WCM Research & Innovation

Scruitanising manufacturing aspects for innovative lightweight composite components production: EnLight project results

Daniele Bassan,
CRF, WCM Research & Innovation, Project Management

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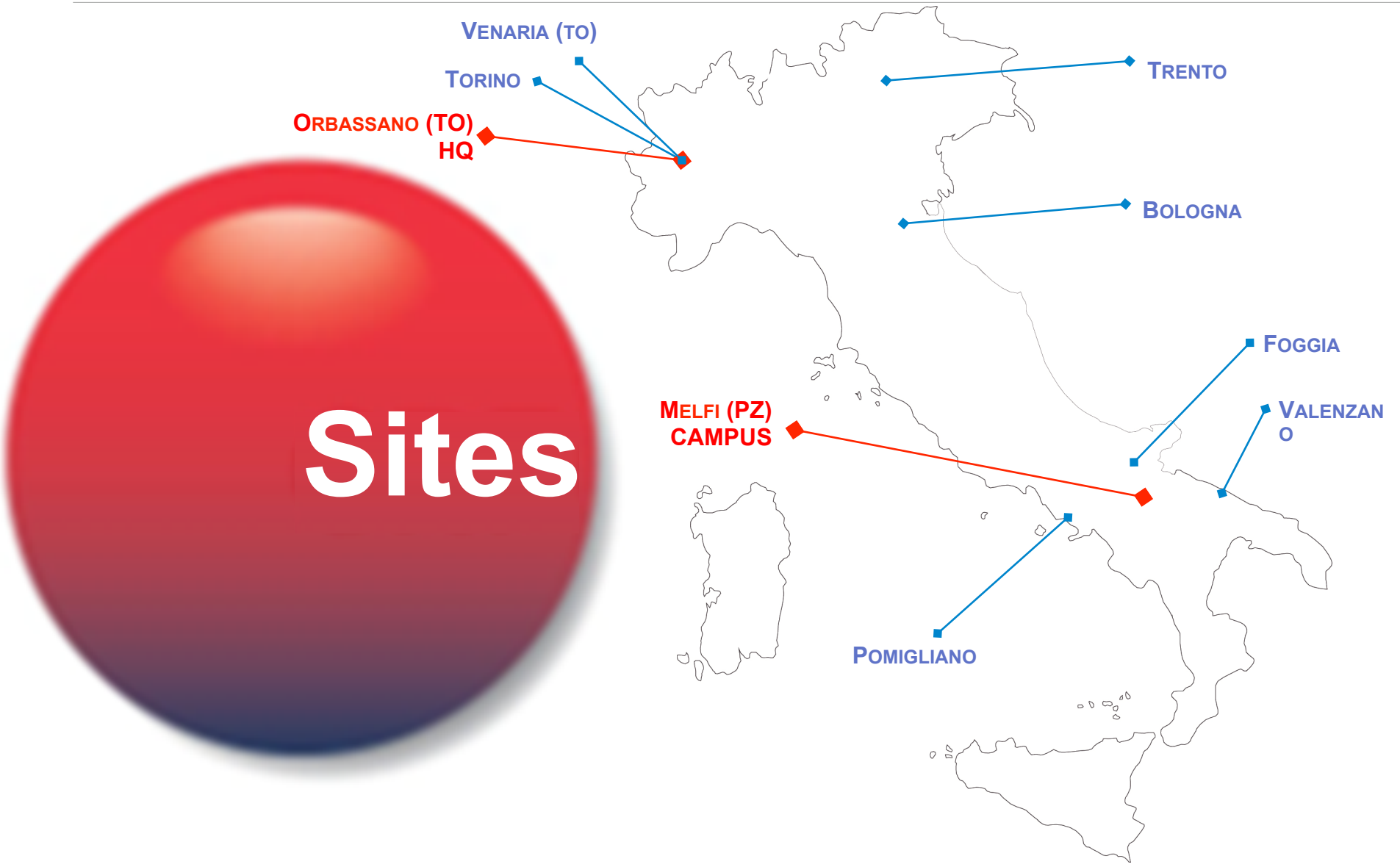
- CRF
- Automotive needs/trends
- Hybrid material approach, lightweight composite
- ENLIGHT project results

CRF: facts & figures

- Founded in 1978
- Global innovation and research hub
- 874 employees
- Global network with 400 Universities and Research Centers
- 2,223 patent rights, protecting over 600 inventions

CRF: sites


VENARIA (TO)
TORINO
ORBASSANO (TO)
HQ
TRENTO
BOLOGNA
FOGGIA
VALENZANO
MELFI (PZ)
CAMPUS
POMIGLIANO
Sites

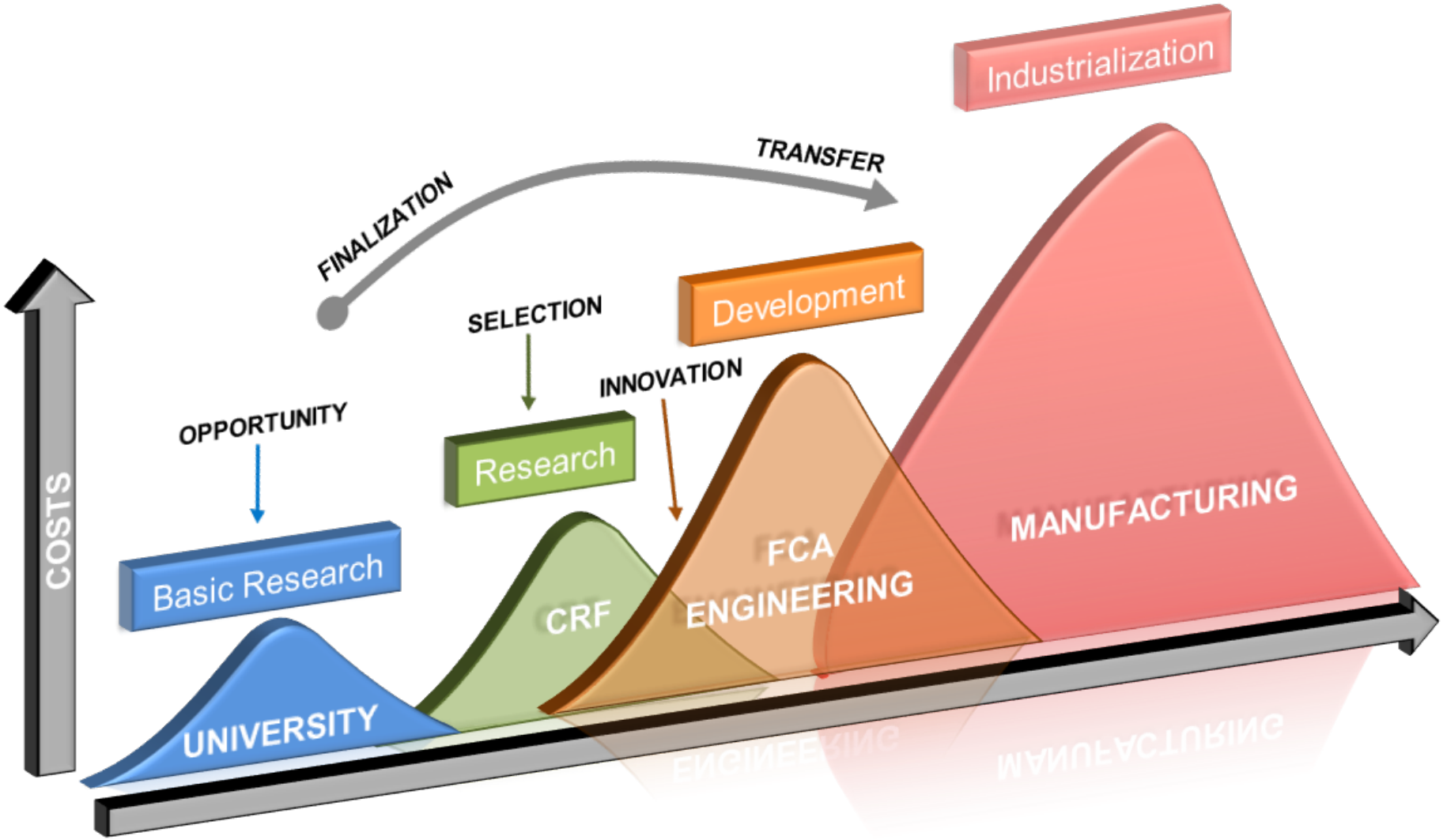
CRF: Mission

Develop and transfer innovative powertrains, vehicle systems & features, materials, processes and methodologies together with innovation expertise in order to improve the competitiveness of FCA products

Represent FCA in European and National collaborative research programs, joining pre-competitive projects and promoting networking actions

Support FCA in the protection and enhancement of intellectual property

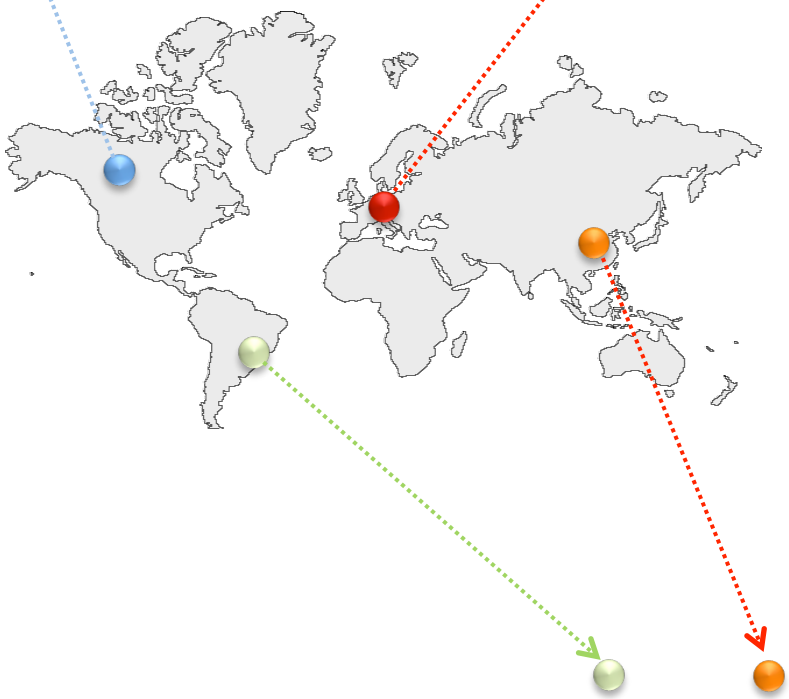
CRF: Focal point for research and innovation activities



Strategic collaborative research

Focus on North America (NAFTA)

- USCAR
- USDrive
- Canada

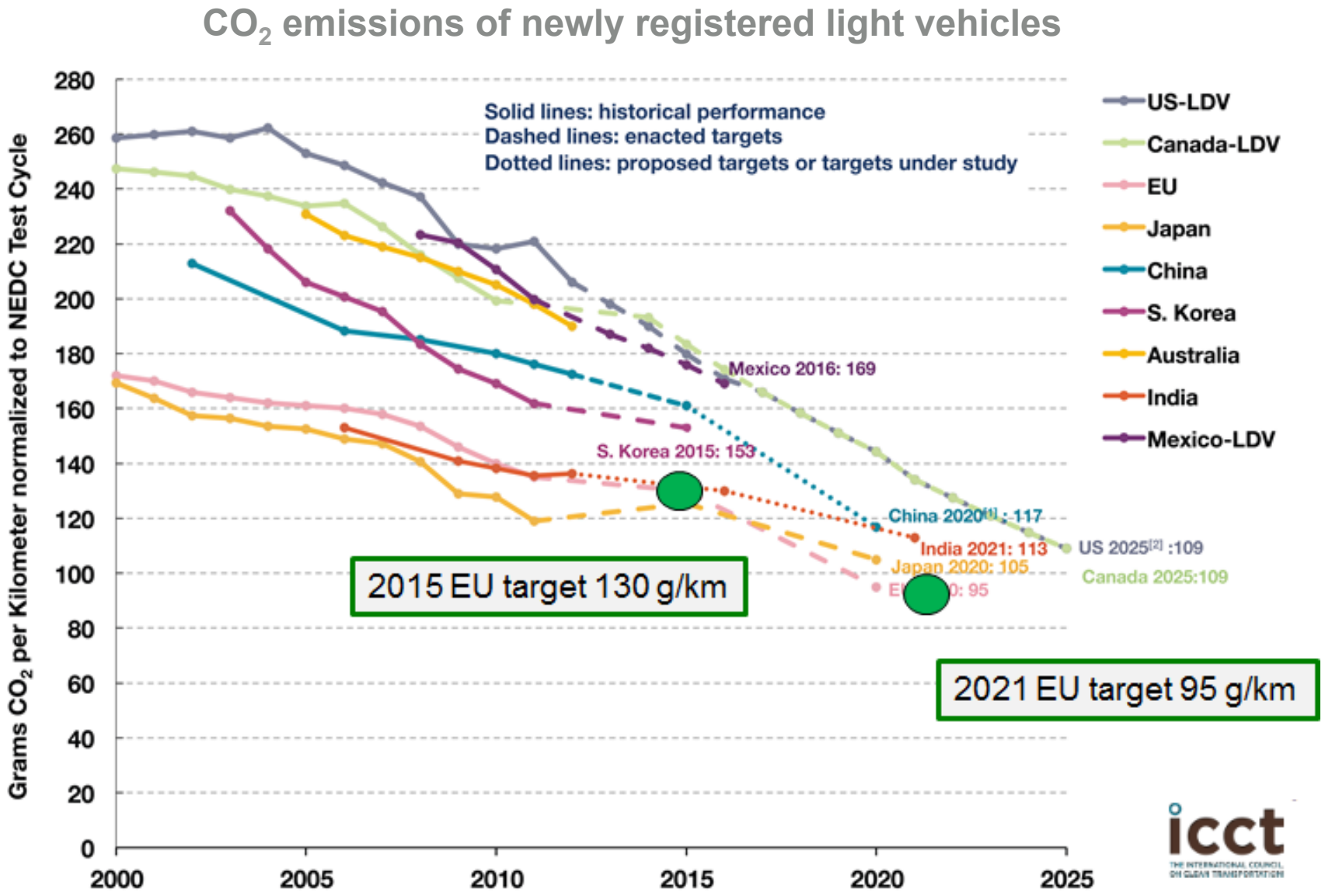


Perspective on other regions **(LATAM, APAC)**

Focus on Europe (EMEA)

- **National and Regional Programs** (Italy).
- **European Technology Platforms:**
  - ERTRAC: Road Transport
  - EPOSS: Smart Systems
  - MANUFUTURE: Manufacturing
  - EUMAT: Materials
- **Public Private Partnerships (PPP):**
  - Green Cars Initiative
  - Factories of the Future
- **Joint Undertakings:** Artemis, ENIAC
- **EUCAR:**

From voluntary basis to Regulation EC 443/2009



CO_2 reduction strategies

Aerodynamics SCx 5dm^2 reduction saving 2g CO_2)

More efficient powertrain (10% fuel consumption ~ 13g CO_2)

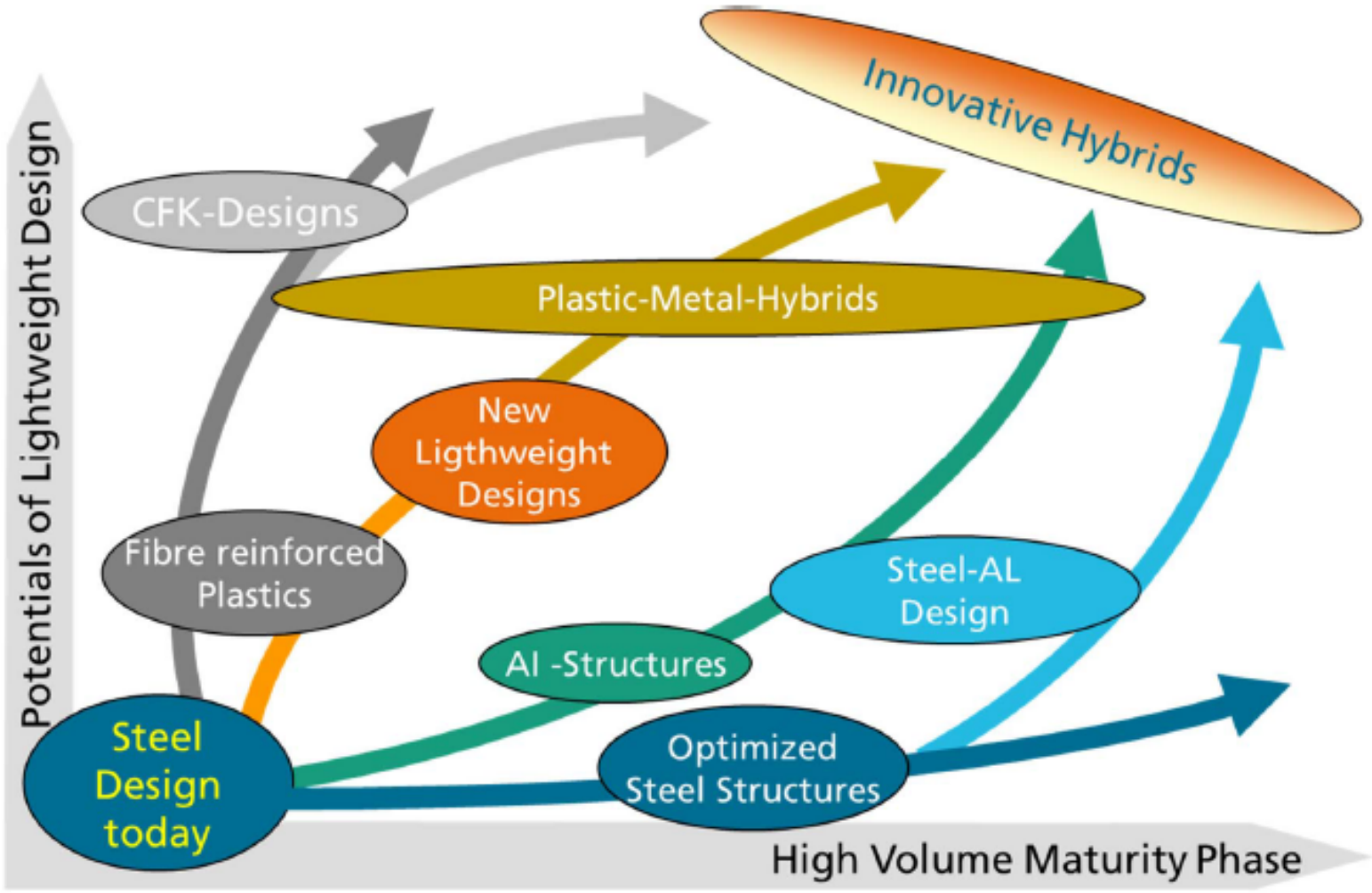
More efficient powertrain (10% fuel consumption ~ 13g CO_2)

Vehicle weight reduction (110 kg saving 10g CO_2)

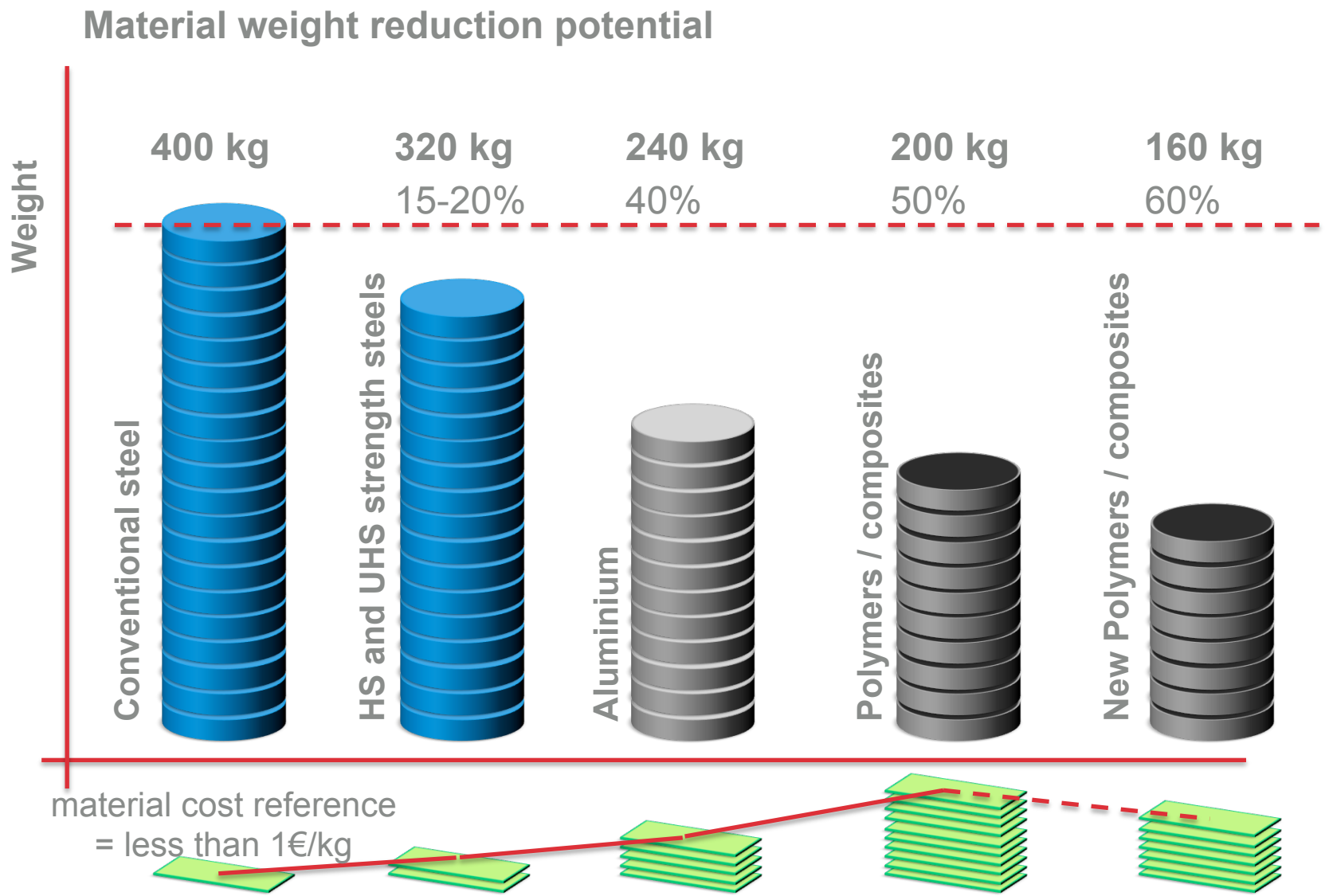
Road resistance (-10% saving 2g CO_2)

OEMs must address the sustainability challenge cost effectively, with reliable solution for mass production

CO_2 reduction strategies: multi material approach



CO_2 reduction strategies: multi material approach



Polymers / composites current status

Market readiness:

Medium-low volume series for BiW (higher strength requirement and cost)

Mass production for front module, fender, tailgate

Current needs:

- Develop new manufacturing technologies for high volume production
- Develop new material with reduced costs (different fiber type or manufacturing process)
- Improve design know-how (also to reduce costs) and reliability
- Class A surface (where required)
- Online – offline painting
- Thermo mechanical performance / warpage
- Galvanic separation in potential wet areas

New process:

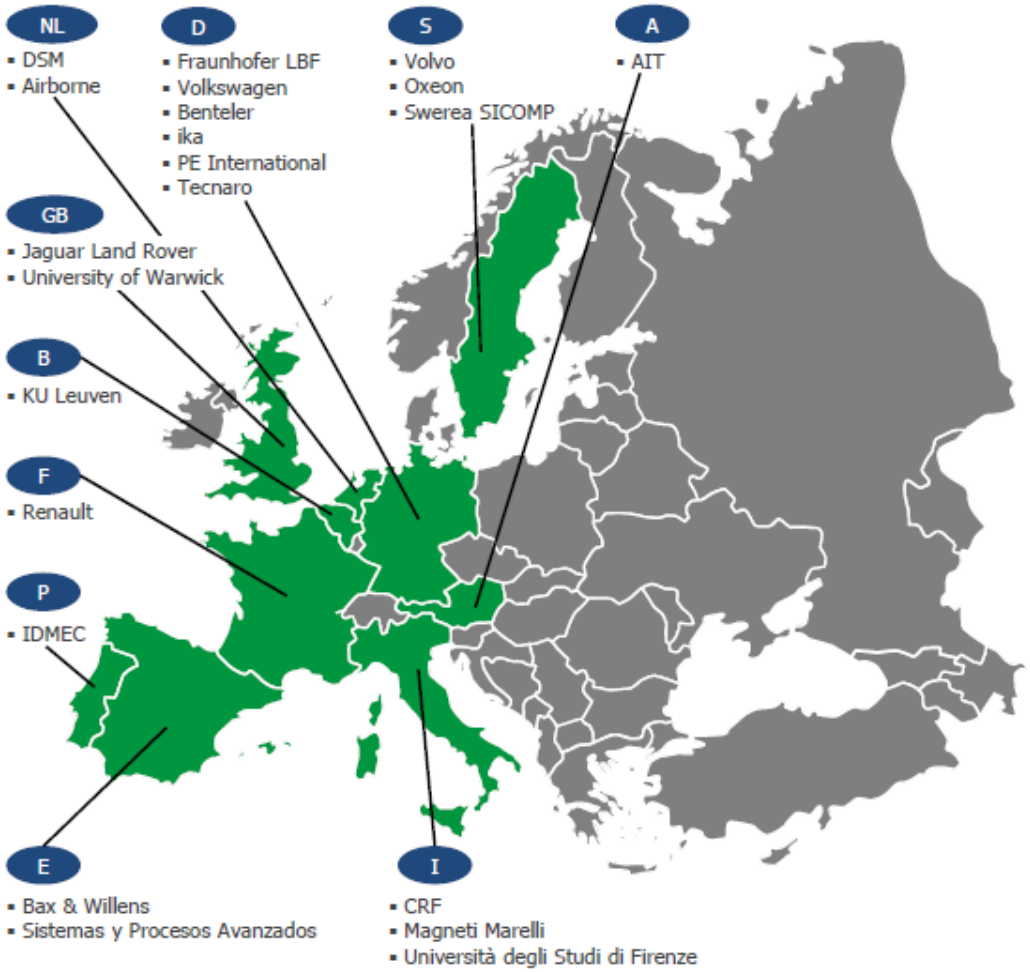
- Fast RTM for aesthetical parts (tool optimization)
- New production process ongoing for large inner structural parts …

The ENLIGHT Project
Enhanced Lightweight Design
SCP2-GA-2012-314567

General Information

Project full title:	Enhanced Lightweight Design (ENLIGHT) THEME [GC.NMP.2012-2 GC.NMP.2012-2]
Coordinator:	Fraunhofer LBF, Prof. Thilo Bein
Start Date of contract:	01/10/2012
Duration:	48 months

Partners



Fraunhofer LBF

CRF CENTRO RICERCHE FIAT

JAGUAR LAND ROVER

VOLKSWAGEN AKTIENGESELLSCHAFT

RENAULT

VOLVO

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DSM BRIGHT SCIENCE. BRIGHTER LIVING.

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SISTEMAS Y PROCESOS AVANZADOS S.L.

Airborne

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oXeon

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

idmec

swerea|SICOMP

ika INSTITUT FÜR KRAFTFAHRZEUGE RWTH AACHEN UNIVERSITY

KATHOLIEKE UNIVERSITEIT LEUVEN

THE UNIVERSITY OF WARWICK

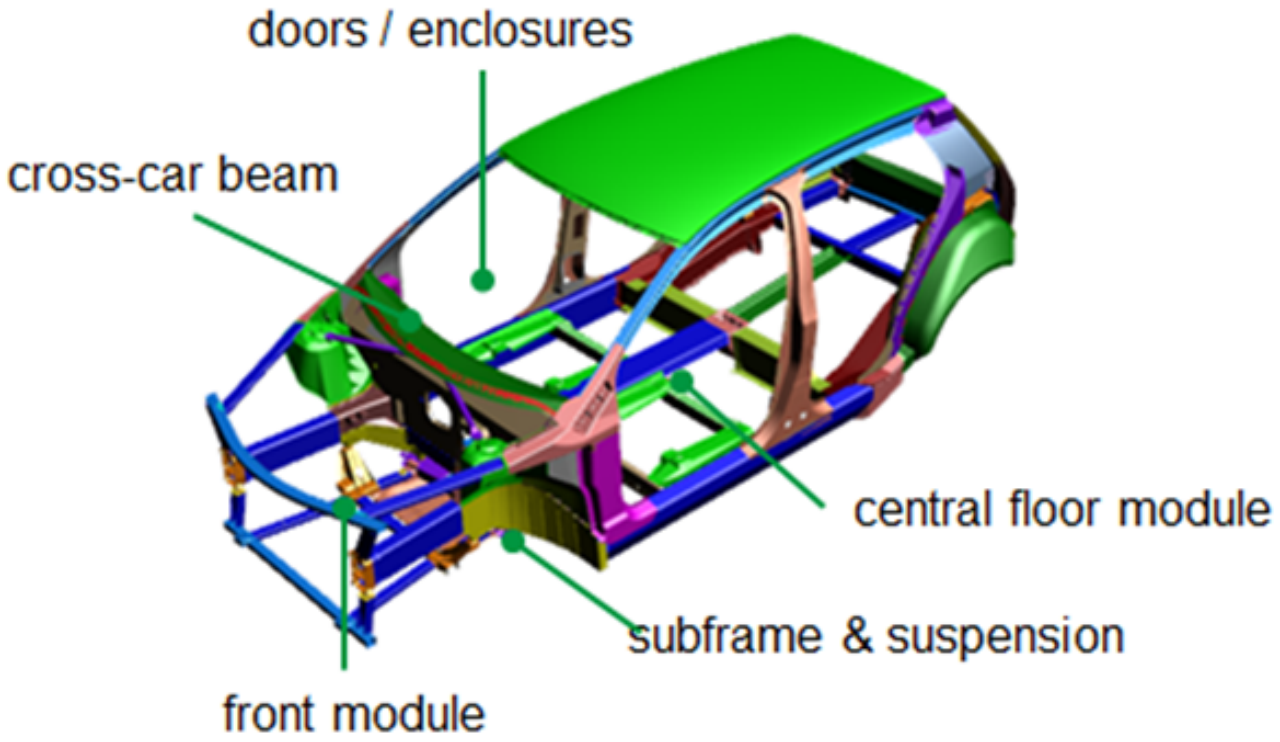
STUDIORUM UNIVERSITAS FLORENTINA

Objectives

- Development of highly innovative lightweight / low embedded CO2 materials for their application in medium-volume automotive production (50.000 units/ year)
- Design capabilities
- Manufacturing and joining capabilities
- LCA and economics analysis
- Demonstration of the proposed solution thought the realization of 5 full scale demonstrator modules:
  - Front module
  - Firewall
  - Central floor section
  - Subframe & suspension
  - Doors / closures

~ 220 mm

Concept overview
Focus on five different modules



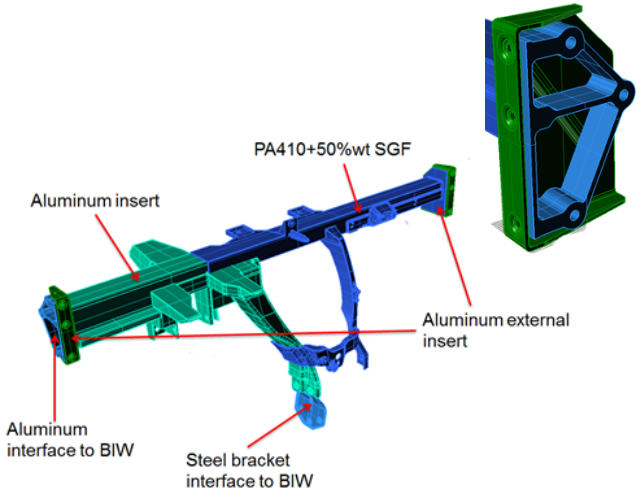
Hybrid material approach: thermoplastic CFRP in combination with aluminum

The described hybrid structure concepts may partially be realized by separated metal and FRP manufacturing steps that lead to an assembly step.

module	Implementation of hybrid materials
Suspension control arm	Thermoformed CFRP structure with aluminium sheet insert
Cross-car beam	Aluminium and CFRP inserts overmoulded with short fibre reinforced thermoplastic
Central floor section	Aluminium joining flanges bonded to CFRP/GFRP floor panel

Cross Car Beam Manufacturing Technologies (WiP)

- CCB Manufacturing and material choice:
  - EcoPaXX Q-HG10 (PA410+50%wt SGF)
- Manufacturing processes
  - Thermoforming of CF layers
  - Over-injection of PA410+50%GF on CF layers and metal inserts
  - All processes are already used in mass-production
- Joining technology definition:
  - co-moulding of threated inserts - over-injection of metal inserts
  - Hybrid joints between aluminum (surface treated) and composites



Composite Suspension Arm
Description of the Composite Concept

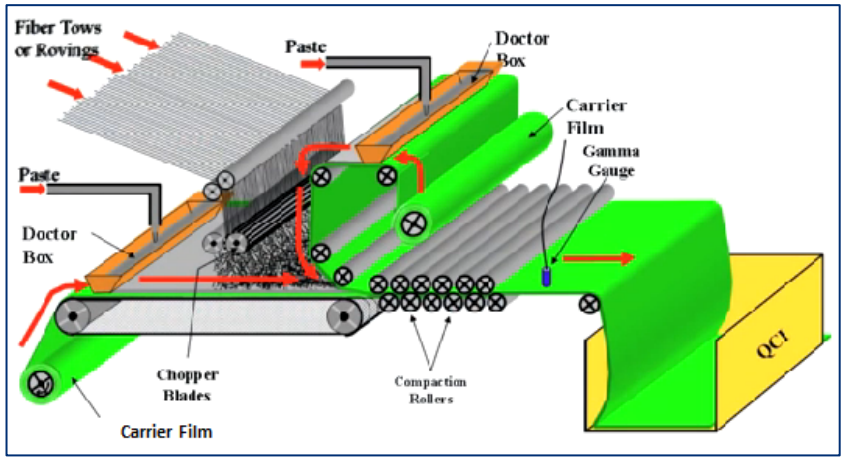
- Vinyl Ester Resin reinforced through chopped carbon fibers (2 inch. Length) – Quantum AMC 8592 :
  - Carbon Fibre Content: 53% w/w
  - Resin Content: 47% w/w
  - E= 39128 [MPa]
  - σ_R = 205 [MPa]
  - A% = 0.5%
- Aluminum Inserts:
  - E= 71000[MPa
  - σ_R = 340 [MPa]
  - A% = 8%
- Weight: 1.79 [kg]

MMSS Composite Suspension Arm

From a mass comparison, we are able to claim that the composite solution allows us to have a **mass saving of approx. 54%,** if compared with the reference steel solution (3,9 kg).

Composite Suspension Arm Manufacturing process

- The AMC 8592 Engineered Structural Composites (ESC) is a compound with fibers impregnated between two layers of a resin paste. Below the process description.



- The steps to realize the ESC are the following:
  - Paste ingredients are mixed together.
  - Paste is doctored onto a conveyor of polymeric carrier film.
  - Fibers are distributed onto the paste layer (a dry bed, mat, is formed).
  - Mat is sandwiched between a carrier film and layer of paste.
  - Calendering of the Sandwich.
  - Compaction and impregnation.

Composite Suspension Arm Manufacturing process

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- The pre-impregnated sheets – that is Engineered Structural Composites (ESC) - are cut and put into the core of the mould, to simulate the shape of the component. The metallic inserts are located into the mould as well. When the mould closes, a cycle of pressure/temperature/curing starts, and finally the part is extracted for cooling.

MMSS Composite Suspension Arm - Advanced Sheet Moulding Compression

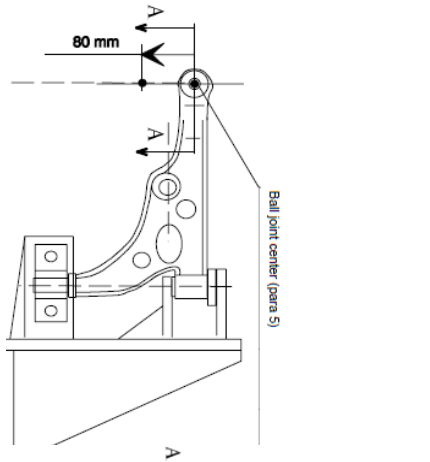
Advanced Sheet Moulding Compression (ASMC) – Assets

- ***Strength and Stiffer parts*** – During the process, the long fibres keep their original length. Besides, these compounds generally show a very high fibre content.
- ***Isotropic Mechanical Properties*** – After moulding, the fibre orientation, inside the part, is somewhat random. For this reason, the mechanical properties are quasi-isotropic.
- **Adding inserts/reinforcement ribs** – This process allows to co-moulded metallic inserts directly during the moulding. Due to the very high forming pressures used, the cohesion between composite and metal is very strong.

Composite Suspension Arm Validation

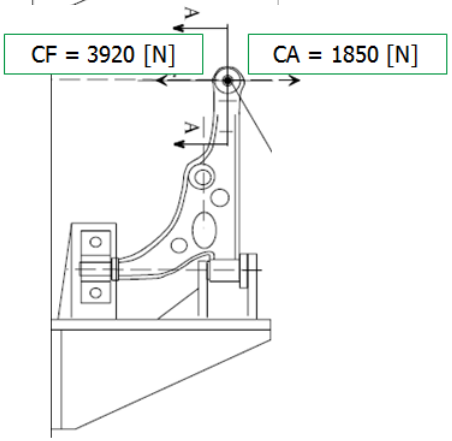
- Tests to validate the composite suspension arm are the Longitudinal Static Yield and the Fatigue with Longitudinal Loads.

❖ **Longitudinal Static Yield**



- Make the actuator cover a 80 [mm] stroke in 5 [min] directly recording load – movement trend on diagram paper by plotter x-y.
- **Target Load Collapse: 17610 [N]**

❖ **Fatigue with Longitudinal Loads**



- Stress swinging the arm as the test conditions show.
- **Target: min 200.000 [cycles]**

Composite Suspension Arm Validation

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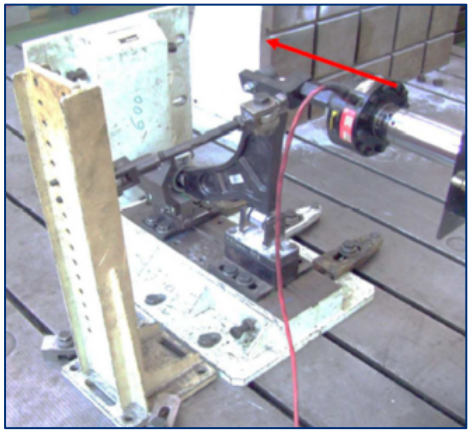
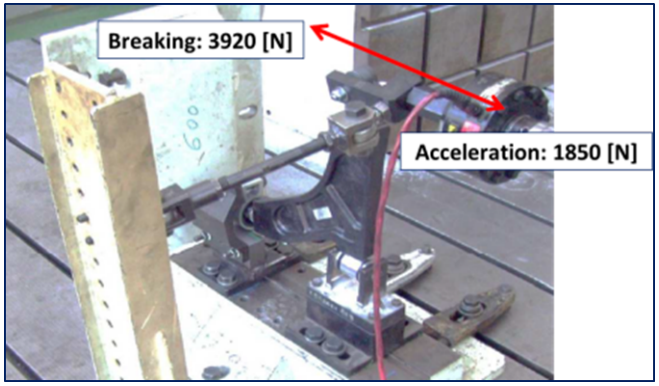


MMSS Composite Suspension Arm – Longitudinal Collapse

Longitudinal Static Yield (during brake application) - Summary Table					
No.	Collapse load [daN]		Displacement mm*	Weight	Remarks
	Actual	Target			
1	1918	1761	39	1795	Test passed



MMSS Composite Suspension Arm – Fatigue with Longitudinal Loads

Longitudinal Static Yield (during brake application) - Summary Table			
No.	Cycles No.		Remarks
	Actual	Target	
1	281.000	200.000	Test passed

- Once that the 200.000 cycles has been reached, it has been increased the number of cycles with steps of 20.000 cycles up to 281.000 cycles (breaking).

Central floor Overiview

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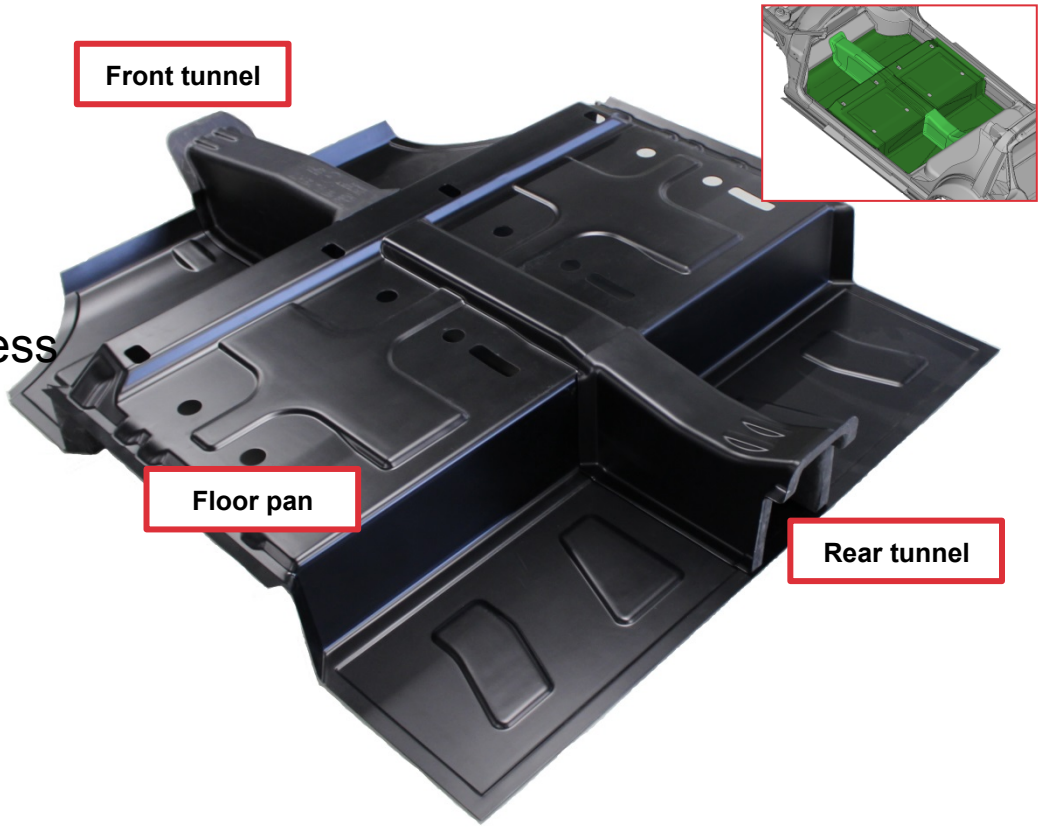
- Three thermoplastic composite components
- Front Tunnel: prototype manufactured in series scale thermoforming process
- Floor pan and rear tunnel: prototype manufactured by VARI

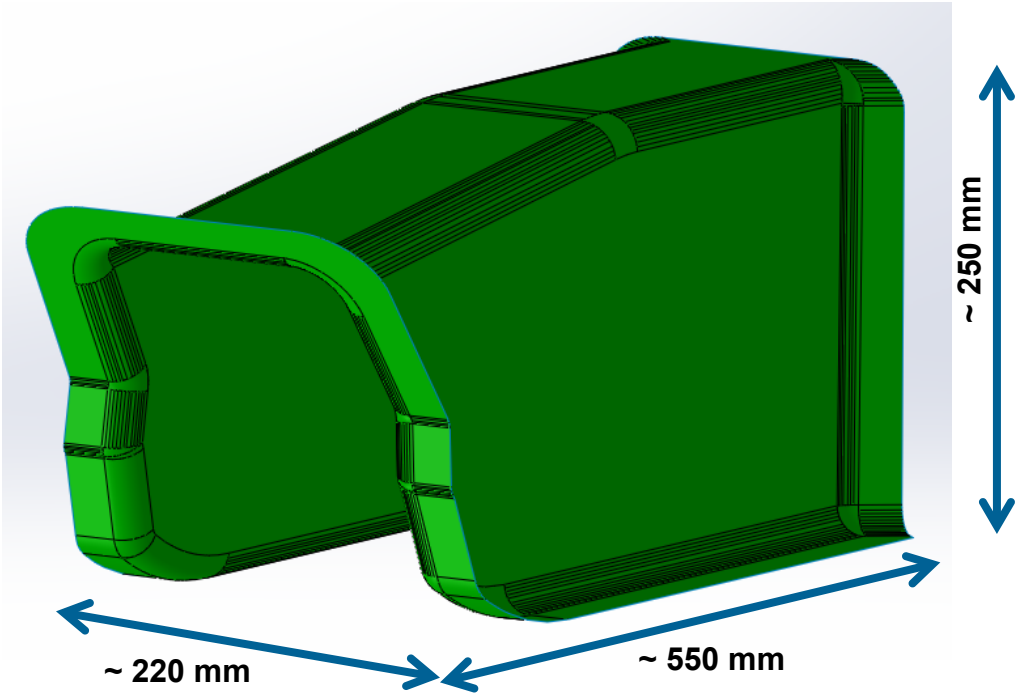


Central floor
Front tunnel: part description

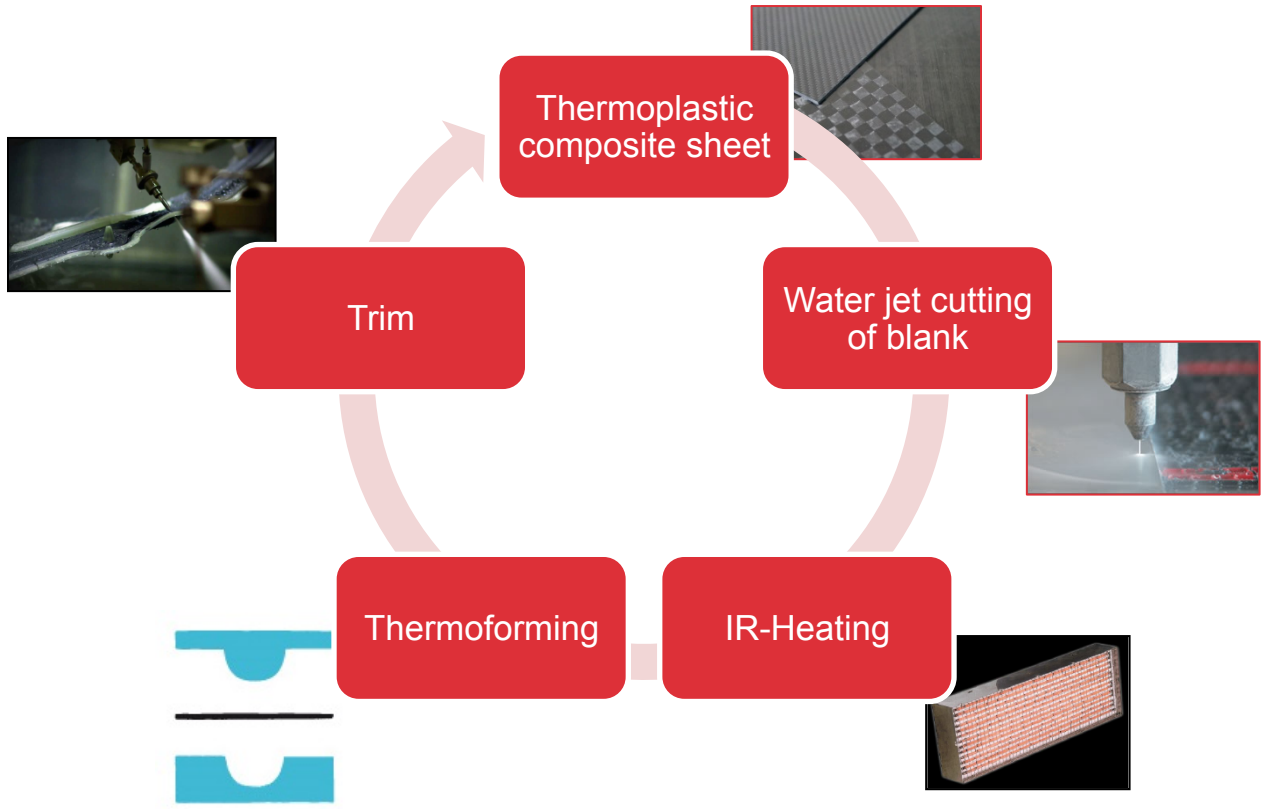
- 2.0 mm thermoplastic composite,
  radii R20 mm
  draft angle 4°

- CAD/CAE concept:
  2.0 mm EcoPaxx woven GF tape

- Hardware Prototypes:
  - 2.0 mm sheets of GF-PA6
  - 2.0 mm EcoPaxx woven GF tape



Central floor
Front tunnel: thermoforming process cycle



Central floor
Front tunnel: semi-finished products

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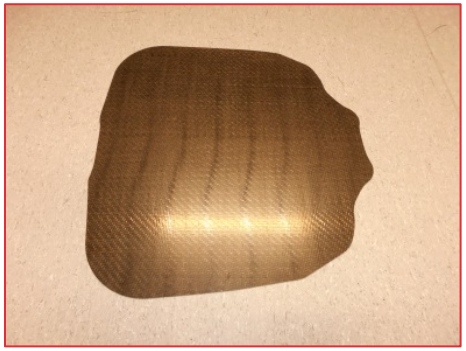
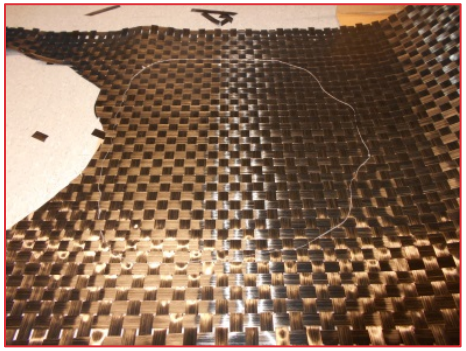
- Thermoplastic composite plates for moulding trials:
  - 4 layers of 600 g/m² E-glass twill weave in PA6 matrix
  - 2.0 mm, pure 0/90° orientation



- DSM/Oxeon woven tape for process validation
  - 4 layers of woven tape, glass fibres in PA410 matrix
  - 2.0 mm, 50% in 0/90° orientation, 50% in 45/-45° orientation
  - Blanks pre-consolidated in vacuum-bag / oven process (0.9 bar, 290°C, 30 min)



Central floor
Front tunnel: blank geometry optimisation

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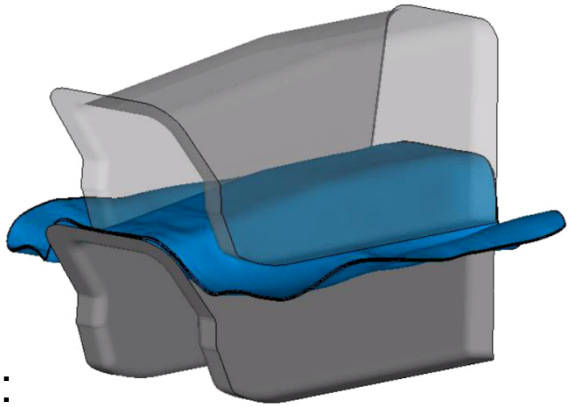
1. Feasibility proved by CAE draping simulation
2. Unfolding of sheet design from net CAD geometry
3. Addition of 50 mm surrounding trim surplus
4. Iterative optimisation of sheet contour during forming: Reduction of surplus near bulging areas



Central floor
Front tunnel: Infra-Red heating for thermoforming

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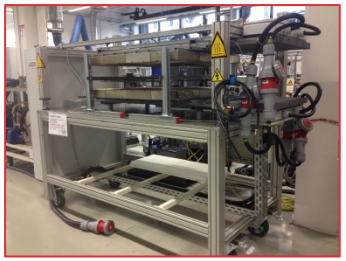
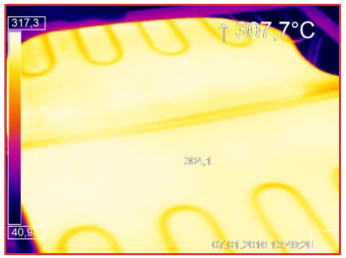
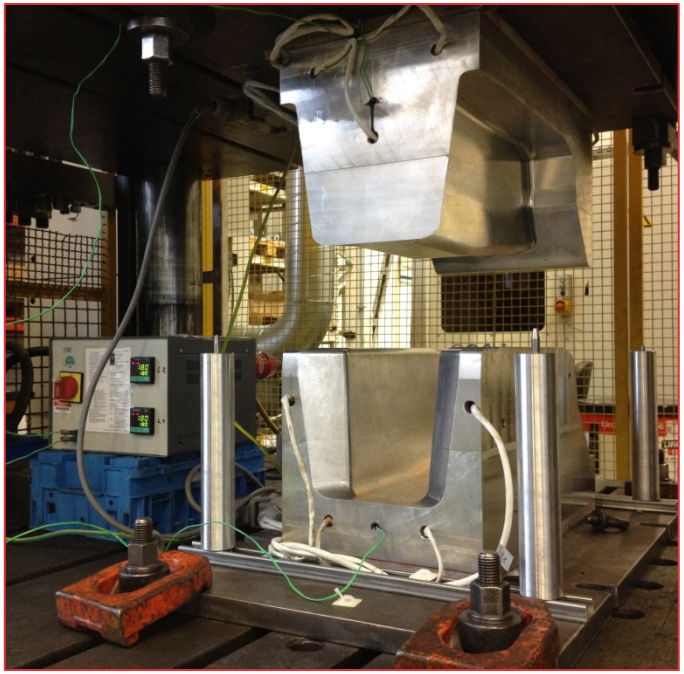
- Double-sided IR-heating device
  (medium and long wave emission, max. 28 kW)
- Surface temperature measurement and PID control
  (2 optic pyrometers)
- Heating of 2.0 mm thermoplastic composite blanks
  to 290 °C (~ 150s @ 60% power)
- Handling and positioning of blank via supporting frame
- Homogenous heating proved by thermography
  (lower heat on supporting frame)
- PA410 matrix showed strong smoke development





Central floor
Front tunnel: Thermoforming

- Aluminium mould at 180°C
  (for improved surface quality of prototypes)
- Series process would run at ~ 80 °C
  mould temperature (cooling time ~ 60 s)
- Consolidation @ ~ 3.3 MPa pressure
  on projected surface



Central floor
Front tunnel: prototypes before trim and finish

Thermoformed GF-PA6 sheet, weight 1,16 kg

Thermoformed GF-PA410 woven tape, weight 1,08 kg

Central floor
Front tunnel: prototyping results

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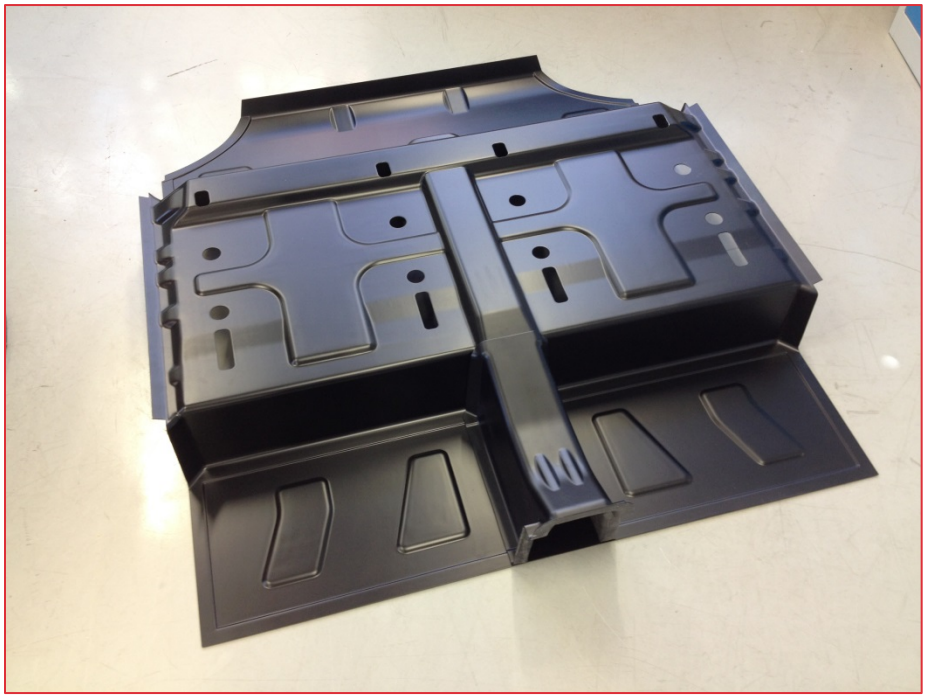
- Good draping behaviour of composite sheets observed:
  no wrinkles, even in complex 3D-contours
- Analogue forming behaviour to metal sheets:
  stretching and thickening over contours
- Thermoforming approach has been validated for mid-sized component
  → process feasible for full floor pan manufacturing

Central floor
Floor pan + rear tunnel

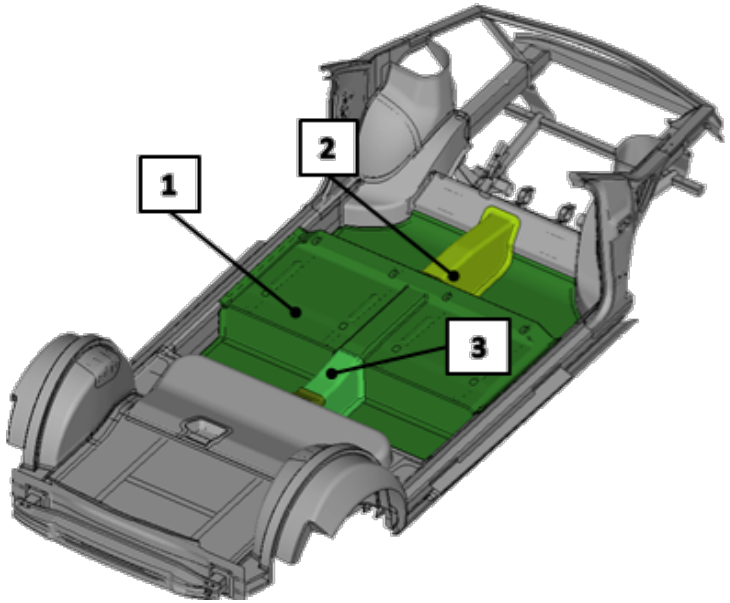
- Manufactured by vacuum assisted resin infusion (VARI)
- 2.0 mm, Quasi-isotropic layup E-glass fabric)
- Matt black painted (upper side) peel ply structure (bottom side)



Central floor
Weight overiview

	Component	Material	Perimeter	Area	TH	Mass Calc [kg]	Real mass
1	Floor	DSM ECOPAXX QXC-HG12	ENLIGHT	2559000.0	2.0	8.701	approx +5%
2	Tunnel Ant	DSM ECOPAXX QXC-HG12	ENLIGHT	301554.0	2.0	1.025	
3	Tunnel Post	DSM ECOPAXX QXC-HG12	ENLIGHT	240334.3	2.0	0.817	

Reference C segment	34 kg
ENLIGHT total	25,2 kg (-25.8%)



Expected results

- Each considered modules saves 20% weight compared to the respective reference component
- Availability and implementation of advanced lightweight materials such as hybrid, CRFPs, or thermoplastic has been exploited
- Elaboration of cost-efficient joining and manufacturing technologies for new material suitable for medium scale production (50.000 units / year)
  - Elaboration energy efficient processes enabling a CO2 foot print equal or lover that of conventional solutions made from metals
  - Elaboration of continuum manufacturing processes for new, advanced lightweight materials reducing cycle times
- Elaboration of function integration into lightweight modules (number of parts of a sub-system reduced)
- New advanced lightweight materials implemented in optimal design

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