

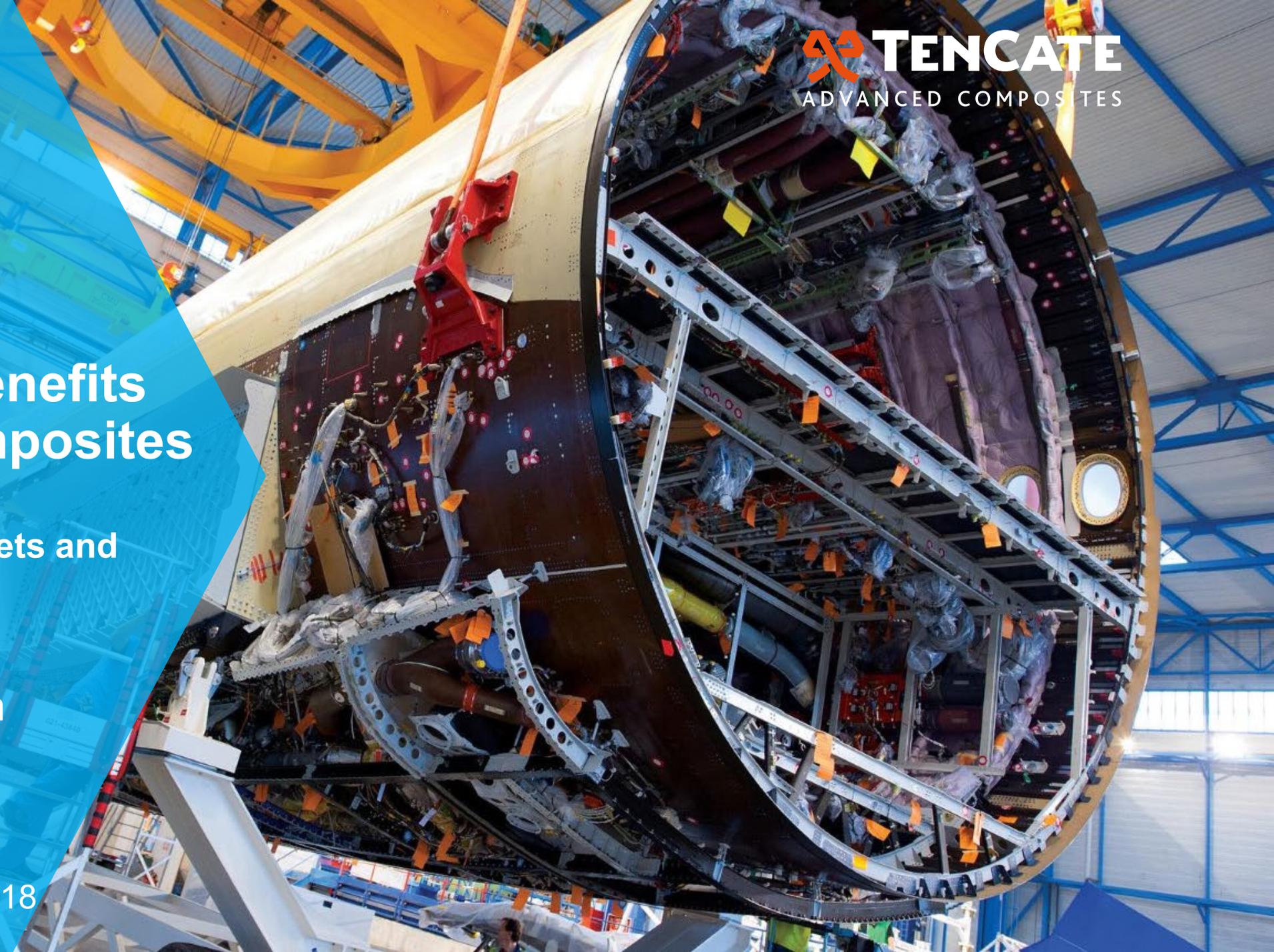
# Compound Benefits of Hybrid Composites

Maximising Thermosets and  
Thermoplastics

Dr. John Darlington

Global Director Product and  
Market Strategy

CAMX, October 18th 2018



# Organization Overview

## › TenCate Advanced Composites

- › Total Employees: 750; Sales - \$200+ MM
- › Manufacturing in North America, Europe, and China

## › Toray Group

- › Total Employees: 46,000; Sales - \$20 BN
- › Manufacturing in North America, Europe, and Asia

## › Markets Served

- › **Aerospace** - Aerostructures, Aircraft Interiors, Radomes, Satellite/Launch
- › **High Performance Industrial** - Consumer Electronics, Footwear/Orthotics, F1 Racing, Tooling

## › Key Product Lines

- › Thermoset Prepregs
- › Thermoplastic Prepregs and Laminates
- › Low Density Syntactic Films
- › Film Adhesives and Surfacing Films,
- › Honeycomb core and Syntactics
- › Bulk Molding Compounds and Molded Parts

# Core Competence

Vision and Values

## WHO WE ARE

- We are a company that makes a difference in our industry & with customers by being responsive and dependable

## OUR CORE VALUES

- Responsive
- Collaborative
- Reliable
- Partnership oriented

## WHAT WE DELIVER

- Advanced Composite Material Solutions and Expert Services



## WHO WE SERVE

- Customers who need and value a responsive partnership-oriented organization with broad advanced composite materials technologies

In the following markets:

- Aerospace
- High Performance Industrial

## HOW WE ARE DIFFERENT

- We surround our customers with collaborative technical teams to reduce risk, speed material implementation, and then back that with outstanding customer service

# Portfolio Snapshot

Advanced Composites

- › Largest supplier of **ultra pure/low dielectric prepregs** for commercial aerospace SATCOM, military and shipboard **radome** structures.
- › Key supplier of **epoxy prepregs** to the **general aviation, launch vehicles, helicopter programs, and UAV industries** (*Cirrus, Kestrel, ICON, General Atomics Predator/Reaper, Boeing Apache, Marengo Swisshelicopter, Erickson AirCrane, Rocket Lab*).
- › The leading supplier of **high-modulus advanced composites** for satellite structures.
- › Primary supplier of **thermoplastic-based composites** for commercial aerospace structural and interior applications under the TenCate **Cetex**® Thermoplastic brand.
- › Key provider of **composite tooling prepregs** under TenCate **AmberTool**® brand.
- › Provider of chopped fiber **compression molded parts** with internal tool design and part fabrication capabilities.



# Principle Markets

Commercial Aircraft  
T/P for *primary and secondary structure*



Military Aircraft *incl High Temp Materials*



Unmanned Systems



Space/Satellites and  
Launch Vehicles

Radomes and  
Antennas



Aircraft Interiors

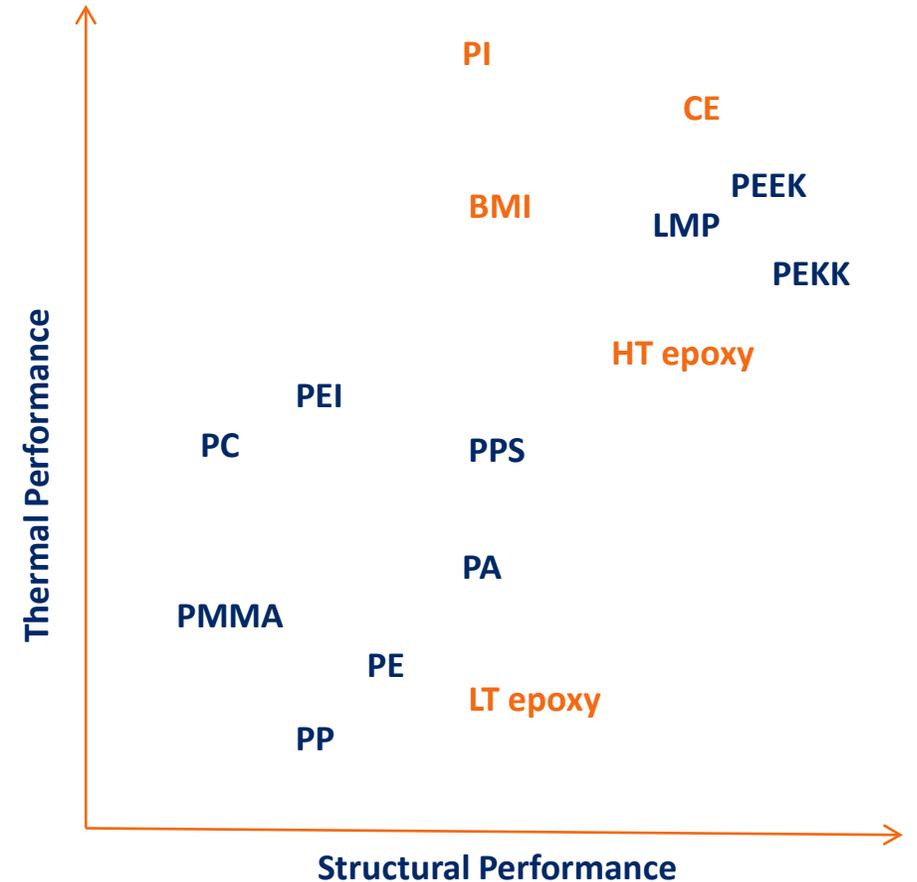
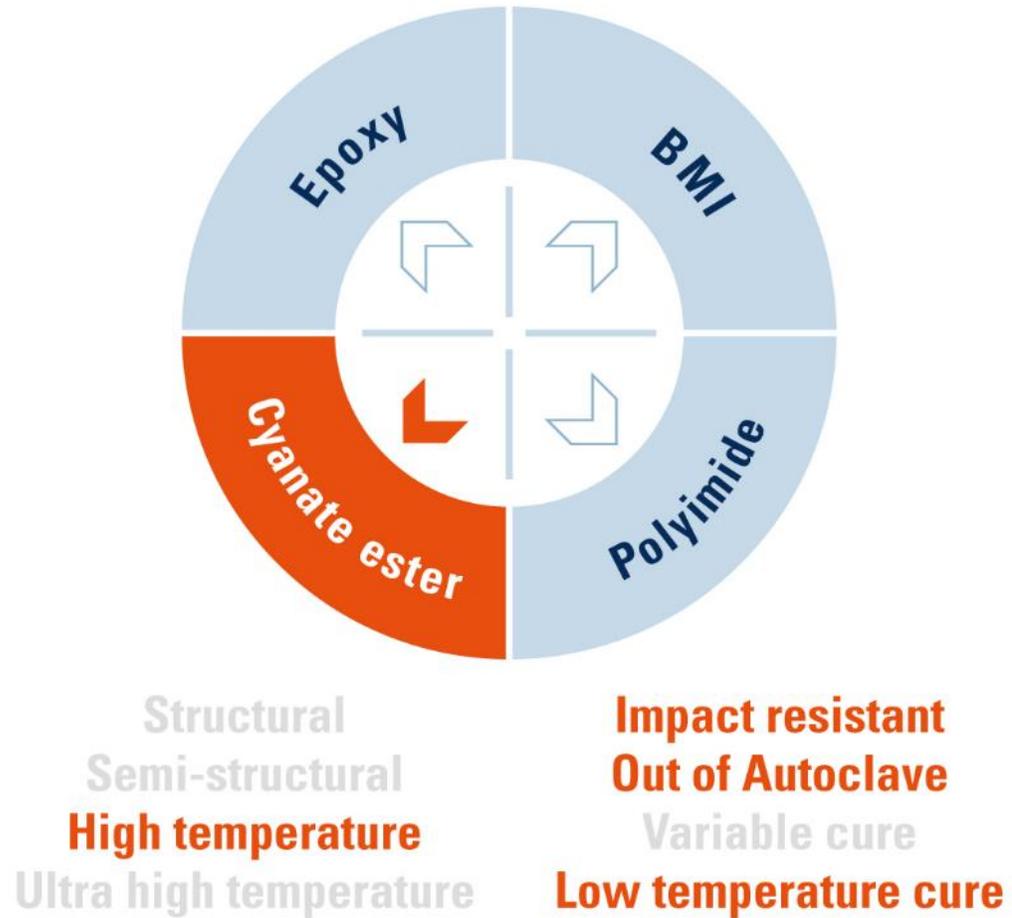


General Aviation



Industrial and  
Composite Tooling

# High Performance Thermoset



# High Performance Thermoplastic Composites

Performance Pyramid



## OUR HIGH-PERFORMANCE THERMOPLASTIC POLYMERS AND PRODUCT FORMS

● UD tape

● Fabric prepreg

● Laminate

\* Laminate parts

### High-performance thermoplastics

● TC1000, PEI

TC1320, PEKK ●

NEW TC1225, Engineered PAEK ● ● ●

TC1220 / TC1200, PEEK ● ● ●

TC1100, PPS ● ● ●

### Engineering thermoplastics

● TC925 FST, PC

● TC950, PMMA\*

TC940, PET\* ● ●

TC910\*, PA6 ● ●

### Standard thermoplastics

● TC920, PC/ABS

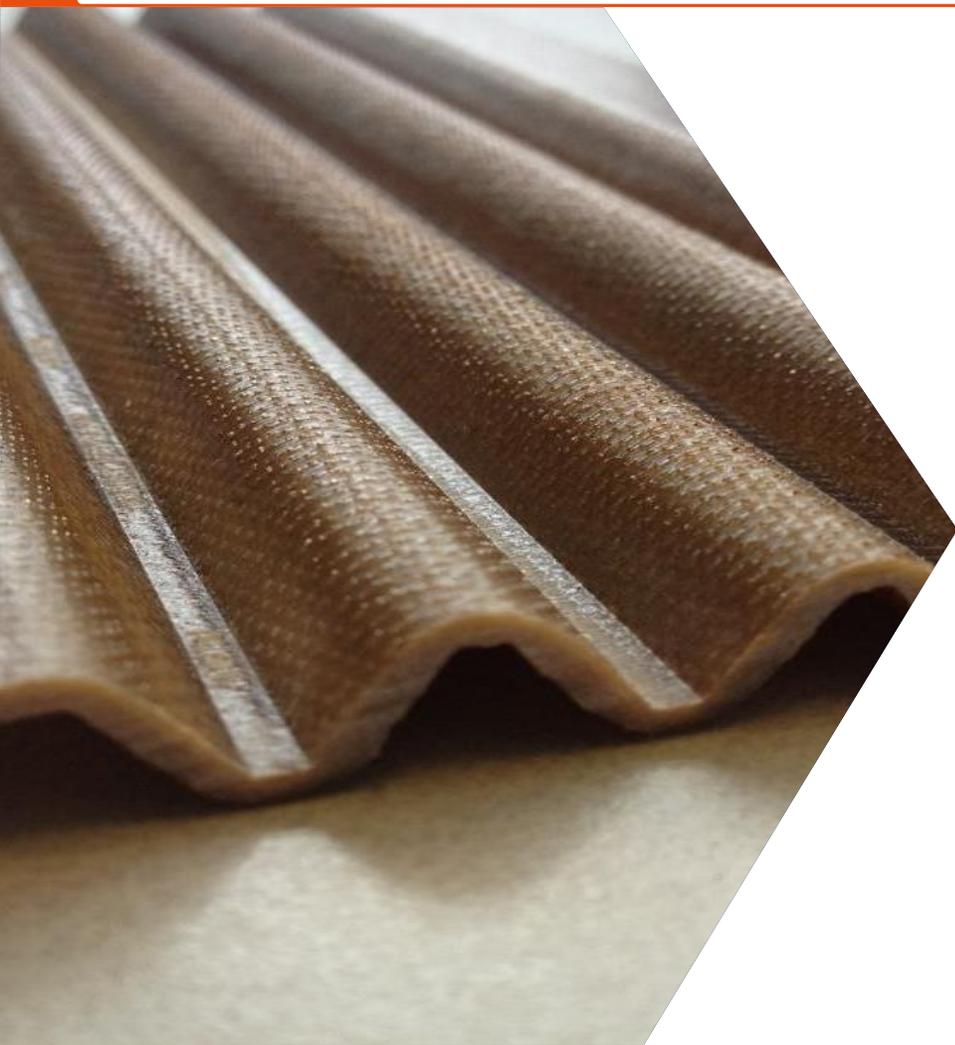
TC960, PP ● ●

TC930, HDPE ● ●

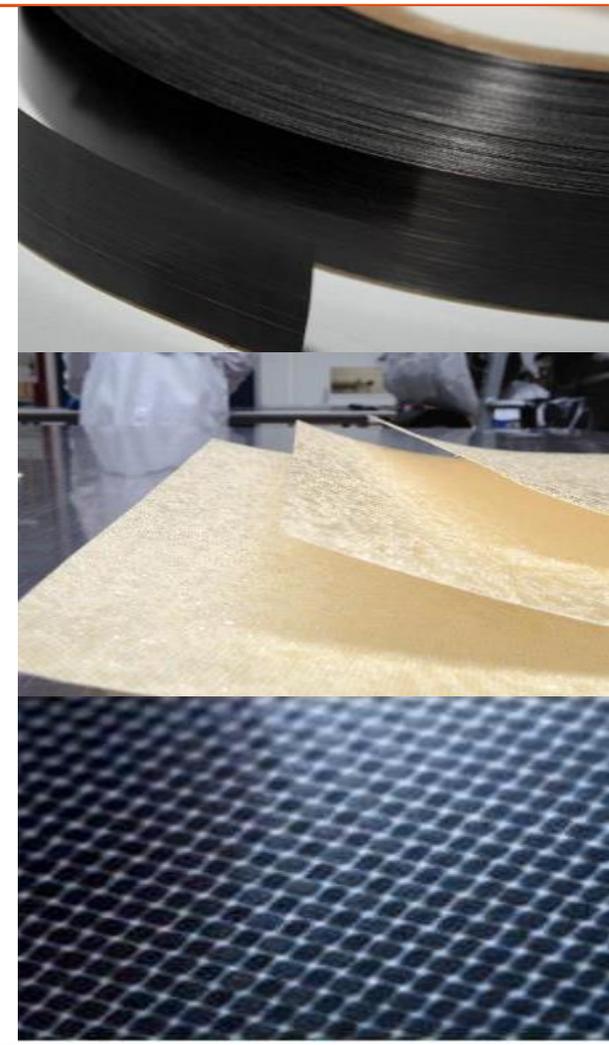
Amorphous

Semi-crystalline

# Thermoplastic Product Solutions



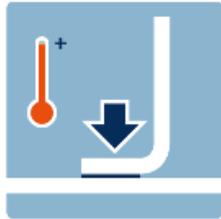
- › TenCate **Cetex**<sup>®</sup> thermoplastic advanced lightweight materials offer outstanding mechanical properties, durability, and strength.
- › **Qualified** to Boeing, Airbus material specifications. Unsurpassed performance delivers proven resistance to extreme conditions and environments.
- › Established choice for high volume manufacturing, TenCate Cetex<sup>®</sup> family of **UD tape, prepreg, and laminate (RTL)** thermoplastic composite materials is available in a wide range of fiber/resin combinations and product formats.



# Thermoplastic Processing

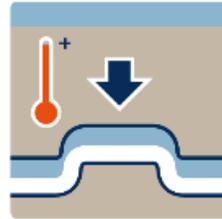
Significant Improvements for Part Consolidation and High Volume Production

TenCate Cetex® thermoplastic composite materials are suited to a diverse range of processing methodologies, thus providing design and operational efficiencies.



## Welding

Welding provides a seamless joint between substrates and can be married with overmolding to add functionality and integrate additional parts, making it an ideal alternative to time-consuming and potentially weaker adhesive bonding and mechanical fixation techniques.



## Thermoforming

The high quality consolidation of TenCate Cetex® thermoplastic composites in both UD tape and RTL formats allows for simple heating and forming processes that take minutes.



## Overmolding

Integrating Cetex® endless fiber reinforced composites in an injection molding process combines the strength of high-end composites with the design freedom and complexity of injection molding parts.

# Material Benefits

## › Thermosets

- + Pedigree of data
- + Broad production basis
- + Cost effective processing
- + Mechanical performance
- + Tailored characteristics
- + Adhesion performance
  
- Fire Performance – by resin
- Moisture tolerance\*
- Cure cycle limitations – by resin
- Limited by secondary operations

## › Thermoplastics

- + Mechanical performance
- + High volume manufacturing
- + Moisture tolerance
- + Fire performance
- + Fatigue performance
- + Secondary operation integration
  
- Limited installed supplier base
- High cost to entry for equipment
- Processing limited by geometry
- Historical database of mechanical performance

\* Stated in terms of moisture ingress for a sandwich panel

# Material Benefits

What Are the Limiting Benefits of The Individual Technologies?

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- Post processing operations

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# Material benefits

Increasing the Performance of Installed Supplier Capability

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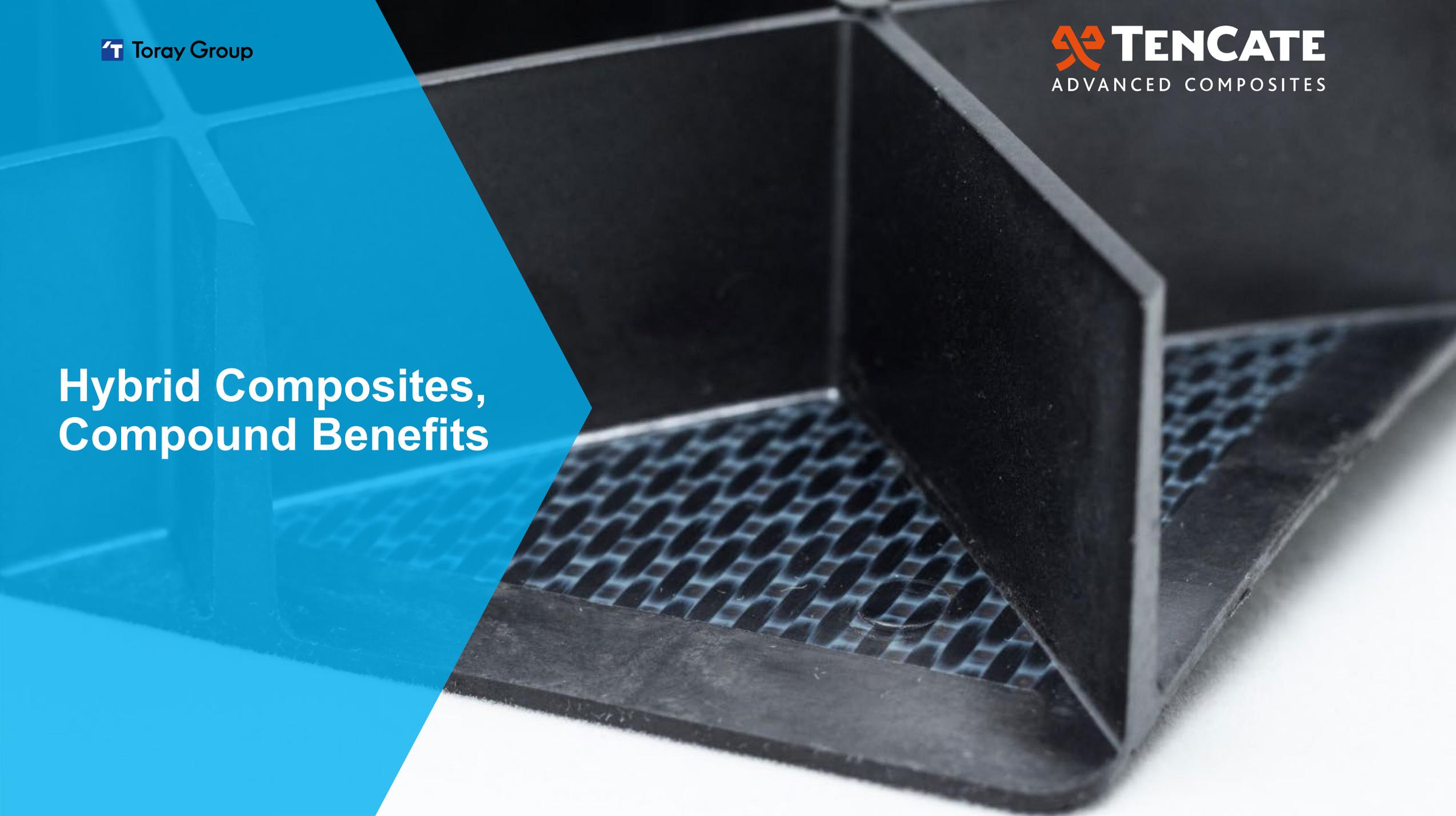
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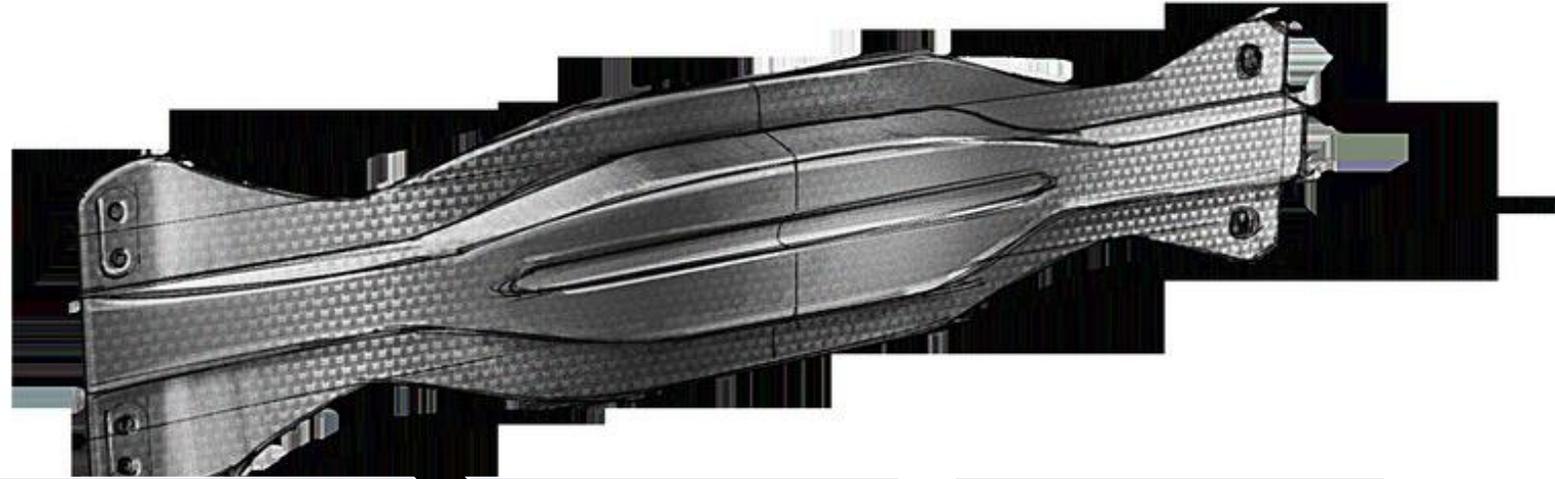
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# Hybrid Composites, Compound Benefits



# Overmolding

Next Generation Part Design



Continuous  
fibre  
material

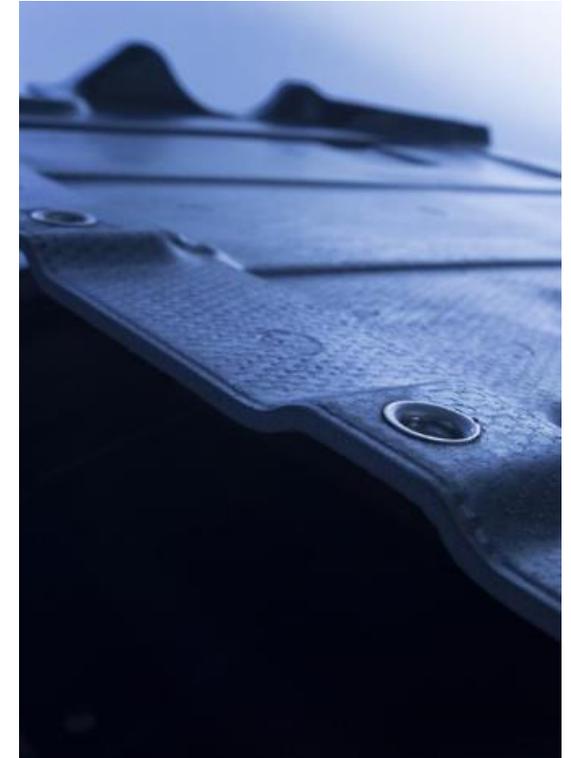
Minimised RTL/UD  
tape format,  
customised to meet  
mechanical needs

Short fibre  
injection  
moulding

Neat resin or short  
fiber molding provides  
mechanical  
performance

Final part

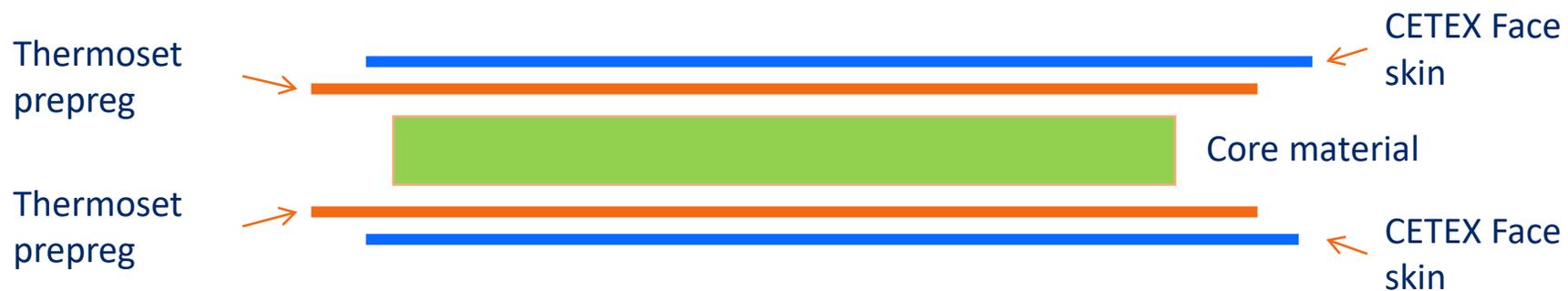
Integrated part design  
with multiple  
functionalities



# Hybrid Composite Solutions

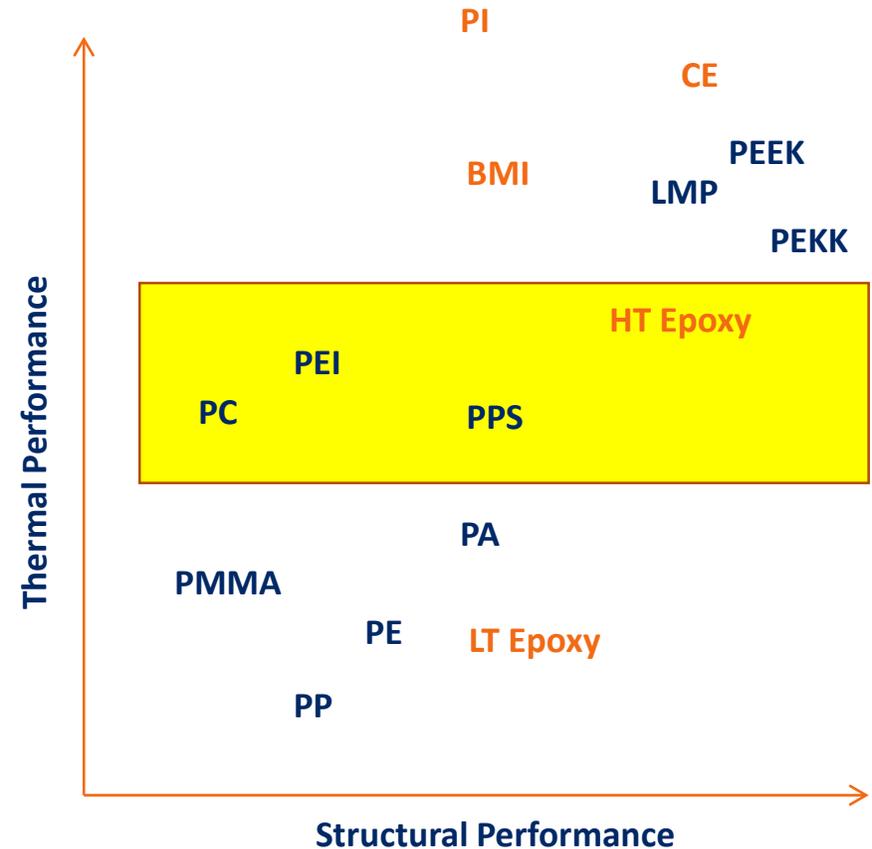
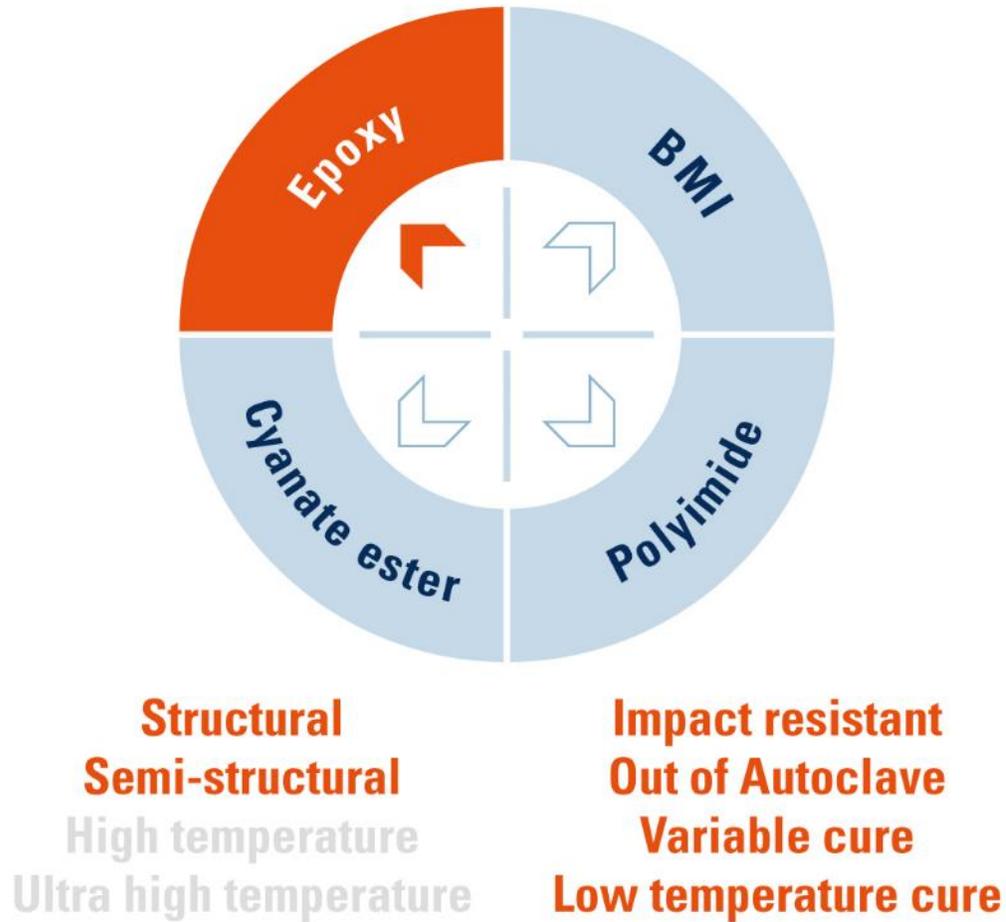
Unite the Best of Thermoset and Thermoplastic Composites

- › Maximise weight reduction by eliminating adhesive film weight (100-200gsm)
- › Achieve excellent surface finish with CETEX
  - Secondary benefits include, color, welding
- › Mechanical performance comparable to Thermoset (peel strength)
- › Existing production equipment can be utilised.
- › FST performance OSU 35/32 for sandwich panel with PVC foam core.
  - 1-ply CETEX TC1000 – Design (Carbon)
  - 1-ply E721-FR – (Carbon)

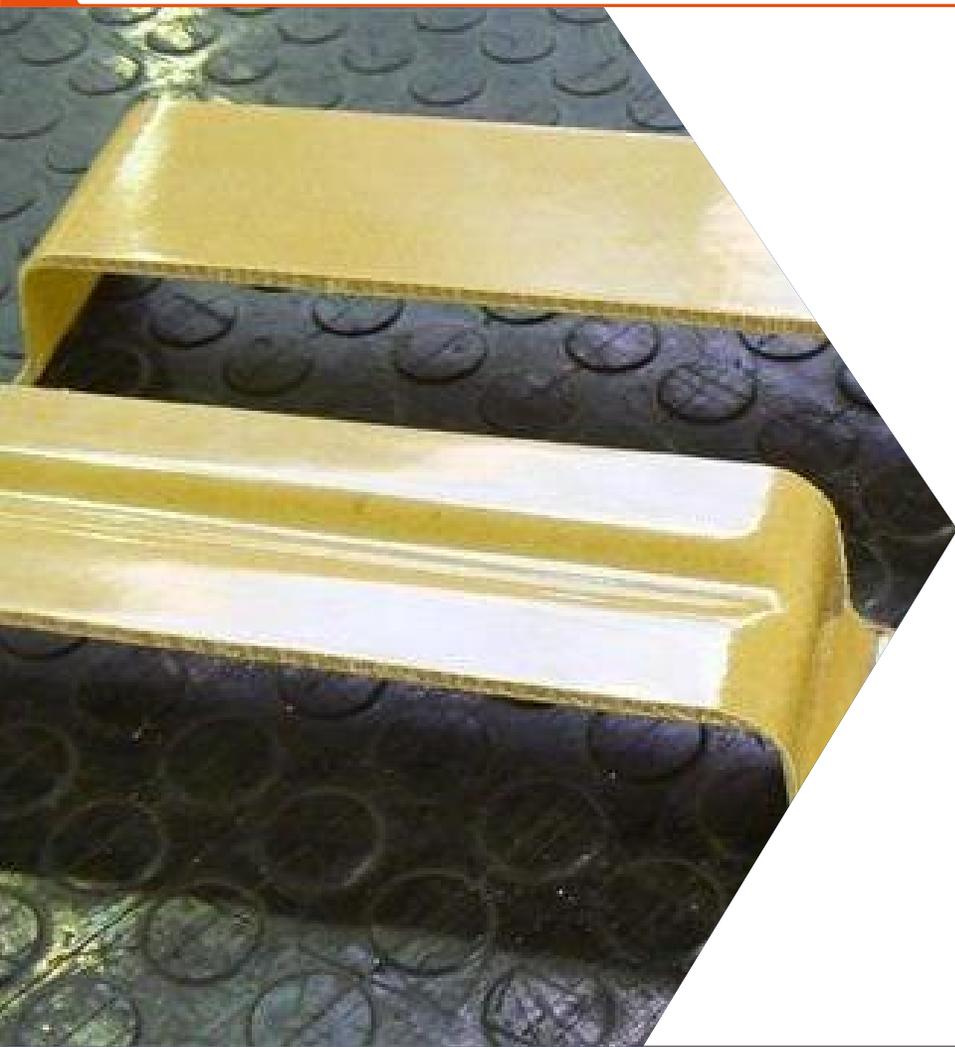


# Target for Hybridization

Process Screening across Amorphous and Semi-crystalline Chemistry



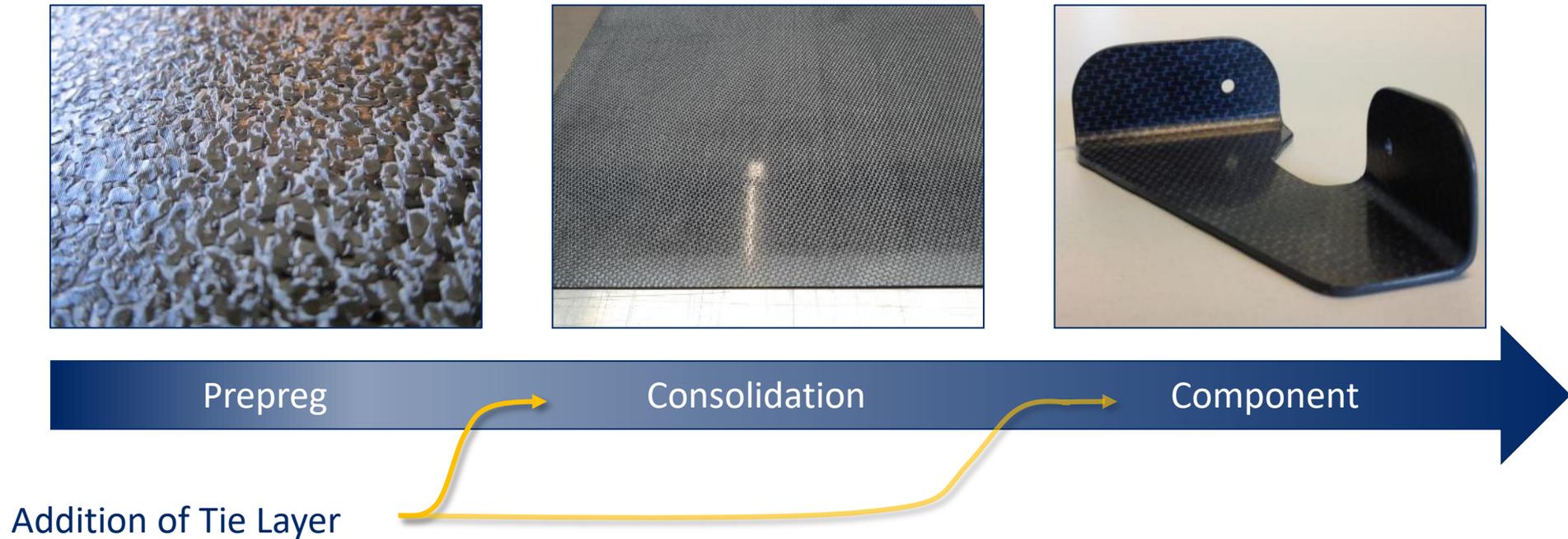
# Amorphous Hybrid Benchmark



- › Fire Performance
  - **FAR25-853 (OSU 29/24)\***
  - Smoke – PASS (<50)
  - 60-second vertical = 4.3” (6” limit)
  - 12-second vertical = 0” (8” limit)
- › Mechanical Performance
  - Drum peel = 25.1 lb/3” wide sample
  - 4-point bending – 58.3 ksi
- › Functional Performance
  - **No dimpling (surface flatness)**
  - **Established cure cycles (existing epoxy cure)**

# Semi-crystalline Hybrid Baseline

- › Included **tie layer** preferably during laminate consolidation
- › Balance between material compatability and processing parameter



# Tie Layer

Facilitate Joining and Coating Technologies

- › Origin from coextrusion technology to promote adhesion between different layers with different constituents.
- › Mechanism for TenCate Cetex® materials
  - Surface treatment forms an intermediate layer that bonds well to PPS and PEEK and various other materials such as adhesives and coatings
- › Applications:
  - Coating of exterior parts
  - (Adhesive) bonding using various epoxy adhesives for joining with (thermoset) composites and metals
  - Welding at lower temperatures (repair)



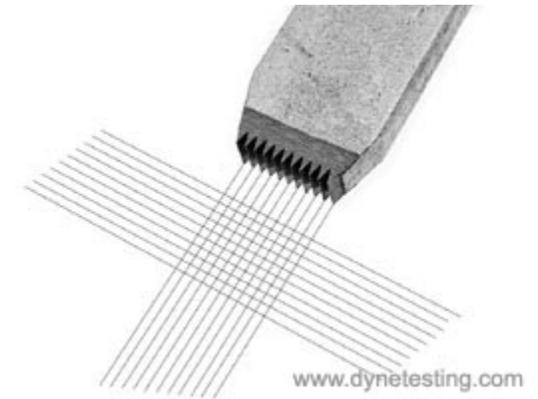
Source: Arkema



# Coating of C-PPS with Tie Layer

		Requirements	C-PPS	Tie layer
1 mm squares	Dry*	0	1	0
	Wet**	1	1	0
2 mm squares	Dry*	0	2-4	0
	Wet**	1	1-2	0

- › Tested at Akzo Nobel Aerospace coatings (ISO 2409)
  - Rating (0 = good adhesion, 5 = complete delamination of coating)
- › Primer
  - Low solids composite primer, isocyanate cured, with epoxy functionality
- › Surface treatment
  - Cleaning with IPA
- › Results **Tie layer is a good adhesion promotor between PPS substrate and coating for dry as well as conditioned samples**



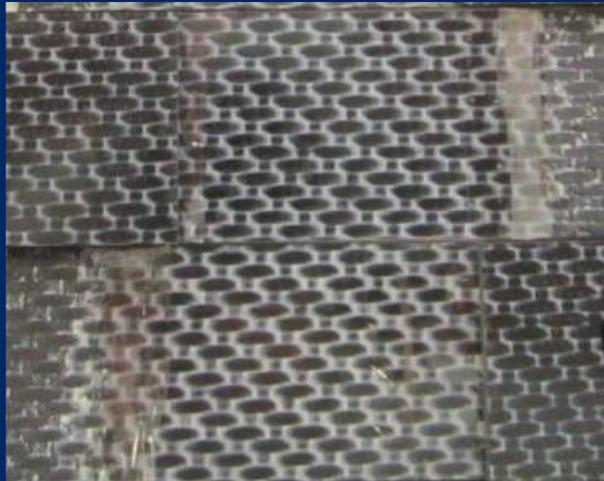
\* Not conditioned

\*\* Immersed in water for two weeks

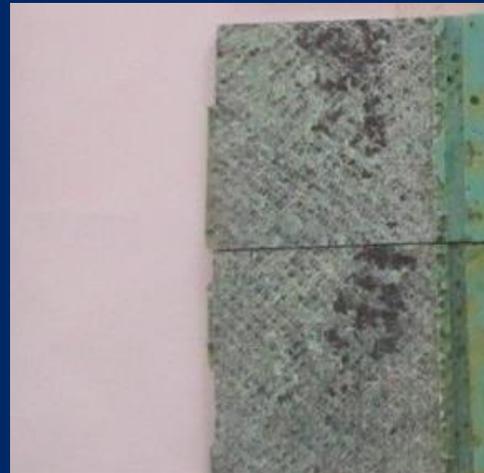
# Bonding and Welding of C/PPS with Tie Layer

## Lap Shear Testing

Set	$\sigma_L$ [Mpa}	Failure Mode	Remarks
Welding of C/PPS with tie layer below $T_m$ of PPS	9.31 ( $\pm 0.53$ )	Predominantly at fiber surface	Very thin bondline*** (~0mm)
C/PPS with tie layer + FM300	19.40 ( $\pm 0.61$ )*	Cohesive failure	Very thin bondline*** (~0mm)
3. C/PPS no surface treatment + FM300	0**	100% adhesive	Tested manually



Sample set 1



Sample set 2



Sample set 3

# Processability of C/PPS Including Tie layer

Production Results



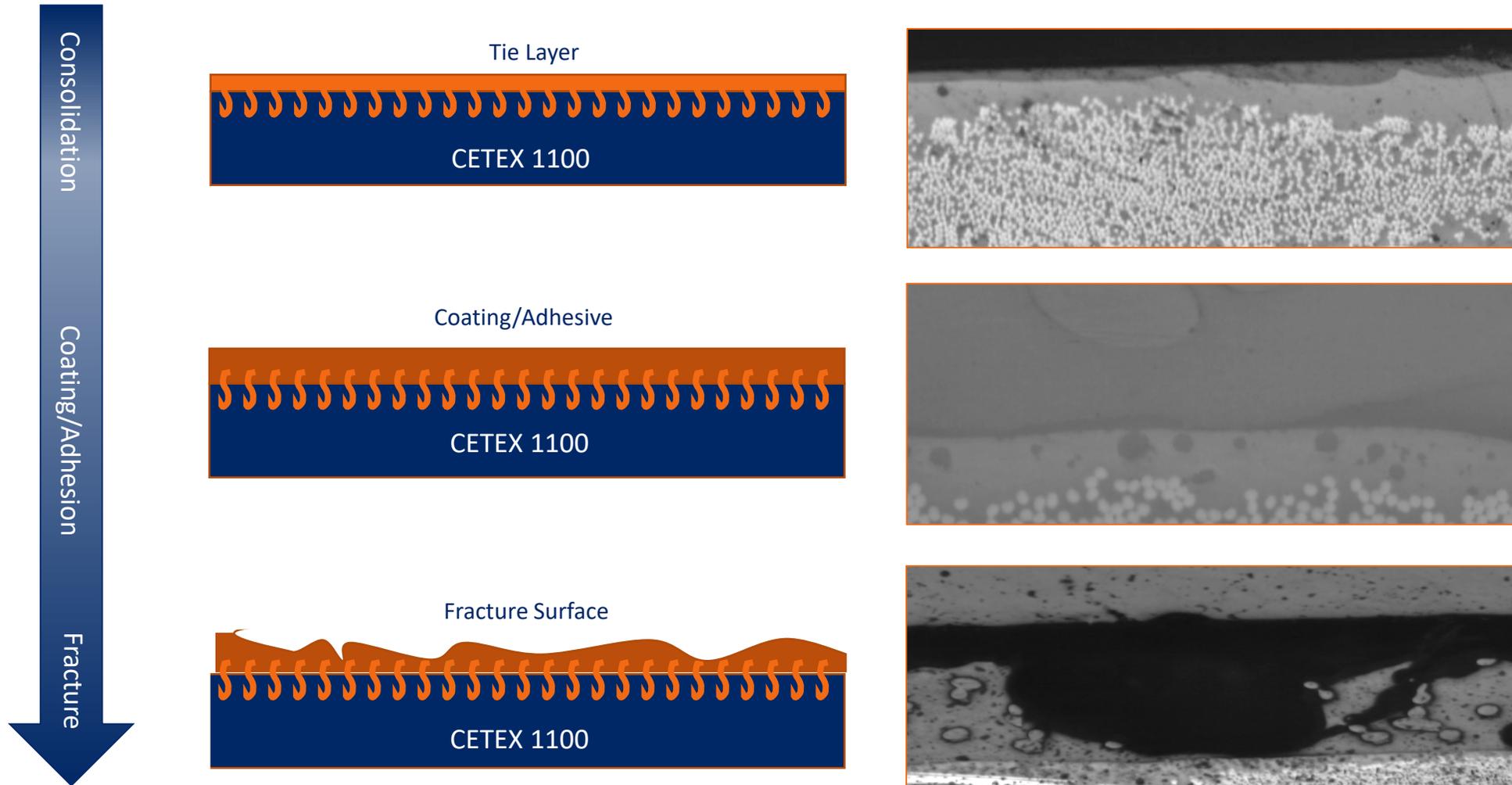
- › Laminates with tie layer were thermoformed, treated, and coated at Daher
- › Coating trials with tie layer were performed on part
- › Cross hatch test showed good adhesion between coating and substrate

		Requirements	Results with tie layer
Crosshatch test #2 mm	Dry*	0	0
	Wet**	1	1

\* Not conditioned

\*\* Immersed in water for two weeks

# Tie layer adhesion



# Key Market Applications

## Potential Market Adoption of Hybrid Technology

### › Aerospace

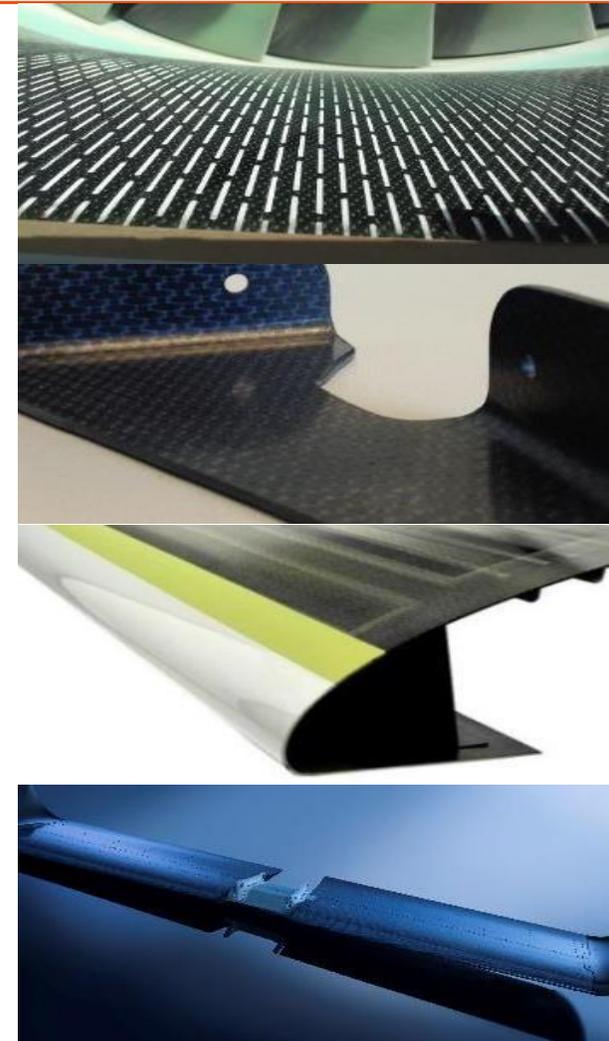
- **Wing control services and access panels** – **chemical resistance**, moisture ingress, impact performance
- **Aircraft flooring** – fatigue performance, **moisture resistance**
- **Galleys and lavatories** – **surface quality** (dimpling), impact performance
- **Engine casing** – fatigue performance, **acoustic performance**
- **Galley trolleys** – **welding** and fatigue performance
- **Cargo lining systems** – **in-color**, impact performance, fatigue performance

### › Rail

- **Train bodies** – **lightweighting** and FR performance
- **Train flooring** – **impact performance** and FR performance

### › Mass transportation

- **Trailer bodies** – **FR performance** for high use in tunnels



## Any Questions?

Dr. John Darlington  
j.darlington@tencate.com  
+44 7557 126772

Dr. Hans Luinge  
h.luinge@tencate.com  
+31 612 977067

