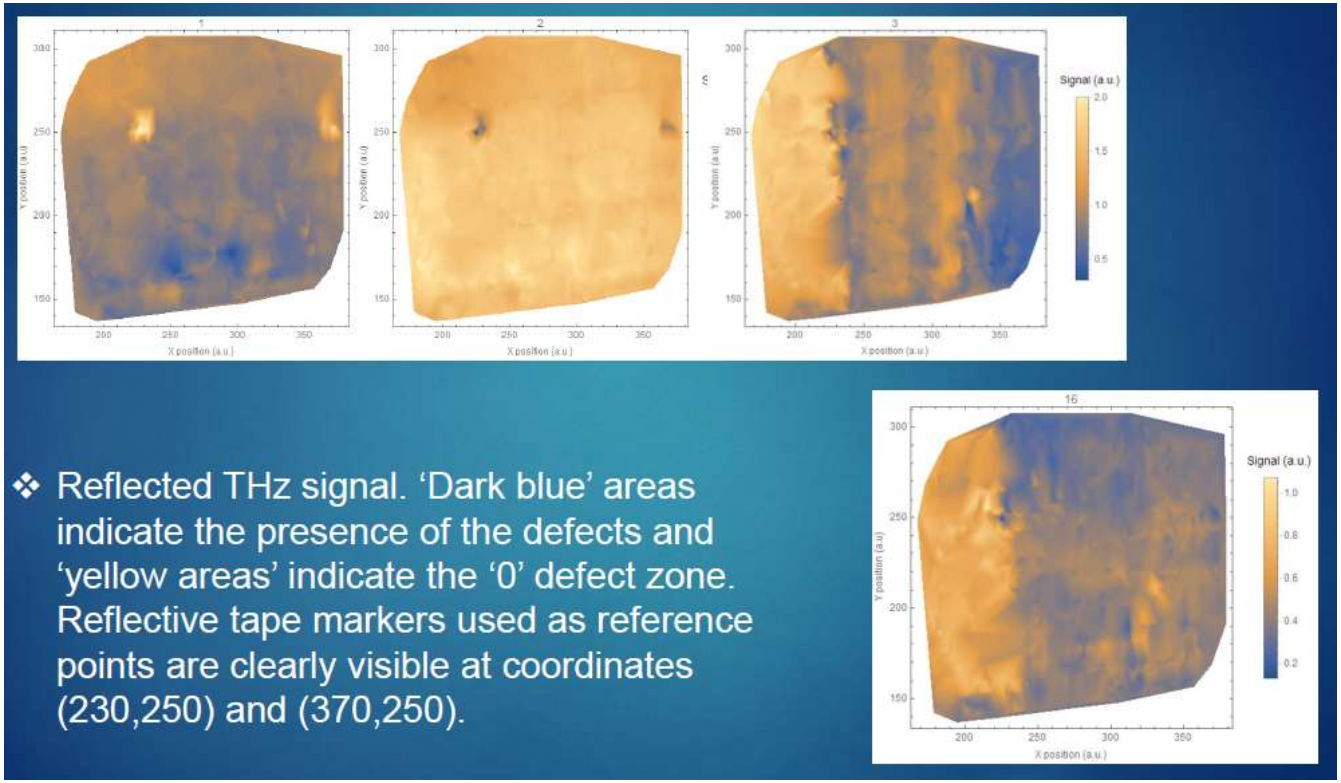
Non-destructive evaluation (NDE)

- Terahertz inspection



❖ Reflected THz signal. 'Dark blue' areas indicate the presence of the defects and 'yellow areas' indicate the '0' defect zone. Reflective tape markers used as reference points are clearly visible at coordinates (230,250) and (370,250).

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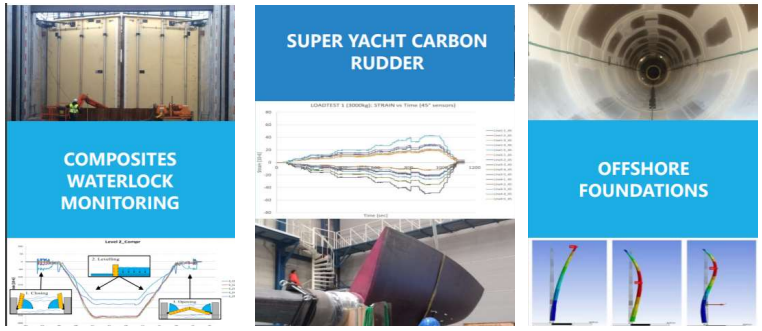
Structural health monitoring (SHM)

- Acoustic emission
  - See previous report
- Fibre Bragg Gratings
  - See presentation by E-LASS Vigo 2019



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Sensor mapping

AquaSmartXL

Remotely Controlled Aquatic Drones

- Flexible, easy and quick to deploy platform
- High quality sensors and data capturing
- Easy accessibility to difficult and dangerous to reach places
- Observation and inspection of assets as well as their surroundings

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Sensor mapping

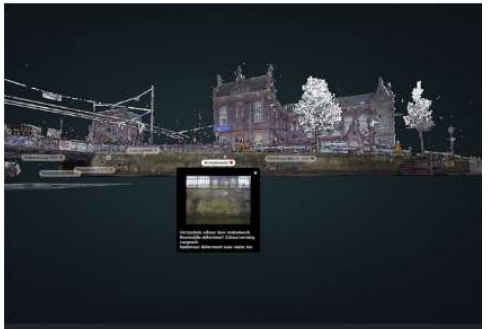
https://www.youtube.com/watch?time_continue=113&v=fWz4b2FxgkM&feature=emb_logo

INSPECT ASSETS

We operate where other technologies cannot, either because these technologies are too dangerous, too expensive or simply not practical to use

MAINTENANCE

We deliver a basis for Predictive Maintenance and Reliability Centred Maintenance. Repeatable measurements and modeling allows for tracking changes over time



DATA DRIVEN

Robust data processing chain covering acquisition, network communication, storage, processing, integration, visualisation and distribution risk mitigation

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Sensor mapping

Xtend Technology: visual inspection, NDT & sample drilling

Did You know that Xtend Technology already have inspected several bridges both in Norway and Germany . We Will soon Also include AI function and offer services where we are going from fly and see to fly, see & work. Meaning our Drone will perform NDT and drilling like sampling of concrete test samples and other

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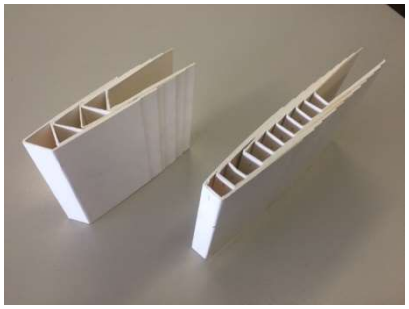
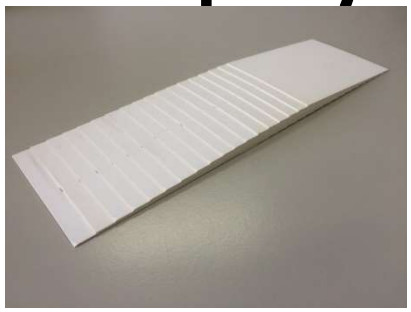
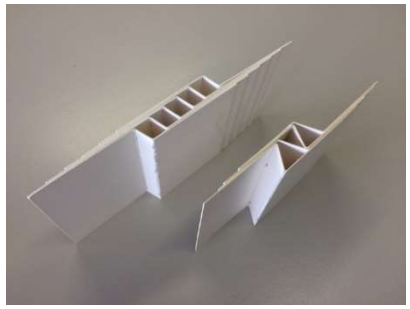

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