How Supply Chain Collaboration can accelerate the Adoption of Thermoplastic Composites in Aerospace

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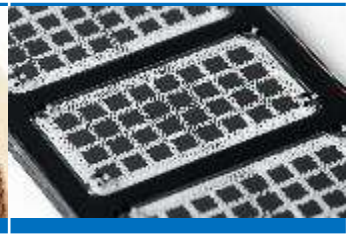
Sao Paulo, Brazil – 8 November 2018

Toray Group Snapshot

Materials can change our lives

- Possibilities, turning seawater into drinking water, reinforcing genetic analysis for medical breakthroughs, furthering the evolution of eco-cars, producing plant-based functional clothing, extending the shelf life of food for reduced waste, and creating a world where everyone can achieve their personal best.
- Materials have the power to do all of this and more, because materials make our modern world. The world is full of possibilities and our materials can change the world, which we will never stop believing.

"TORAY"
Innovation by Chemistry

Fibers & Textiles	Performance Chemicals	Carbon Fiber Composite Materials	Environment & Engineering	Life Science & Other Businesses
				

TENCATE ADVANCED COMPOSITES

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TenCate Advanced Composites Snapshot

A division of the Toray Group

- 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**
- 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®** 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.
- Supplier **to high end industrial applications** including F1, niche automotive, sport footwear and recreational.

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Global Footprint

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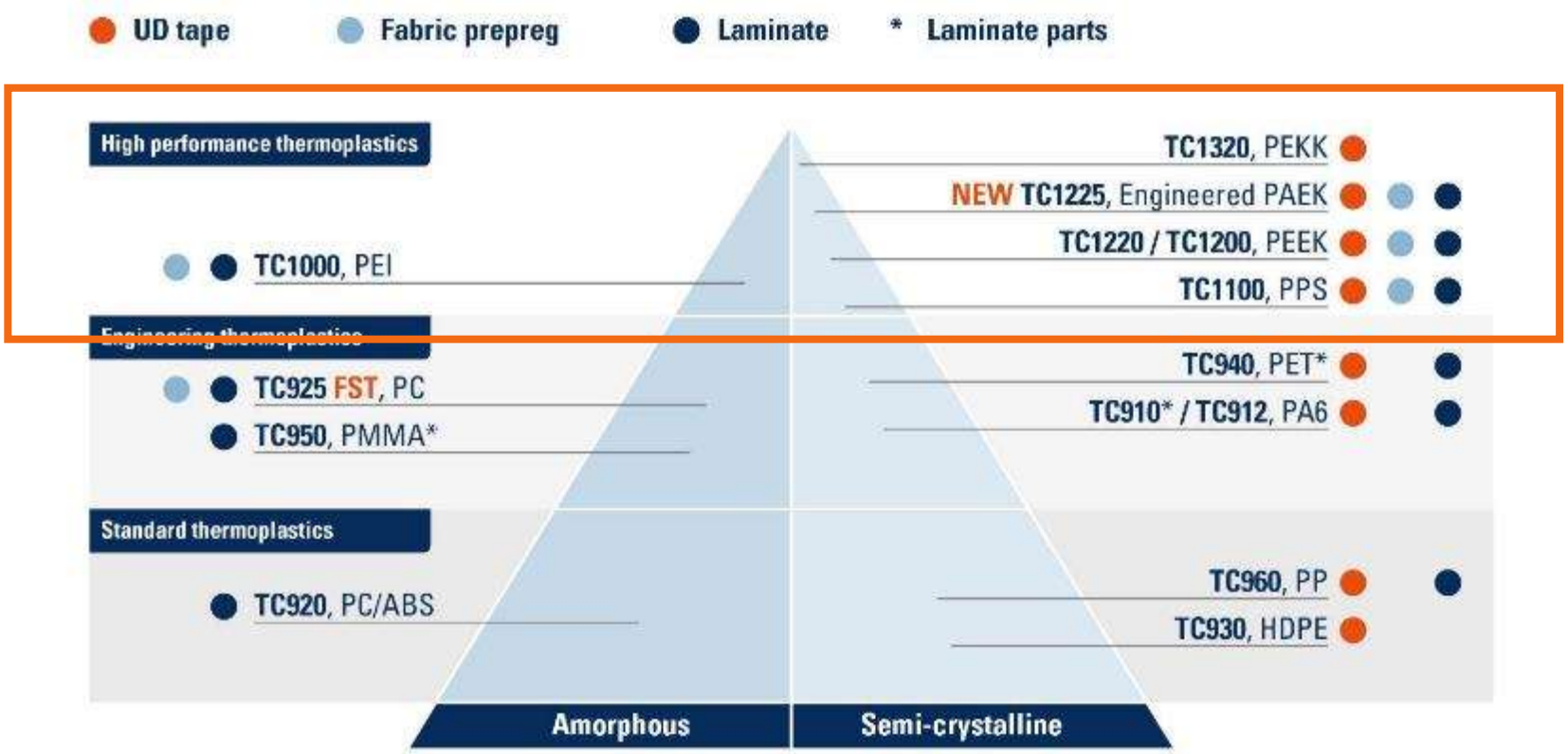
High Performance Thermoplastic Composites

TenCate product line depth along the performance pyramid



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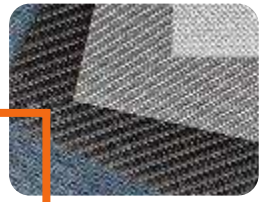
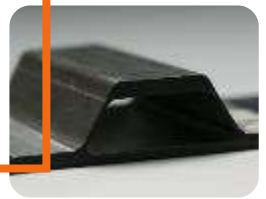
Cetex® Thermoplastic Composites

Aerospace grades

Product	Resin	Crystalline / amorphous	Toughness	Temperature	Comments
TC1000	PEI	Amorphous	Very high	Tg: 215˚C	› Excellent fire, smoke and toxicity properties › Good for interiors › Limited solvent resistance
TC1100	PPS	Semi-crystalline	Good	Tg: 90˚C	› Excellent solvent / moisture resistance › Excellent fire, smoke and toxicity performance
TC1200	PEEK	Semi-crystalline	High	Tg: 143˚C Tm: 343˚C	› Very good moisture / solvent resistance › Excellent fire, smoke and toxicity performance
TC1320	PEKK	Semi-crystalline	High	Tg: 162˚C Tm: 331˚C	› Very good moisture / solvent resistance › Excellent fire, smoke and toxicity performance
TC1225	LMPAEK	Semi-crystalline	High	Tg: 147˚C Tm: 303˚C	› Very good moisture / solvent resistance › Lowest processing temperature compared to PEEK or PEKK › Similar to PPS processing temperature › Excellent for injection overmolding applications with PEEK

TENCATE Cetex®





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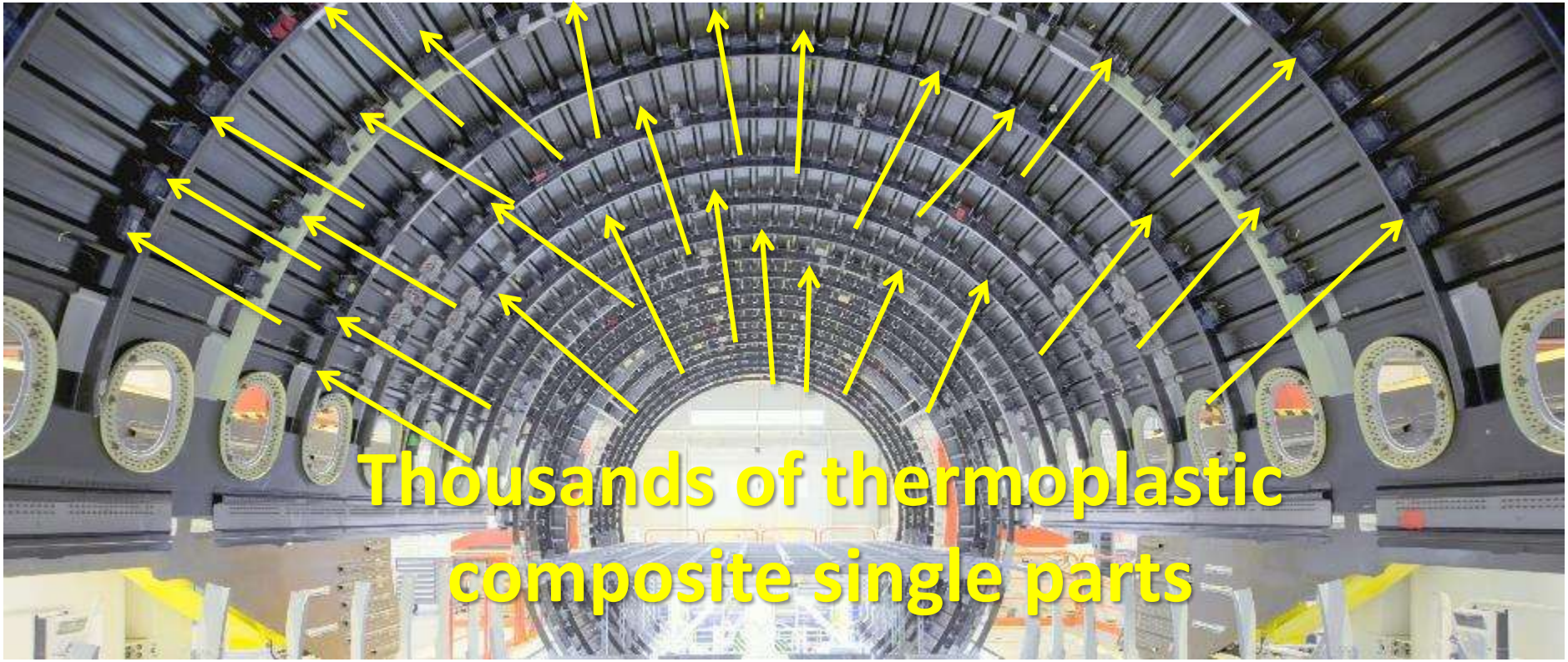
Examples

Airbus A350 fuselage clips – thermoformed C/PPS laminates



Courtesy: Airbus

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Examples

Airbus acoustic engine liner – slit, punched and welded C/PEI tapes

Courtesy: Airbus

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Examples

Gulfstream rudder/elevator – thermoformed C/PPS ribs welded in autoclaved skins

Courtesy: GKN Fokker

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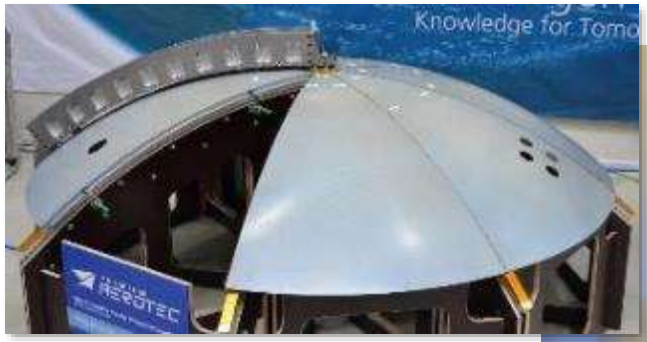
Examples

Airbus A320 rear pressure bulk head – thermoformed and welded C/PPS



Premium AEROTEC is the world's first company to successfully showcase the rising opportunities of thermoplastic carbon fibre composites (CFC). This full scale demonstrator of a rear pressure bulkhead for an aircraft of the A320 Family is made from eight similar pieces which are connected to each other by the latest welding technology.

By proving the unique capability to develop and produce large aircraft components of thermoplastic materials, Premium AEROTEC paves the way for a quantum leap in composite technologies. We are pioneers in taking thermoplastic CFC beyond today's application within the aircraft fuselage.

With the support of a strong network consisting of partners such as the Institute for Composite Materials (IVW) in Kaiserslautern and DLR's Center for Lightweight Production Technology in Augsburg, Premium AEROTEC is underway to shape the future.

Courtesy: Premium Aerotec

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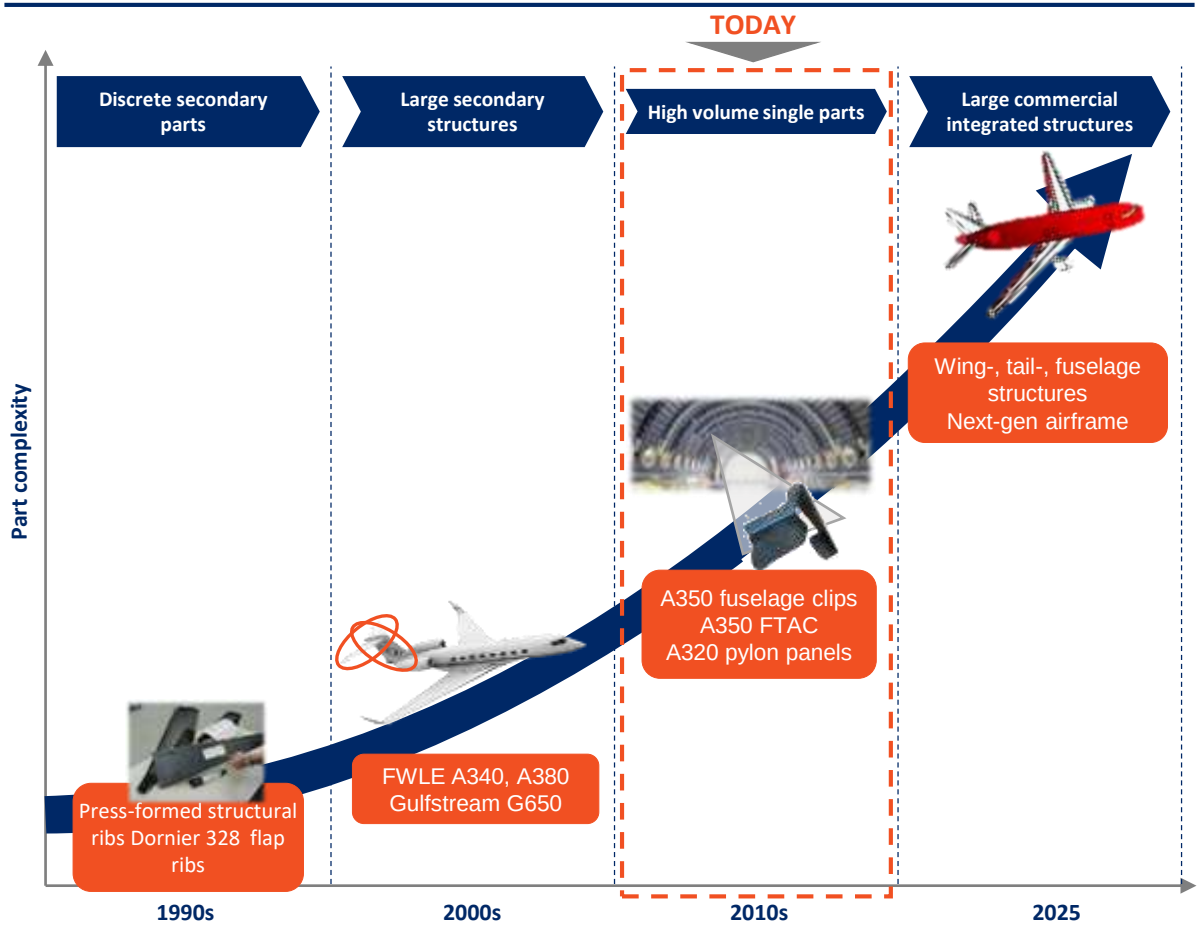
Thermoplastic Composites …. *are not new*

Evolution of TP usage



Commentary

- ✓ Modern aircrafts already consist of more than 50% of composite materials
- ✓ Share of thermoplastic composites is expected to increase significantly in the next few years
- ✓ OEMs are conservative in material adoptions given long product life cycles, risks and regulations associated with commercial aviation
- ✓ Airbus and Boeing initially started to use thermoplastics on small pieces and secondary structures
- ✓ As OEMs and plane manufacturers become more familiar with thermoplastics, usage is moving into more complex parts, welded assemblies and primary structures

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OEM's about Thermoplastic Composites

… recent quotes

- Klaus Richter, Chief Procurement Officer Airbus, AviationWeek, Oct. 15-28
  - "*Long-sought silver bullet*"
  - "*Thermoplastics are super elegant"*
- Tia Benson Tolle, Director of Advanced Materials, Product Development, Boeing Commercial Airplanes, ITHEC2018 conference, Oct. 30-31
  - "*… need head, hands and heart to realize the potential of thermoplastic composites*"
- …. the OEM's believe in the potential of thermoplastic composites but they are also aware that still much work has to be done to fully realize this potential in time for large scale applications on their next generation aircraft.

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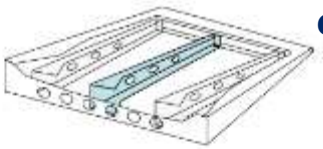
“Solving the Thermoplastic Composites Puzzle”



engineering capabilities
mechanical testing

design

tool design & engineering

materials database

processing technologies
- AFP / ATL
- Thermoforming
- Autoclave / Out-of-Autoclave
- Injection overmolding
- Welding
- Continuous Compression Molding
- Recycling

characterization capability
material design guidelines

Courtesy: TPRC

process simulation /optimization
material – process interaction

….. too many (unknown) pieces to solve the puzzle alone

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Need for Value Chain / Supply Chain Collaboration

› Collaboration and alignment in the value chain (supply chain) is needed to accelerate the development and to realize sufficient critical intellectual mass to make thermoplastic composite technology a success.

› Key Terms
- Collaboration
- Alignment
- Acceleration
- Critical Intellectual Mass (…. *people: engineers, researchers*)

› Example Initiatives: **TPRC, TAPAS, SPIRIT**

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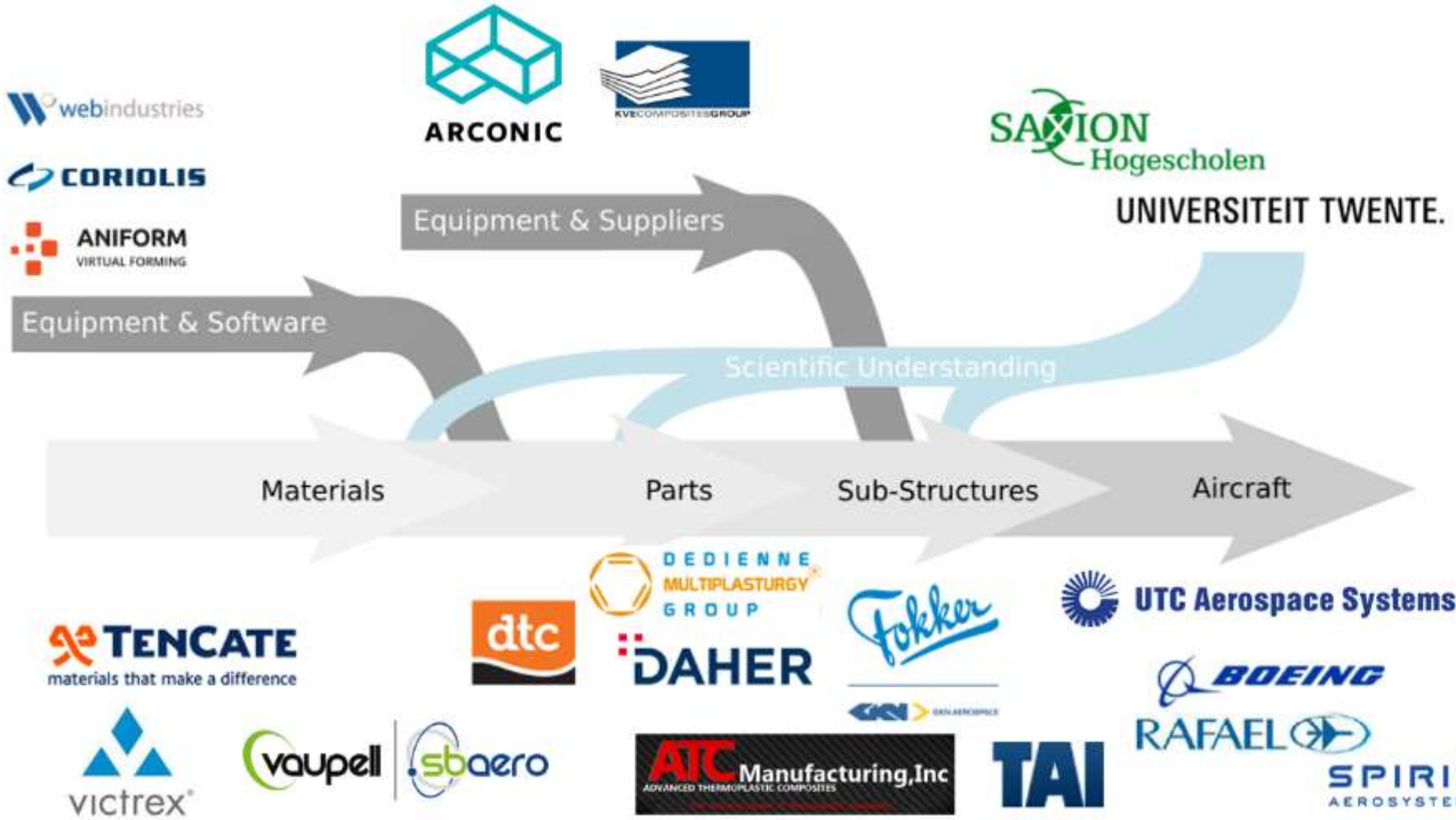
TPRC

ThermoPlastic composites Research Center (2007….)



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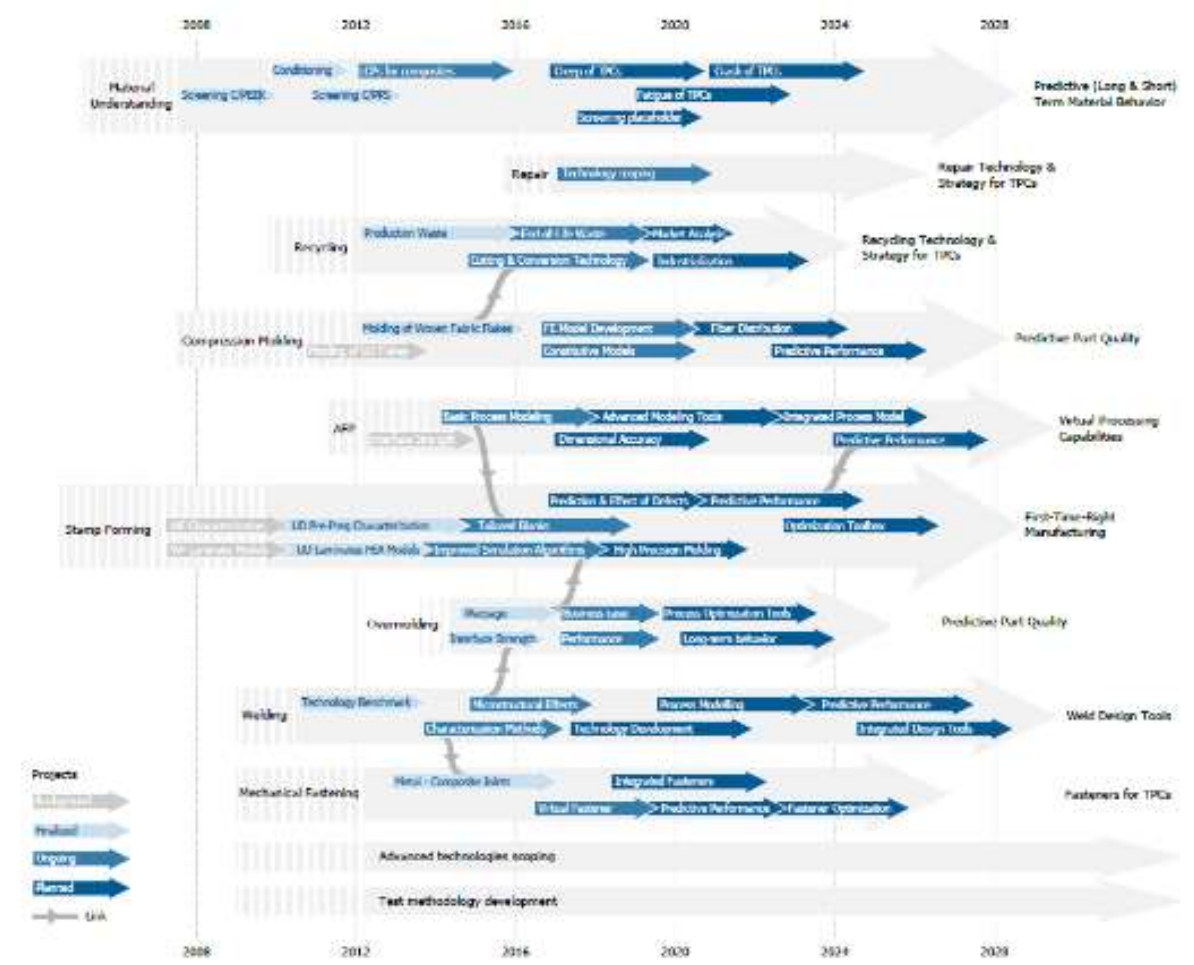
TPRC
Joint Member Roadmap Projects



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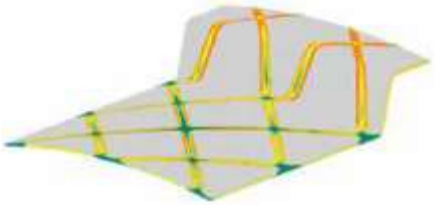
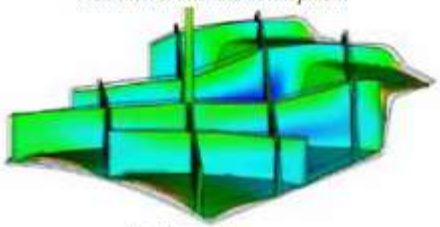
TPRC multilateral partner projects

Injection Overmolding: COMPeTE, COMPeTE2



Prediction of interface development



Simulation of warpage

External parters

- Autodesk
- Harper Engineering Co.,
- KraussMaffei
- Safran S.A.
- Samvardhana Motherson Peguform (SMP)
- Magneti Marelli

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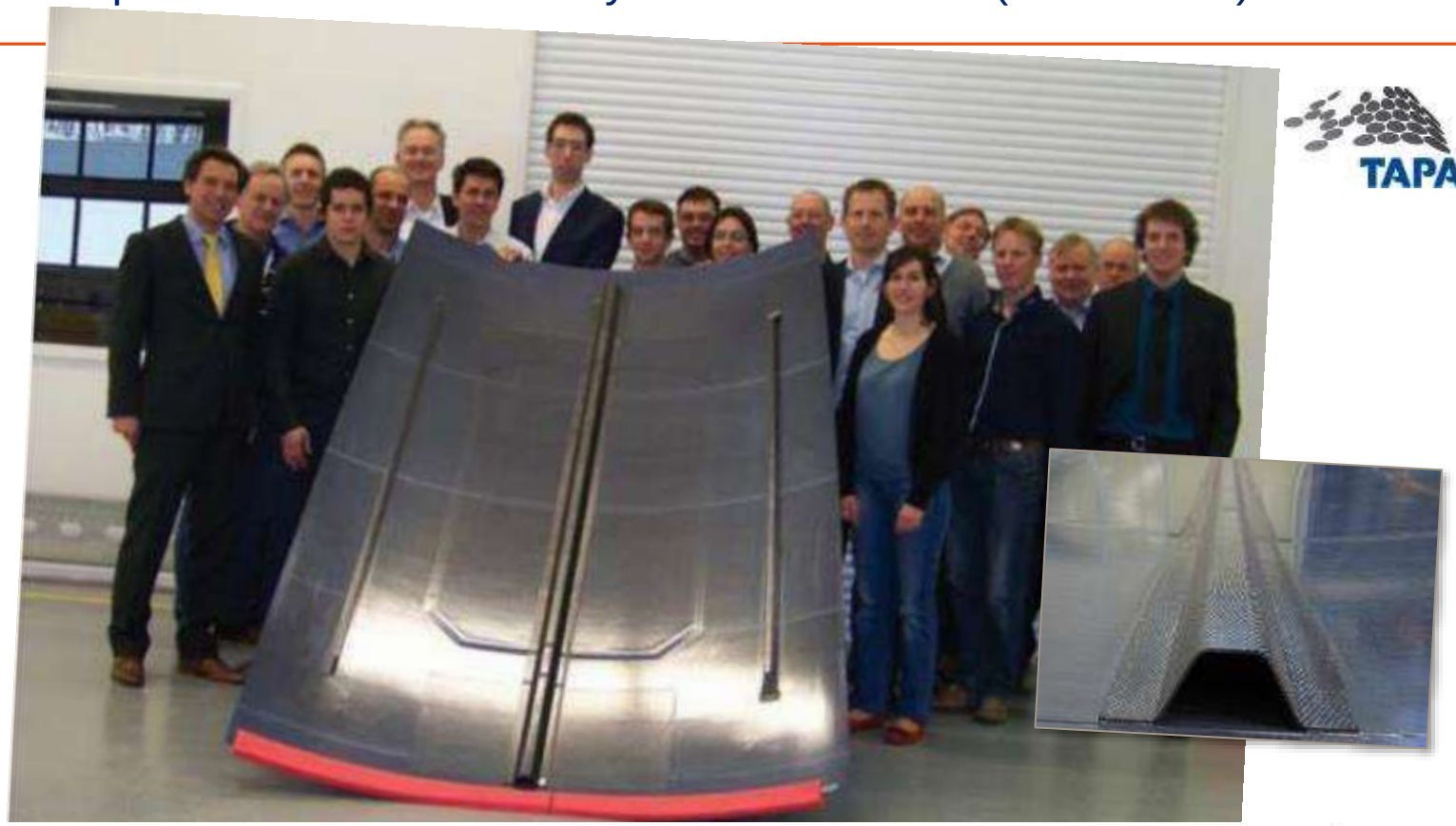
TAPAS

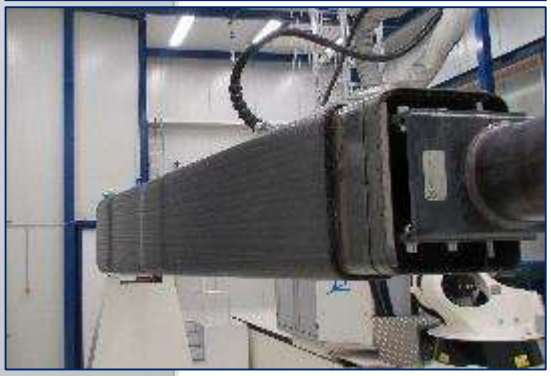
Thermoplastic Affordable Primary Aircraft Structure (2009..2013)



TAPAS2

Successor to TAPAS (2014..2017)

- 6 x 0,5 m
- Thickness 28 mm
- 120 kg



SPIRIT

Sao Paulo Initiative on Research into Thermoplastic Composites (2018….)

AEREI COMPOSITE MATERIALS

unesp

ITA

IAE

EMBRAER

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Holland High Tech
Global Challenges, Smart Solutions
Holland.

lel LABORATÓRIO DE ESTRUTURAS LEVES
Lightweight Structures Lab

ipt INSTITUTO DE PESQUISAS TECNOLÓGICAS

TORAY
Innovation by Chemistry

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SPIRIT
Goals

SPIRIT
São Paulo Initiative on Research Into Thermoplastic composites

- To create a Brazilian Thermoplastic Composites ecosystem (Embraer, Alltec, ITA, UNESP, LEL IPT, IAE, Toray-TenCate) that collaborates to stimulate and accelerate thermoplastic composites innovation.
- To prepare for future adaptation and application of thermoplastic composites on a larger scale on Embraer platforms (structures and interiors)
- To build a local resource pool with in-depth knowledge and experience in thermoplastic composite materials, processes and design.
- To connect this strong Brazilian TPC ecosystem to established international thermoplastic composites networks (e.g. TPRC)

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SPIRIT Launch Event

August 21, 2018

SPIRIT
Sao Paulo Initiative on Research Into Thermoplastic Composites


LUCHTVAART

Brazilië en Nederland werken samen op gebied van lichtgewicht materialen

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Activities

Phase 1 : Material and processing screening

SPIRIT
São Paulo Initiative on Research Into Thermoplastic composites

- Baseline: TC1225 carbon / LMPAEK
  - Laminates
  - Semipreg
  - Unitape
- Mechanical characterization
  - Tensile, flexural, (open hole) compression (after impact), interlaminar / in-plane shear, GIc, ..
- Processing
  - Consolidation
  - Thermoforming
  - Welding
  - Coating
  - Non-Destructive Inspection

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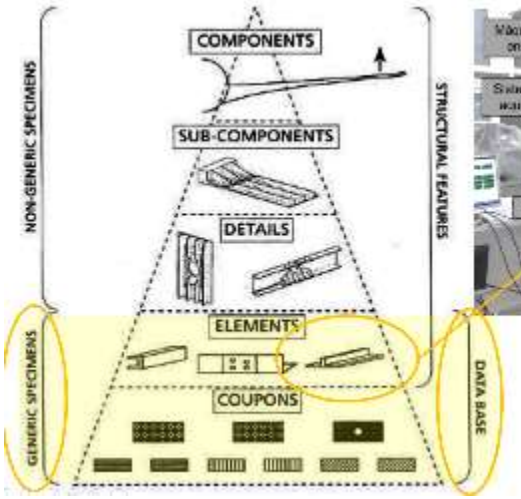
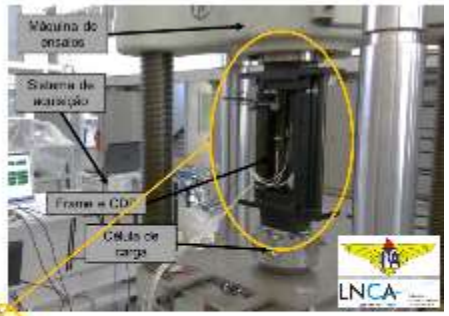
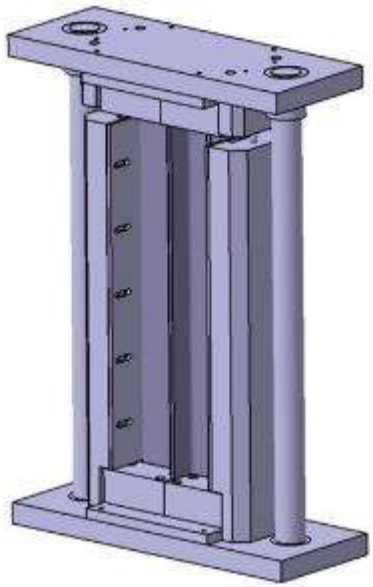
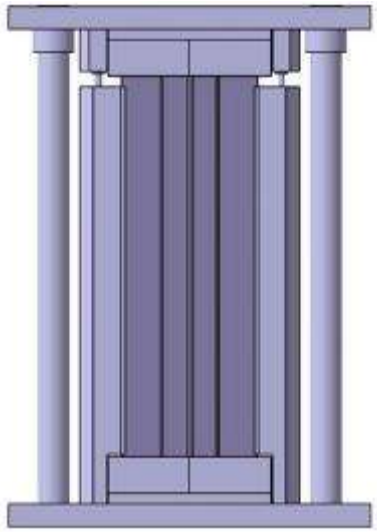
Activities

Phase 2 : Element manufacturing and testing









- Manufacturing of components
  - Thermoforming
  - (Out-of-Autoclave consolidation)
- Assembly of stiffened element
  - Welding (resistance, induction, US, …)
- Testing

Activities

Phase 3 : Demonstrator component - "*The SPIRIT of Flying*"

SPIRIT
SAO PAULO INITIATIVE ON RESEARCH INTO THERMOPLASTIC COMPOSITES

- Application for EUREKA GlobalStars Grant
- Project planning: 2019..2021

EUREKA
innovation across borders

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Thank you for your attention …. *let's work together*.

Visit us at booth **B8C** for further discussion

Winand Kok

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