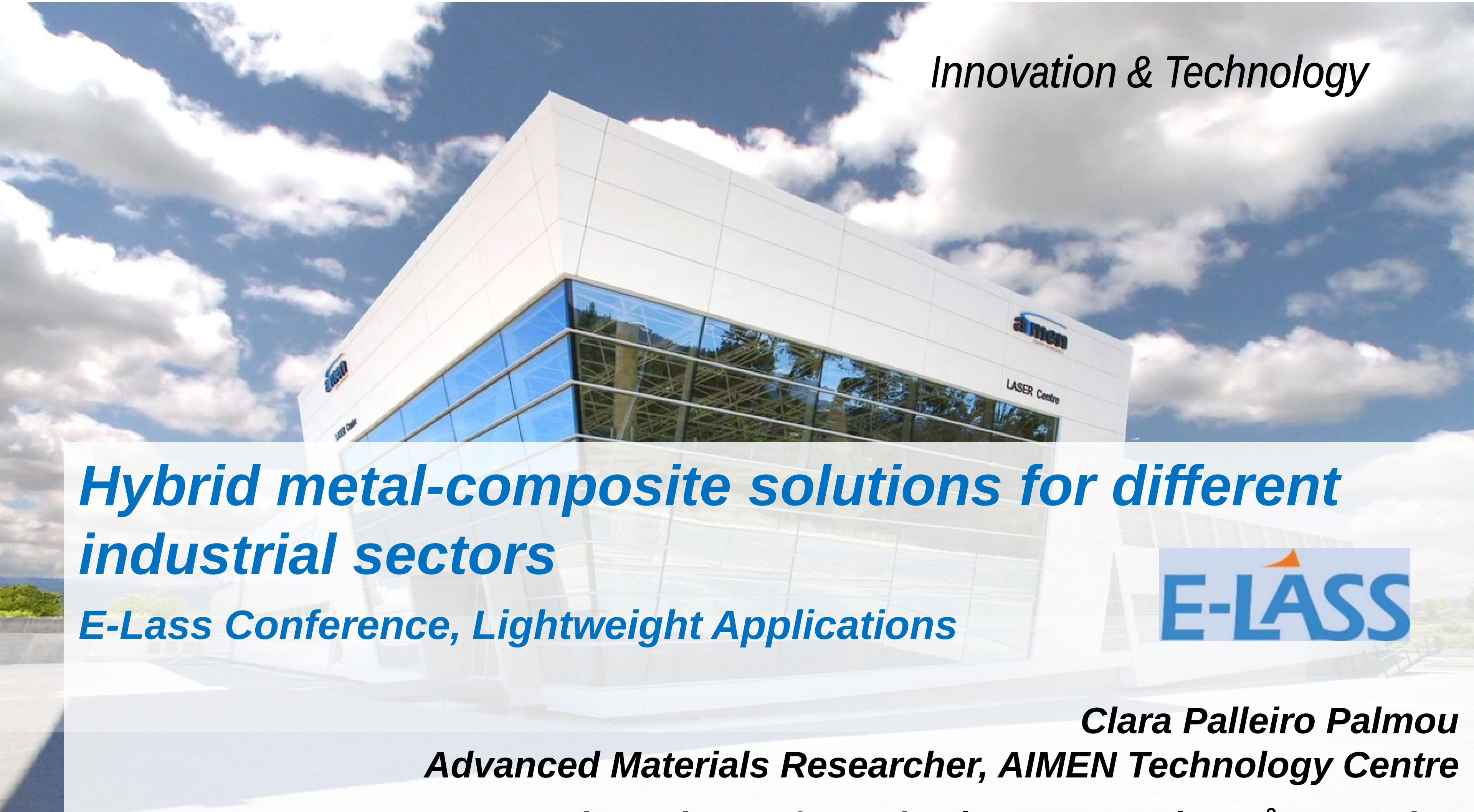
aimen
CENTRO TECNOLÓGICO

Innovation & Technology



Hybrid metal-composite solutions for different industrial sectors

E-Lass Conference, Lightweight Applications

E-LASS

Clara Palleiro Palmou
Advanced Materials Researcher, AIMEN Technology Centre

RISE - Research Institute of Sweden | 30.01.2018 | Borås, Sweden

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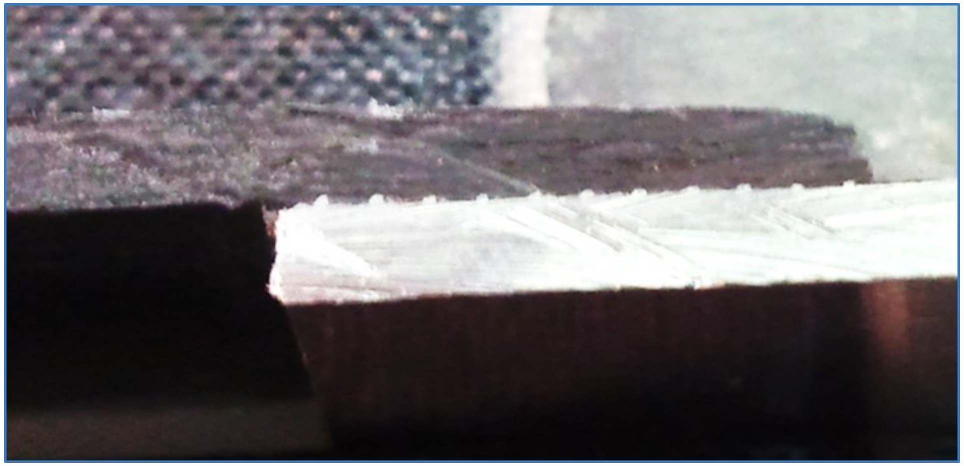
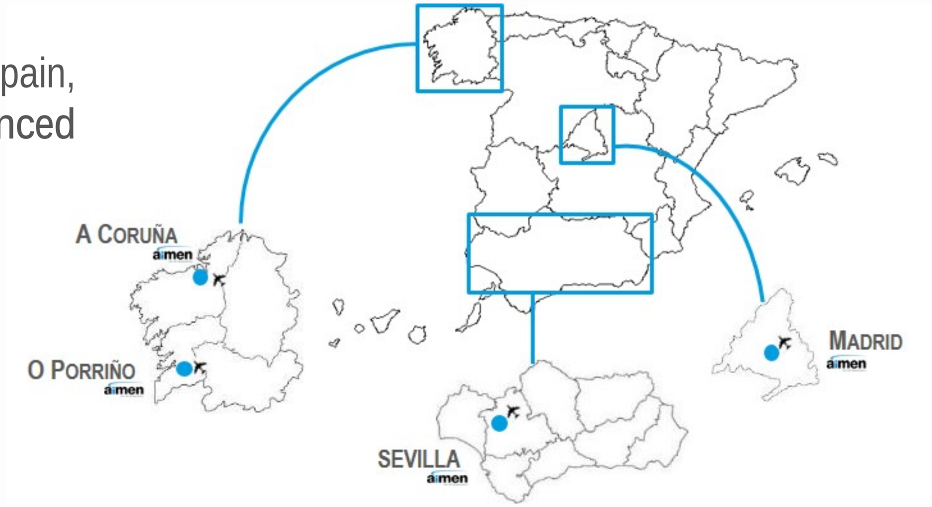
- Current challenges of the industry
- Multi-material approach
- Multi-material challenges
- AIMEN R&D multi-material Projects



We are a Technology Centre sited in the Northwest of Spain, founded in 1967, specialized in R&D and providing **advanced technological services** in the field of:

- ✓ joining technologies
- ✓ advanced materials
- ✓ robotic, automation and control
- ✓ laser technologies applied to materials processing



Headquarters (7.500m²) and Laser Processing Centre (11.100 m²) (O Porriño, Spain)

665
R&D&i Projects
In the last 10 years
European Projects:
18-FP7 & 15-H2020
(6 as coordinator
in H2020)

17
Patents
In the last 5 years

+750
Customers
Annual average
2009-2016

+230
Employees
27 PhD
60% men/40% women

14,5 M€
Annual Income
2016

+260.000
Technical reports
As of 31/12/2016

R&D&i

- •Applied research
- •Extensive network of industrial partners
- •Management of R&D&i Funding Programs

1. Polymers and Composites

2. Structural and Mechanical Integrity

3. Laser Based Manufacturing

4. Additive Engineering

5. Micro and High Precision Manufacturing

6. Smart Systems

7. Smart Manufacturing

8. Environmental and biotechnologies

In 2017:

R&D&i in figures

66

Ongoing projects

11

New approved projects

33%

R&D&i in the european scope

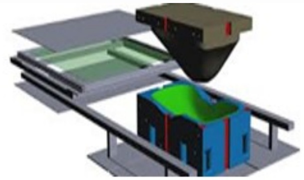
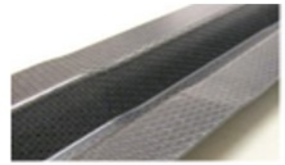
AIMEN: ADVANCED MATERIALS R&D PRIORITIES

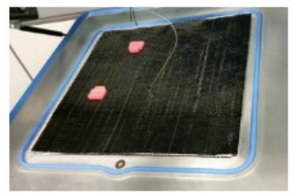
Composites and Polymers Manufacturing

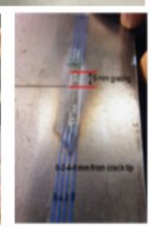
- Out of autoclave (VBO, filament winding, RTM, Press forming, LRI)
- Thermoplastic composites Automated processes (ATL, AFP)
- Process monitoring (embebed sensors)

Multi-materials

- Metal - polymer/composite
- One-shot process
- Joining improvement
- Surface technologies (laser texturing)
- On-line process control





Smart polymers and composites

- Nano-additive foams
- Nano-additive polymers and composites (thermal and electrical conductivity)
- Self-sensing materials



Additive Manufacturing

- 3D printing: new filament development (nano additive polymers, coated fibber)
- Automated composite layering

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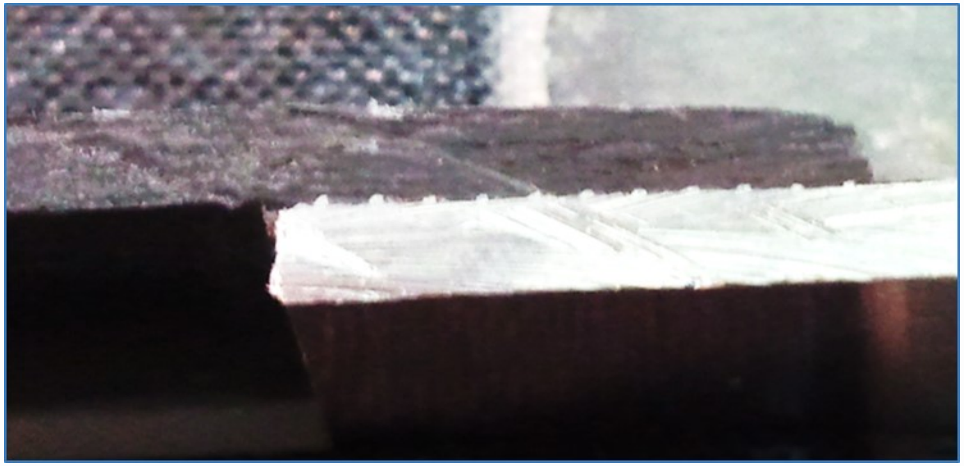
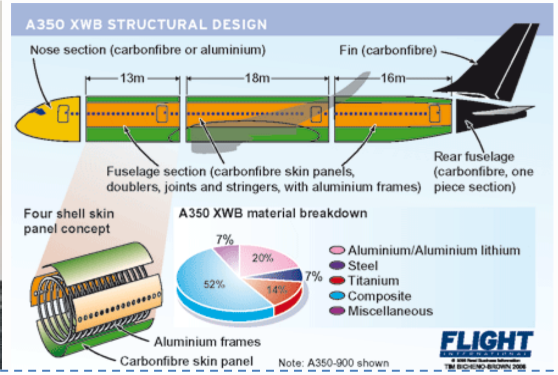




LIGHTWEIGHTING
vs
PERFORMANCE (mechanical prop., security…)

REPAIR OF DAMAGES
REINFORCEMENT
LIGHTWEIGHTING

NEW FEATURES

REINFORCEMENT
REPAIR

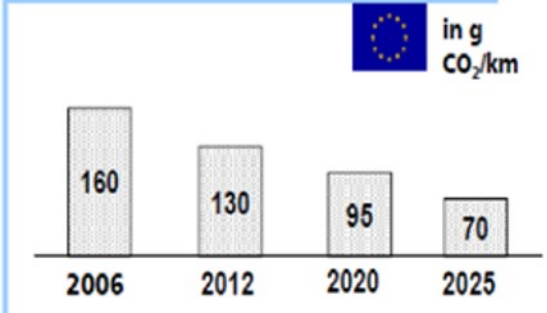
NEEDS OF THE INDUSTRY: CHALLENGES FOR FUTURE MOBILITY

- Industry, and specifically **transport industry (mainly automotive),** is the 2nd highest source of CO_2 emissions in the EU
- Europe is playing a very active role in the global scenario
- EU industry has to meet wider and ever **increasing demanding regulations**

AN AVERAGE GAP REDUCTION OF 20 gr CO_2/km HAS TO BE IMPLEMENTED IN THE NEXT 4 YEARS

A combination of **good design practice**, **appropriate targets** and specifications and **novel material technologies** will yield lightweight transport

CO_2 emission development



Price / availability of oil

Increasing traffic (passenger and transport)

Until 2030 in the transport sector, the predicted increase of fuel demand totals 55 %

SOURCE: Grotendorst, Continental, 2009

NEEDS OF THE INDUSTRY: how to response from materials science

Metallic materials are the best option for everything

Let’s replace every metal with composites!!

BUT..!!!

How much do you weigh?

How much fuel do you consume?

You look a little corroded…

BUT…!!!

How much do you cost?

How long it took to manufacture you?

Does your behavior in service meet all the requirements?

- AIMEN Technology Centre & Advanced Materials
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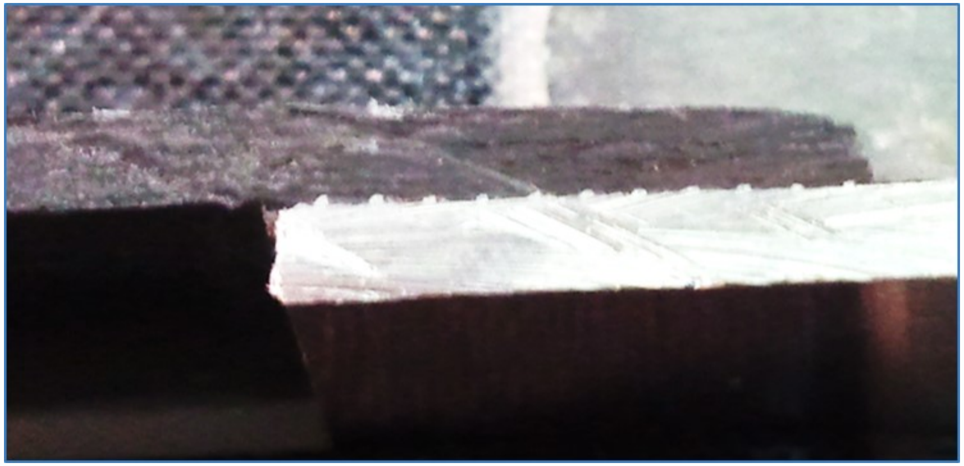
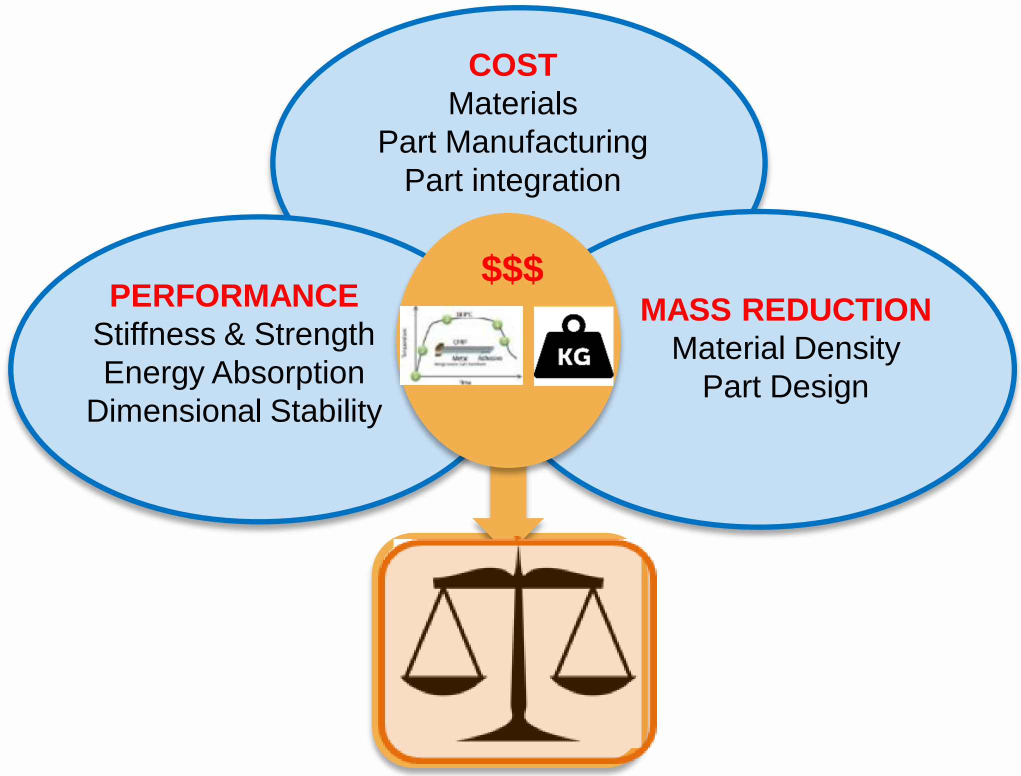


MULTI-MATERIAL / HYBRID APPROACH

WEIGHT REDUCTION

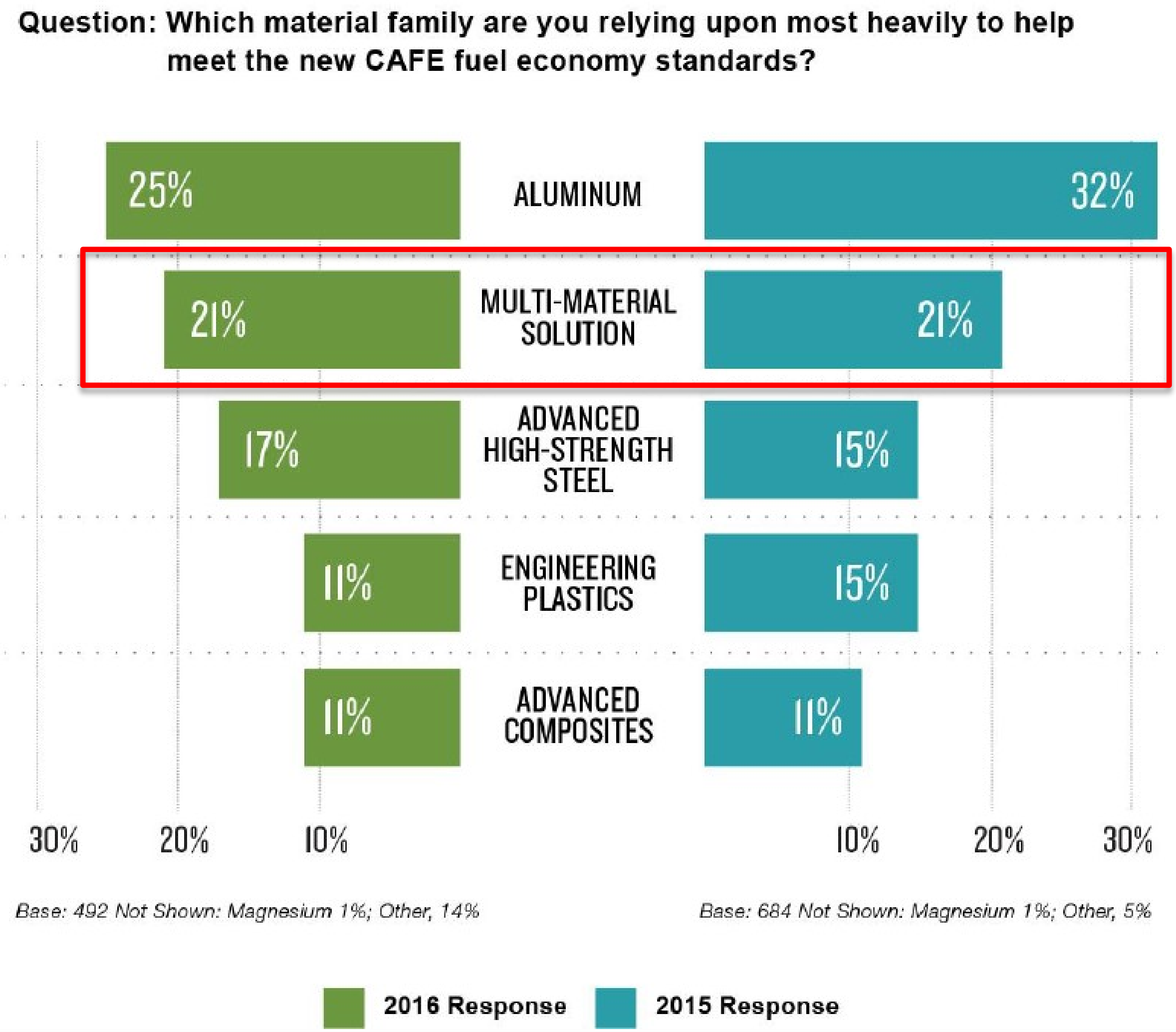
requirement translated downstream to EVERY SINGLE COMPONENT

MATERIAL	WEIGHT REDUCTION (%)	COST
Magnesium	60-75	1.5-2.5
CFRP	50-60	2-10
Aluminium	40-60	1.3-2
Titanium	40-55	1.5-10
GFRP	25-35	1-1.5
HSS	10-15	1



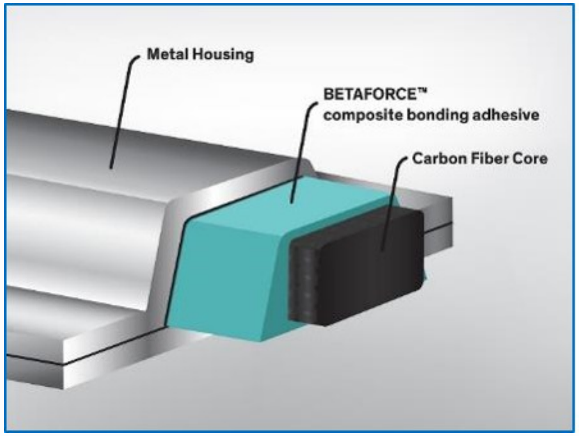
MULTI-MATERIAL DESIGN; overcoming THE COST BARRIER

Top Material Families for Lightweighting

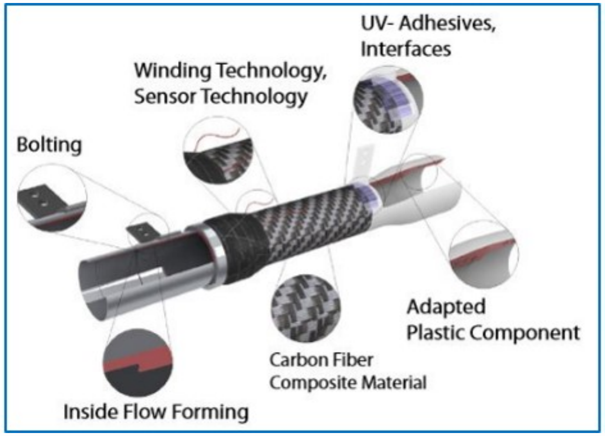


Multi-material combines the properties of different materials (2 or more) to obtain a final product with a synergy of their properties

The right material (only) in the right place



DOW Chemical

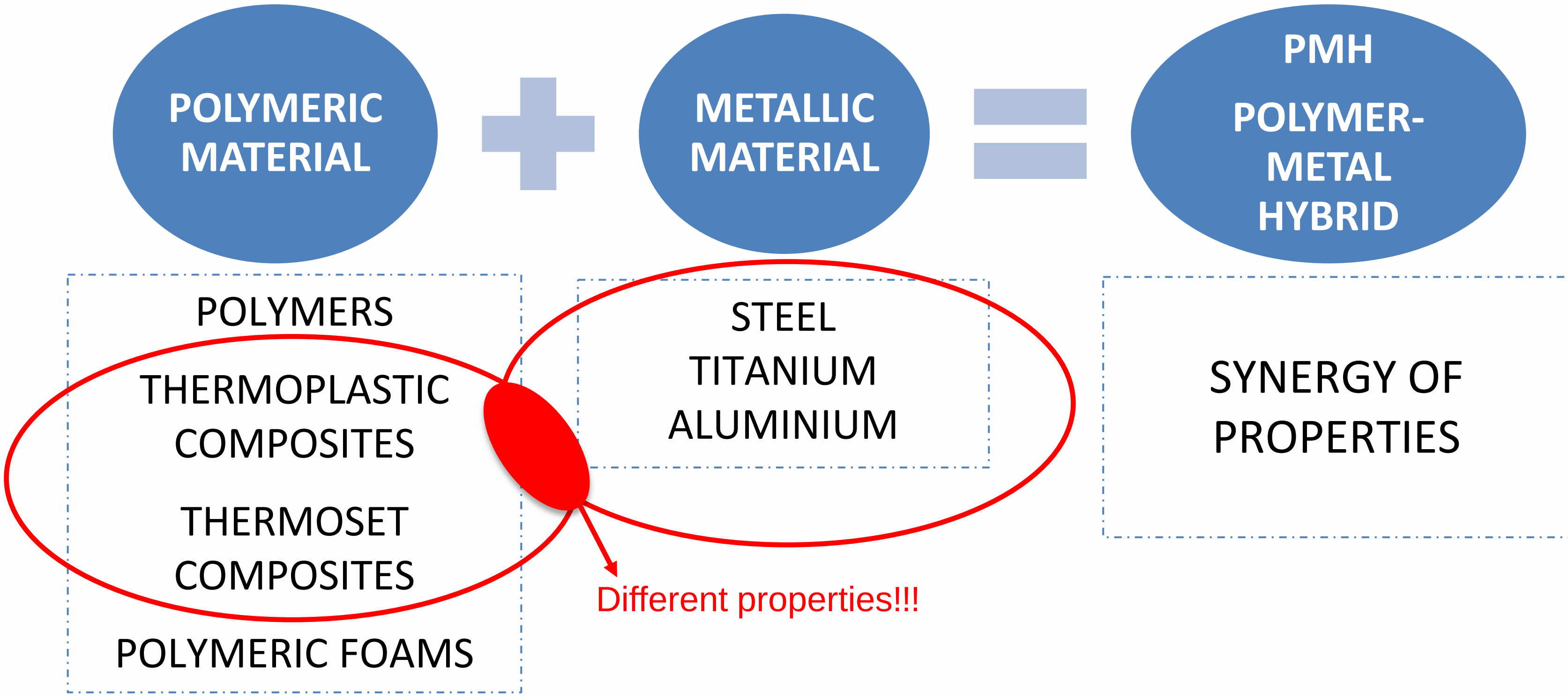


Institute for Lightweight Hybrid Systems (ILH) at the University of Paderborn


AIMEN Technology Center

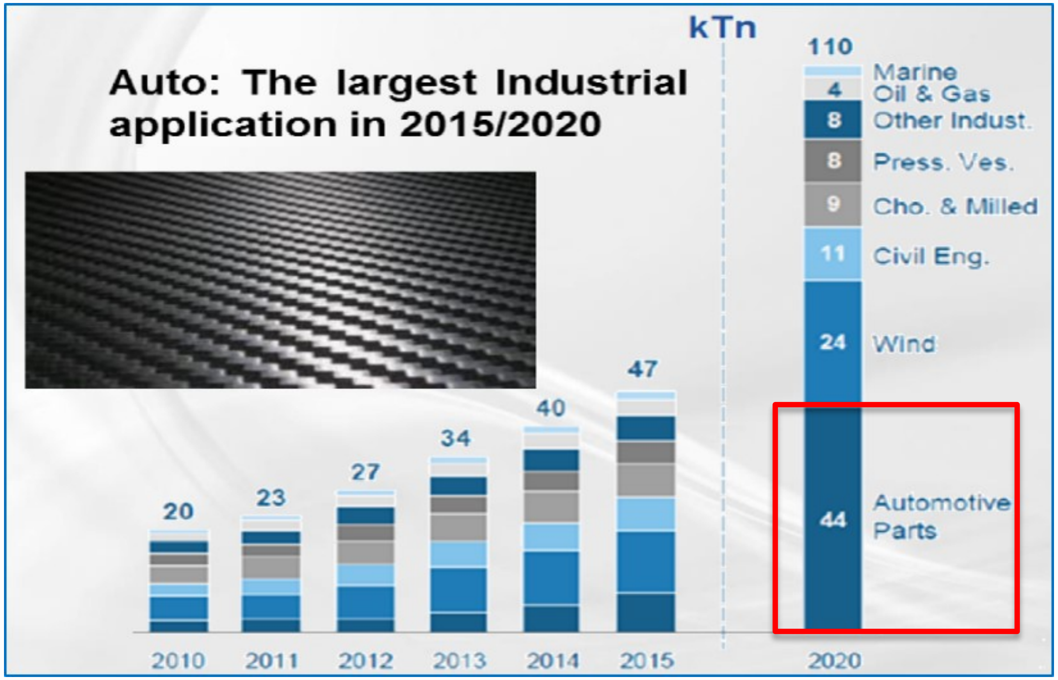
Combination of materials of dif. nature in a single structure → *optimum material for each purpose*

- *performance/cost ratio better than a bulk material*
- *more efficient resources use*


POLYMERIC MATERIAL
METALLIC MATERIAL
PMH
POLYMER-METAL HYBRID
POLYMERS
THERMOPLASTIC COMPOSITES
THERMOSET COMPOSITES
POLYMERIC FOAMS
STEEL
TITANIUM
ALUMINIUM
SYNERGY OF PROPERTIES
Different properties!!!

DRIVERS FOR THE USE OF COMPOSITES

- High specific mechanical properties
- Weight lightening
- Corrosion resistance
- Fatigue behavior
- Flexibility in design and manufacture
- Thermal and acoustic insulation
- Improved vibration resistance
- Low coefficient of thermal expansion
- Electromagnetic permeability



Fibre reinforced plastics used in structural parts (Source: SGL Group)

MULTI-MATERIAL CONCEPT: WHY COMPOSITES?

Thermoplastic (TP) Composite & Metal Components

TP-MATRIX
PP
PPS
PEI
PA
PEEK
…

FIBRES
CARBON
GLASS
ARAMID
UHMWPE
NATURAL FIBRES
…

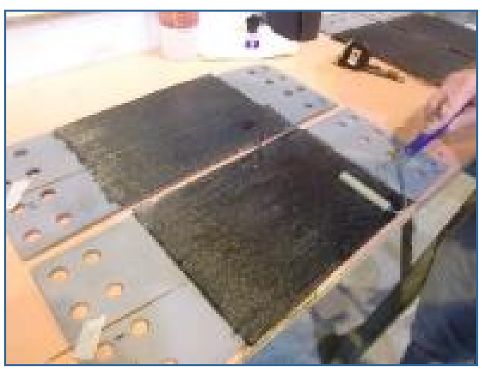
METALLIC PART
STEEL
ALUMINIUM
TITANIUM
…

Thermoset (TS) Composite & Metal Components

TS-MATRIX
EPOXY
POLYESTER
VINYLESTER
PUR
…

FIBRES
CARBON
GLASS
ARAMID
NATURAL FIBRES
…

METALLIC PART
STEEL
ALUMINIUM
TITANIUM
…



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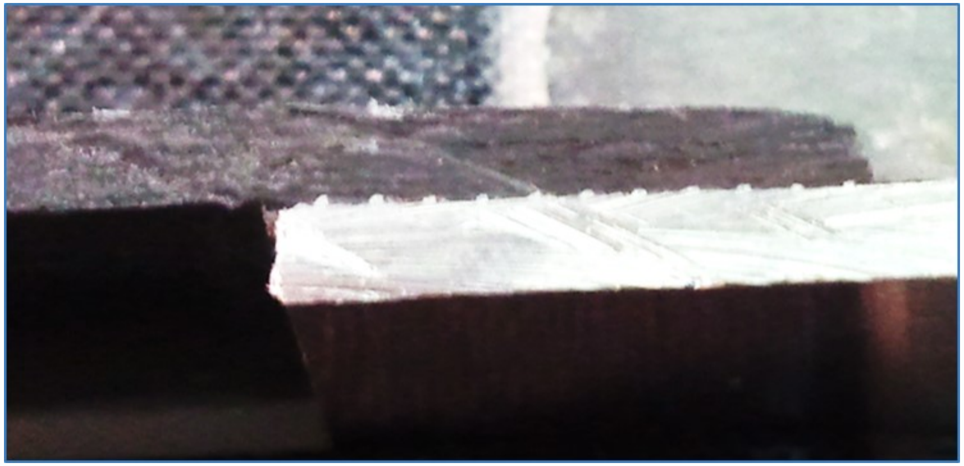
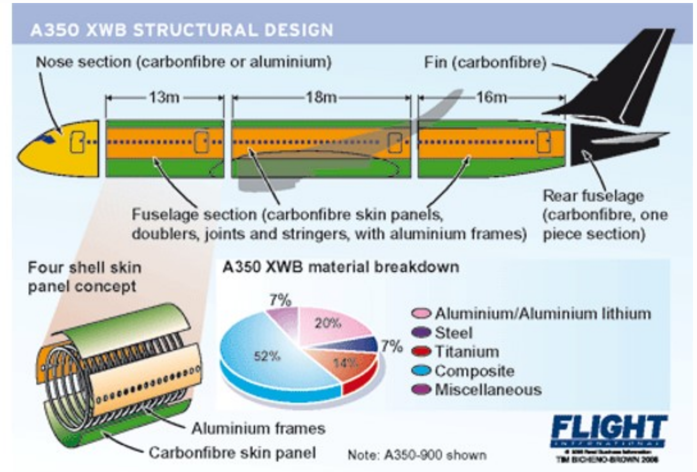


MULTI-MATERIAL / HYBRID CHALLENGES



MATERIALS

STEELS AND HIGH MODULE STEEL ALLOYS + TITANIUM + ALUMINIUM, etc

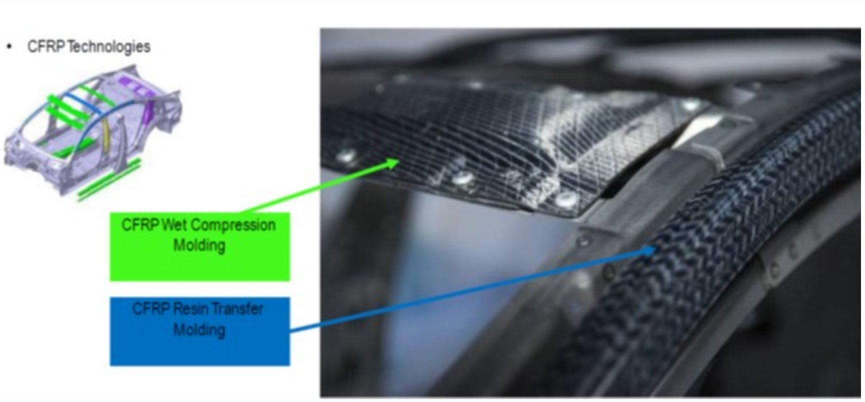
LOW THICKNESS

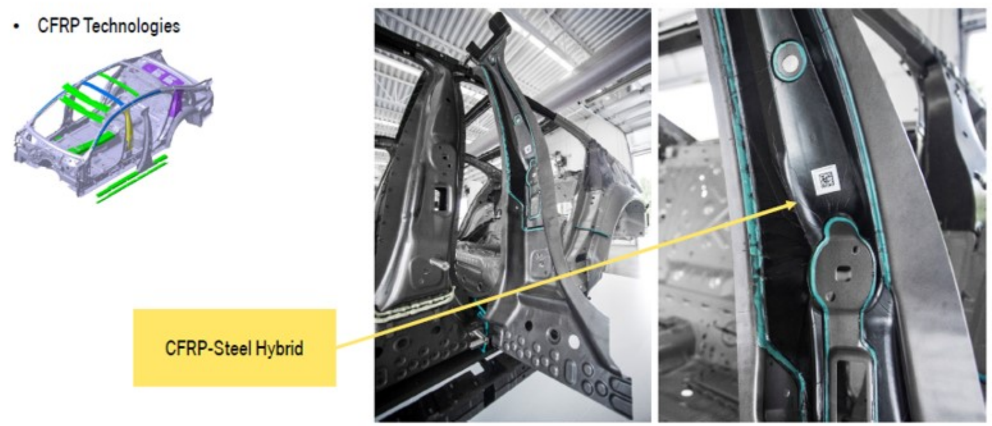
THERMOPLASTIC (PA for automotive, PEI, PPS and PEEK for aeronautics) and THERMOSET COMPOSITES

MANUFACTURING PROCESSES

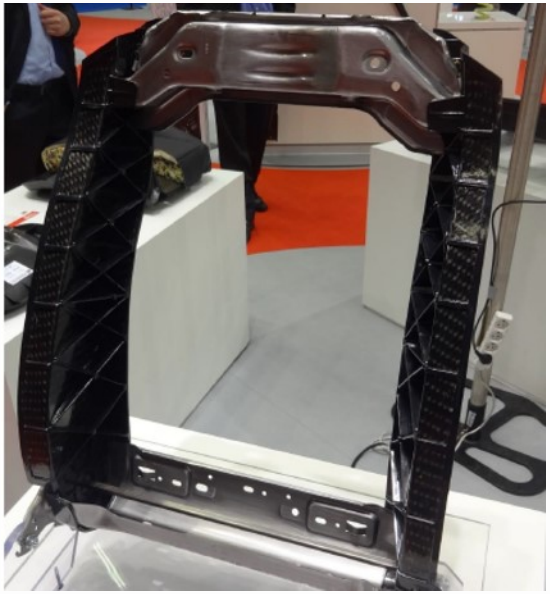
TREND TO THE MAXIMUM AUTOMATION

NEW BMW 7 SERIES – CARBON CORE.





FAURECIA
PA / CFRTP & Steel with
overinjected PP in mould



MULTI-MATERIAL / HYBRID CHALLENGES

MATERIALS

CONVENTIONAL STEELS (MEDIUM QUALITY)

HIGHER THICKNESS

THERMOSET COMPOSITES

HARD ENVIRONMENTAL CONDITIONS

LOW COST

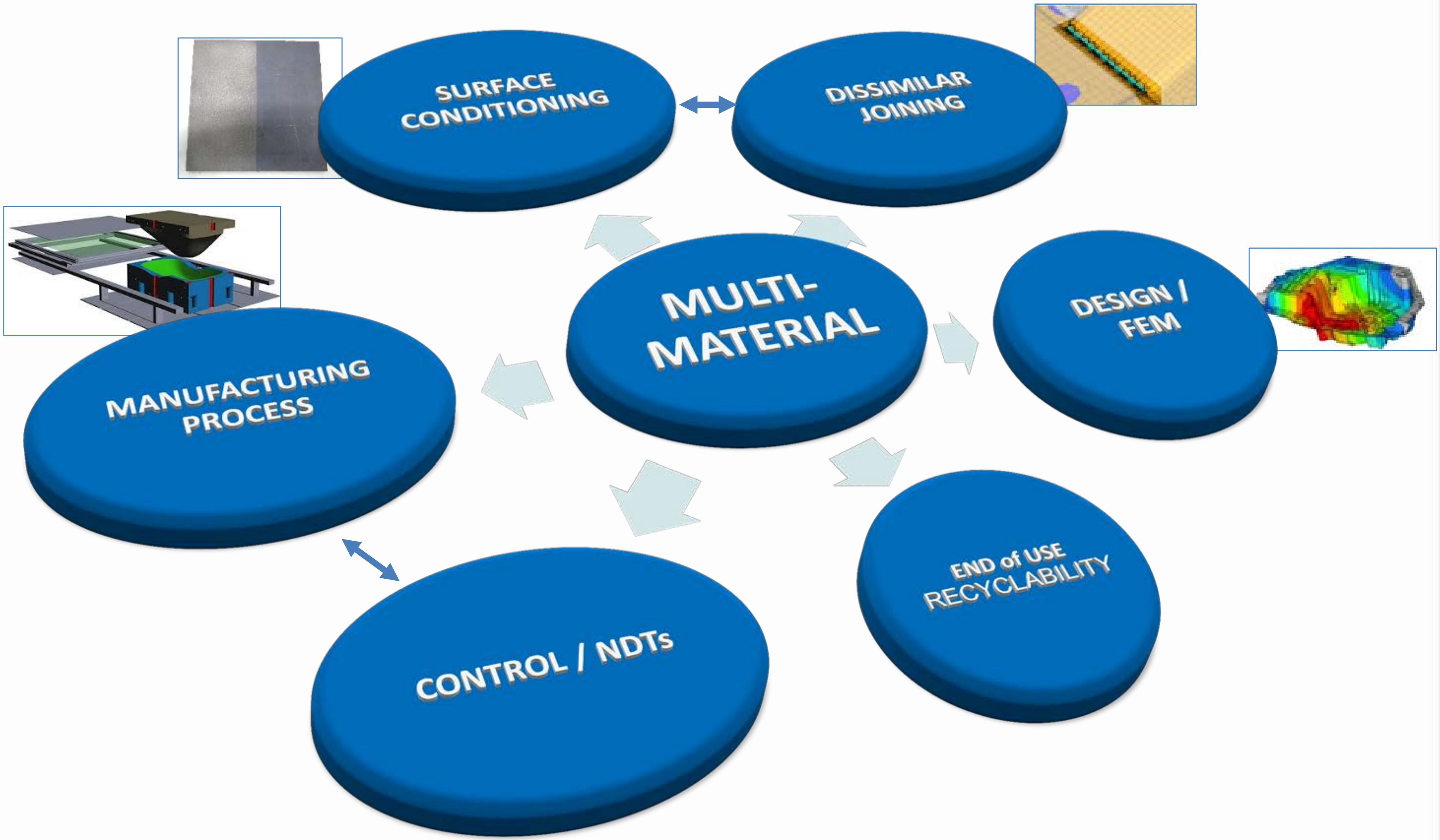
MANUFACTURING PROCESSES

LOW COST

LOW AUTOMATION

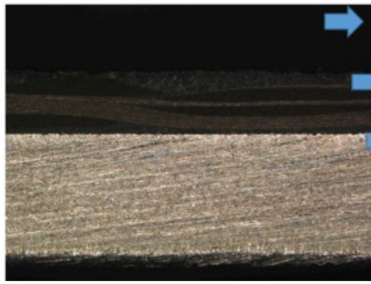
EASY APPLICATION

AREAS OF STUDY IN MULTI-MATERIAL DEVELOPMENT



optimize material choice, multi materials geometry and processes simultaneously

- METALLIC-COMPOSITE **DISSIMILAR JOINT**



- Adequate joint resistance
- Durability (long term performance)
- Avoid galvanic coupling
- Thermal fatigue (coef. Thermal expansion)
- Manufacturing process (cost effective)

- **DURABILITY** of multi-material solutions
- Characterization of multi-material components, mainly **NDT**
- Manufacturing process: **ONE-SHOT** processes, **adaptation** of existing processes
- PROCCESS **MONITORING & CONTROL**
- **Joining** the multi-material component **to other parts**
- MULTI-MATERIAL **DESIGN**
- Take into account the multi-material concept to **design production processes**
- **Regulation** context (Solas, etc)

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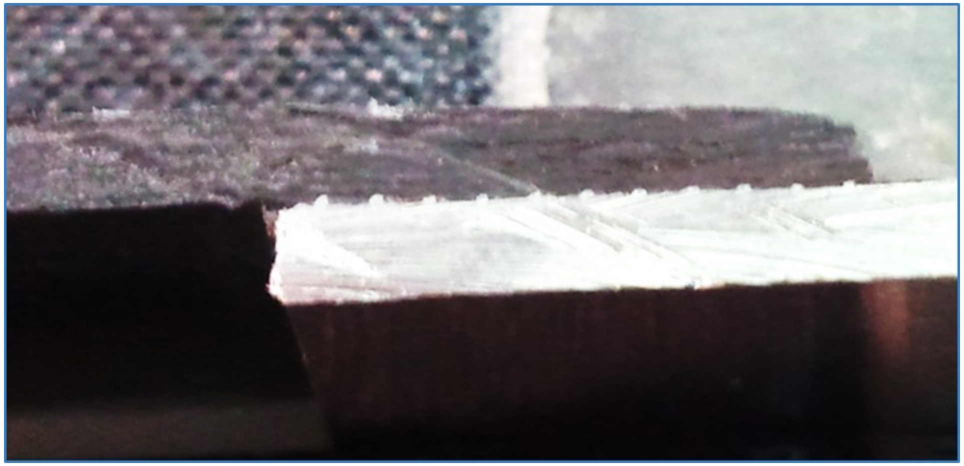
- **AIMEN R&D Multi-material Projects**



MULTI-MATERIAL METAL-COMPOSITE: AIMEN'S RESEARCH EVOLUTION

2008 2012 2014 2015 2016 2017 2018

MARITIME INDUSTRY

WIND ENERGY / ON & OFFSHORE

AUTOMOTIVE / AERONAUTIC

REPAIR of METAL PARTS
- CRACKS
- CORROSION

METAL REINFORCEMENT
- REMODELING THE STRUCTURE
- INCREASE CARGO CAPACITY IN SERVICE

MULTI-MATERIAL DESIGN

LIGHTWEIGHTIH OF ORIGINAL COMPONENT

OPTIMIZE MECHANICAL BEHAVIOR (IMPACT, FATIGUE)

MULTI-MATERIAL STRUCTURAL ANALYSIS

LAY2FORM: "Efficient Material Hybridization by Unconventional Lay-up and Forming of Metals and Composites for Fabrication of Multifunctional Structures"

RAMSSES "Realisation and Demonstration of Advanced Materials Solutions for Sustainable and Efficient Ships"

ComMUnion "Net-shape joining technology to manufacture 3D multi-materials components based on metal alloys and thermoplastic composites"

MOSAIC "Materials On-board Steel Advancements and Integrated Composites"

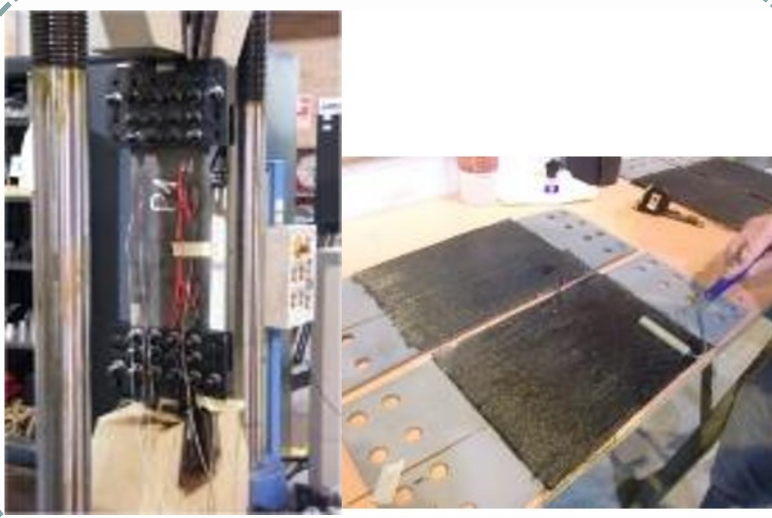
CO-PATCH "Composite patch repair for marine and civil engineering infrastructure applications"

MIAMI "Development of multi-material structures for offshore applications with severe fatigue and durability stresses in marine environment"

EMMA "Development of light and low cost multi-material structures for the automotive industry"

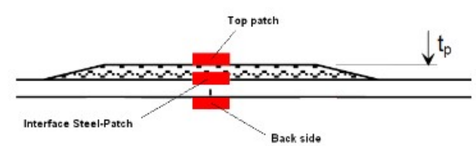
- ✓ Crack repair
- ✓ Steel reinforcement
- ✓ New multi-material structures

Lab small and medium scale

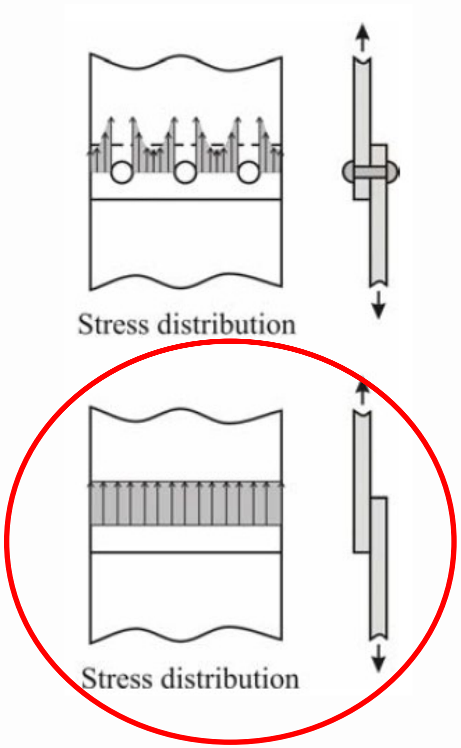


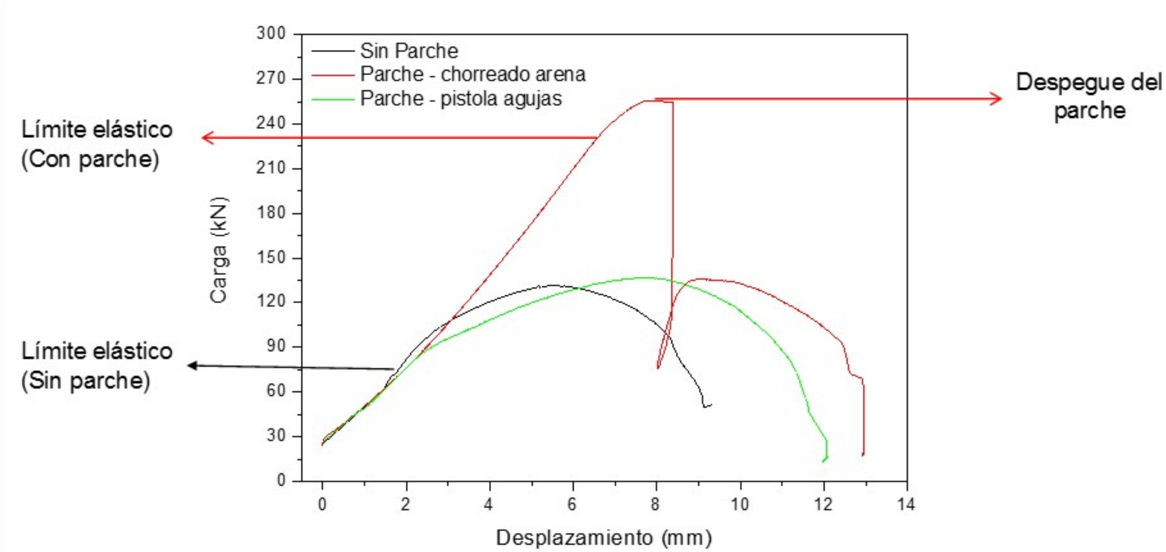
Real scale

Manufacturing processes: HLU, LRI, RTM & prepregs.
Direct joining & Adhesive Joining
Monitoring and Control systems applied (FBGs)



The COPATCH solution bases its operation on the **transfer of stress** from the damaged structure (steel) to the composite material **through the adhesive bondline**.





Composite arrests crack growth, increases the module and maximum load of the structure

WIND ENERGY: joining thermoset composites to steels

miami

Partners: emesa, GHENOVA ingeniería, Fiberglas, galventus, TEAIS

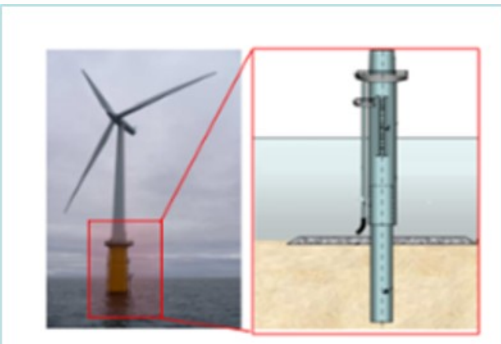
CDTI Centro para el Desarrollo Tecnológico Industrial

INNTERCONECTA CALL

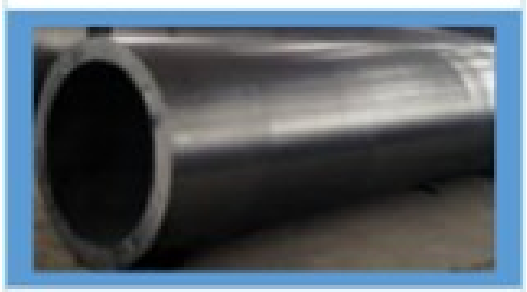
Multi-material off-shore structures subjected to adverse conditions.

- Steel / filament winding composite.
- Monitoring of fatigue and corrosion.

DEMO CASE: ***Transition part of the tower of and offshore windmill***

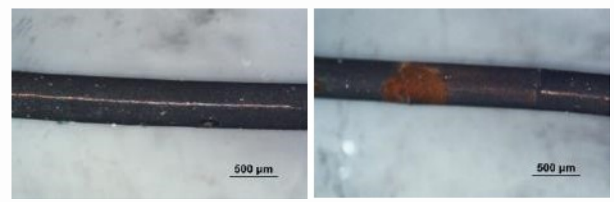


multi-material manufacturing based on filament winding

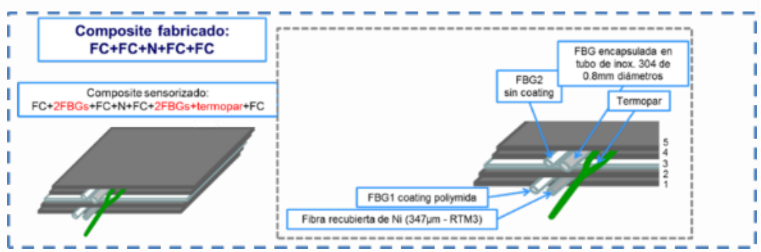


Structural and corrosion monitoring based on embedding fiber optic sensors

Coating development of FBGs

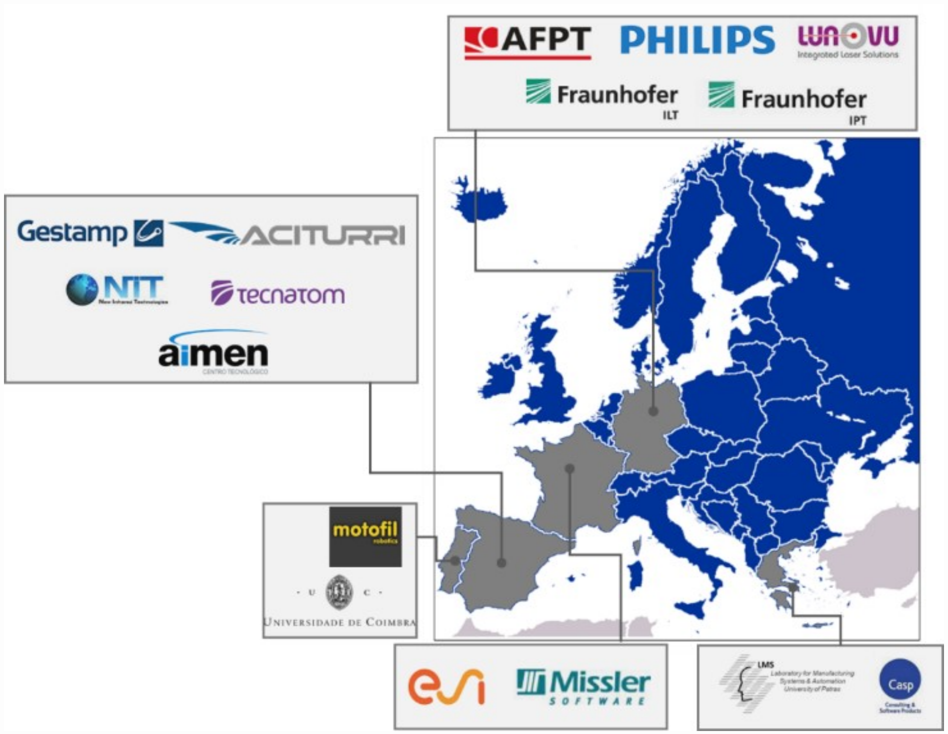


FBGs embedded on composite laminated and interlayer steel-composite



COMMUNION
JOINING OF 3D TPC/METAL MULTIMATERIAL COMPONENTS

NET-SHAPE JOINING TECHNOLOGY TO MANUFACTURE 3D MULTI-MATERIALS COMPONENTS BASED ON METAL ALLOYS AND THERMOPLASTIC COMPOSITES



http://communionproject.eu

- H2020-FoF12-2015
- 15 partners from 5 different EU countries
- Coordinated by AIMEN
- Key and complementary expertise covering the value chain
- End-users:
  - Automotive: Gestamp (TIER1)
  - Aeronautic: Aciturri (TIER1 of Airbus)

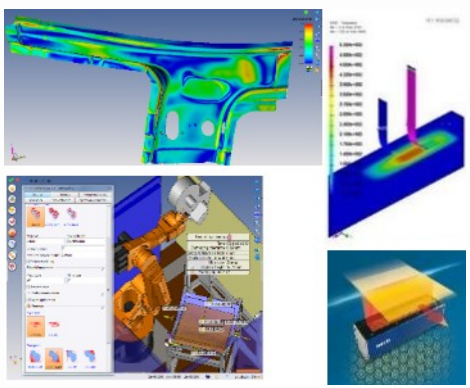
HORIZON 2020 — EFFRA

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 680567.
The dissemination of the project herein reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.

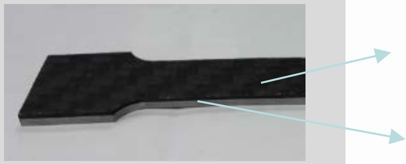
AUTOMOTIVE & AERONAUTICS: joining metal alloys and TP-composites

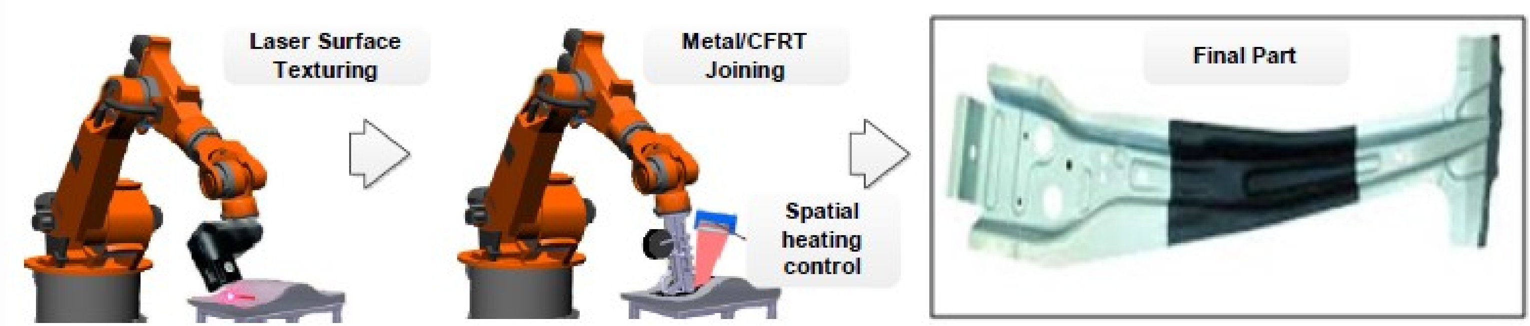
COMMUNION
JOINING OF 3D TPC/METAL MULTIMATERIAL COMPONENTS

- ✓ Direct TP-composite to metal joining optimization
- ✓ Demonstrate durability (corrosion, thermal fatigue, etc.)
- ✓ Develop a cost-effective process



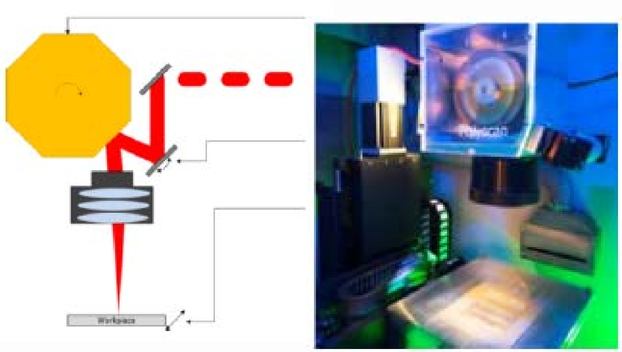
- Automatic tape placement of CF tapes
- Direct bonding between CF and metal
- High-speed laser texturing of metal surfaces:
  - Highly reproducible
  - Easy automation
  - Environmental friendly tool



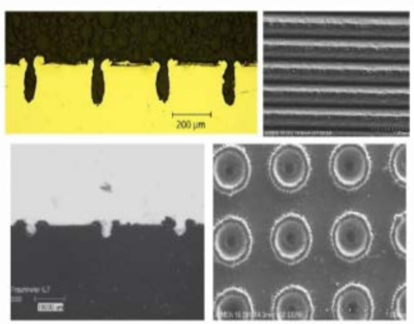


LASER TEXTURING AND CLEANING OF SURFACES

- ✓ Elimination of undesired substances
- ✓ Creation of controlled structures on the metal surface for the anchorage of the



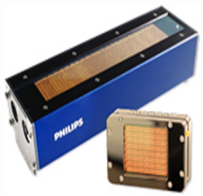
Polygon scan laser (Source: FhG-ILT)



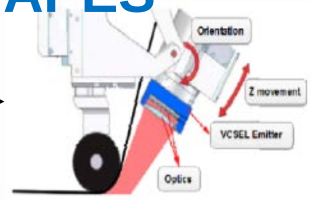
Texturized surfaces details (Source: FhG-ILT & AIMEN)

➢**IMPROVED WETTABILITY AND MECHANICAL INTERACTION COMPOSITE-ADHESIVE/METAL INCREASED**

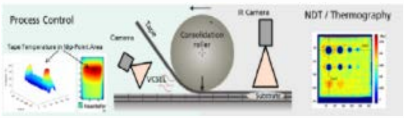
LASER ASSISTED SYSTEM TO HEAT LARGE WIDTH TPCs/ FLEXIBLE HEAD FOR METAL-COMPOSITE JOINING FOR COMPLEX SHAPES



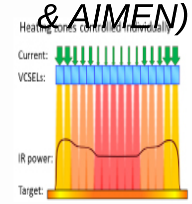
VCSEL heating system (Source: Philips)



Automatic tape placement (Source: FhG-IPT & AIMEN)



Process control (Source: FhG-IPT & AIMEN)



Adjustable heating profile (Source: Philips)

➢**PRECISE CONTROL OF HEATING DISTRIBUTION**

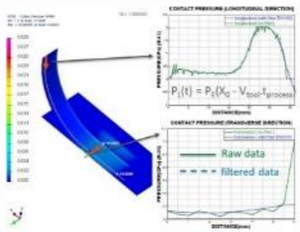
➢ **ADJUSTMENT TO COMPLEX GEOMETRIES**

AUTOMOTIVE & AERONAUTICS: joining metal alloys and TP-composites

PARAMETERIZED ENRICHED CAD/CAM SYSTEM

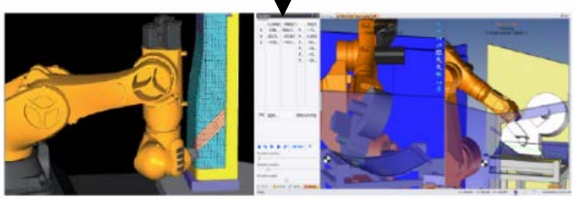
DECISION SUPPORT SYSTEM (DSS)

DESIGN AND MULTI-SCALE SIMULATION



SELF-ADAPTIVE SYSTEM

ENRICHED CAD/CAM
- **geometry information.**
- **laminate information.**
- **process parameters**



CAD/CAM robot planning system applied to tape-laying (*Source: http://www.fibrechain.eu/publication/index.jsp*)

- **DSS: REDUCE THE LEAD TIME IN NEW PRODUCT DESIGN**
- **ENRICHED CAD/CAM: OPTIMIZE THE SET-UP CONFIGURATION PROCESS**

ON-LINE QUALITY DIAGNOSIS SYSTEM BASED ON NDT'S

DUAL STAGE NTD's QUALITY DIAGNOSIS SYSTEM
- Speckle pattern technology for surface condition monitoring
- Active thermography for in-line inspection

PROCESS

KNOWLEDGE BASE SYSTEM

SELF-ADAPTIVE SYSTEM

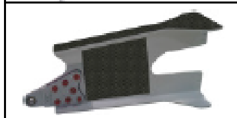
ENRICHED CAD/CAM SYSTEM

IDENTIFICATION OF OUT OF RANGE STRUCTURES

- **PREVENT THE DEFECTS PROPAGATION TROUGH THE DIFFERENT STAGES**

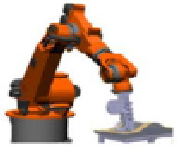
IMPACT

✓ At least 20% decrease in the consumption of high cost and critical materials.

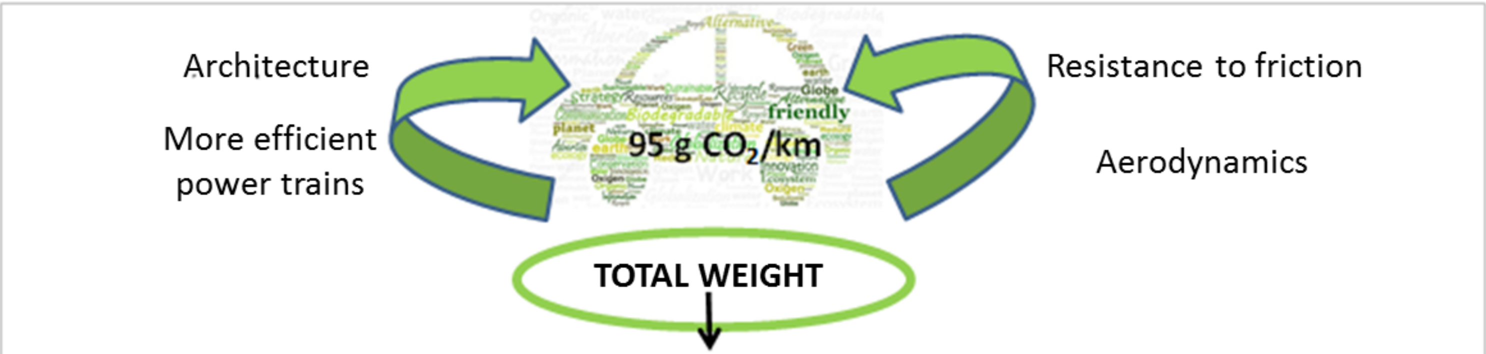
	Reference	Material	Weight (kg)	Cost: material (€)
	Traditional bearing rib	Ti6A14V	100 (ref. value)	6000 (considering ref. weight)
	ComMUnion bearing rib	Ti6A14V /PPS-CFRT	50+15 (titanium+CFRT)	4500

✓ At least 30% improvement of product performance.

✓ High level of automation and lower production times compared to current technologies.

Joining metal/CFRs components		Material	Fabrication	Joining technol.	Surface modification	NDT	Control
Currently Manual		Metal/ TSC	Separately: TSC are manufactured by hand lay-up, infusion	TS adhesives	Manual or automated, little innovative (sand blasting, primer)	Offline	No
ComMUnion approach		Metal/ CFRT	Direct joining: CFRTs are joined to metal surface by laser assisted automated tape placement (with TP adhesive at interface)		Innovative high speed laser texturing and cleaning	Online	Online control of joining parameters

DEVELOPMENT OF LIGHT AND LOW COST multi-material STRUCTURES FOR THE AUTOMOTIVE INDUSTRY



BIW *(Body in white)*: 20% of the total weight, 63% metal

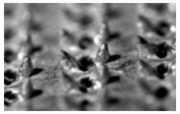
Potential weight savings in a medium vehicle: 140kg*

Case of study:
Bumper: 3,8-3,3kg
Weight saving: 30-40%

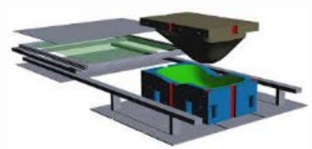
AUTOMOTIVE : joining TP-Composites and TS-Composites to metal alloys

EMMA

Surface laser treatment of steel (reduce thickness)

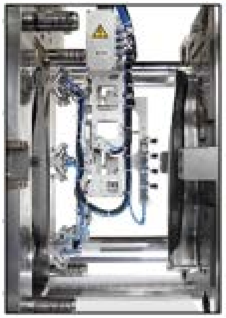


TS-composites (CF/epoxy prepregs)
Press-forming (curing + joining)



TP-Composites (PA/CF):
-Prepregs (reinforcements): press-forming for consolidation and joning

- PA + shor fiber (pellets): overinjection



multi-material
TP-composite+Steel
bumper

LCA
Weight
Mechanical Performance

multi-material
TS-composite+Steel
bumper

- ✓ Multi-material systems represent a very attractive **performance / cost solution.**
- ✓ They have different applications in different industrial sectors: repair, reinforcement, and new component.
- ✓ It is an **intermediate approach** to the complete replacement of a metallic component with a composite one.
- ✓ They **combine the advantages of materials of different nature**, maximizing the benefits of both and reducing the limitations.
- ✓ An **ad-hoc design** must be carried out according to performance specifications.
- ✓ Current trends are:
  - Optimization and greater knowledge of **dissimilar unions** (surface treatments)
  - Improve **productivity** by integrating the manufacture of the multi-material component in the **existing processes** of both metal and composite.
  - Robotization and process **automation**
  - Implement **control systems** over each step of the process in real time.

Sede Central
Centro de Aplicaciones Láser
Polígono Industrial de Cataboi
SUR-PPI-2 (Sector 2) Parcela 3
E36418 O PORRIÑO
Pontevedra – España
Telf. +34 986 344 000

Sede Torneiros
Edificio Armando Priegue
Relva 27 A – Torneiros
E36410 O PORRIÑO
Pontevedra – España
Telf. +34 986 344 000

Delegación A Coruña
Polígono Industrial de Pocomaco
Parcela D-22 Oficina 20
E15190 A Coruña - España
Telf. +34 662 119 796

Delegación Madrid
C/ Rodríguez San Pedro, 2
Planta 6, Oficina 609 Edificio Inter
E28015 Madrid - España
Telf. +34 687 448 915

Delegación Andalucía
C/ Leonardo da Vinci, 18
E41092 Sevilla - España
Telf. +34 670 412 243

aimen@aimen.es
www.aimen.es

Thanks for your attention!

CLARA PALLEIRO | *Advanced Materials Researcher,*
Tlf. +34 986 344 000 | clara.palleiro@aimen.es