



AffordabLe Lightweight Automobiles AlliaNCE

Future of Automotive Lightweighting Day

September 19, 2019



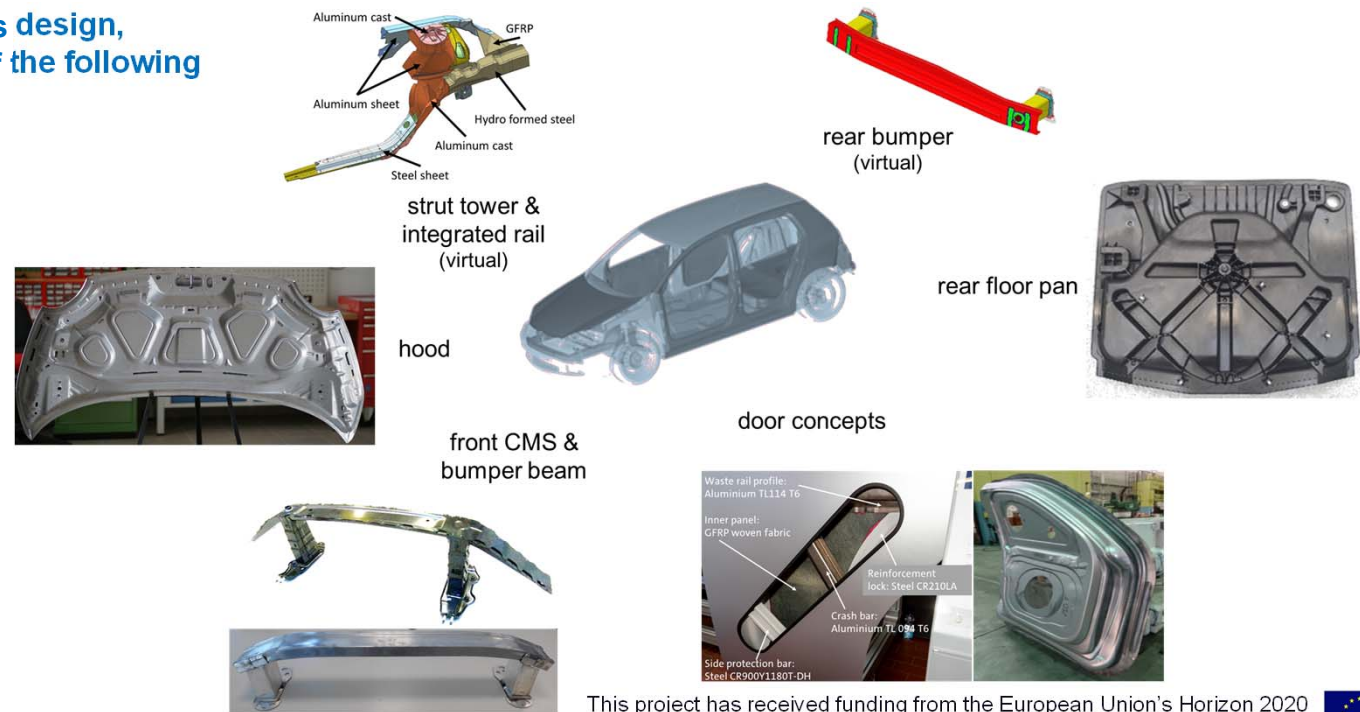
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## Overview on physical demonstrators

Jens Meschke / Volkswagen AG

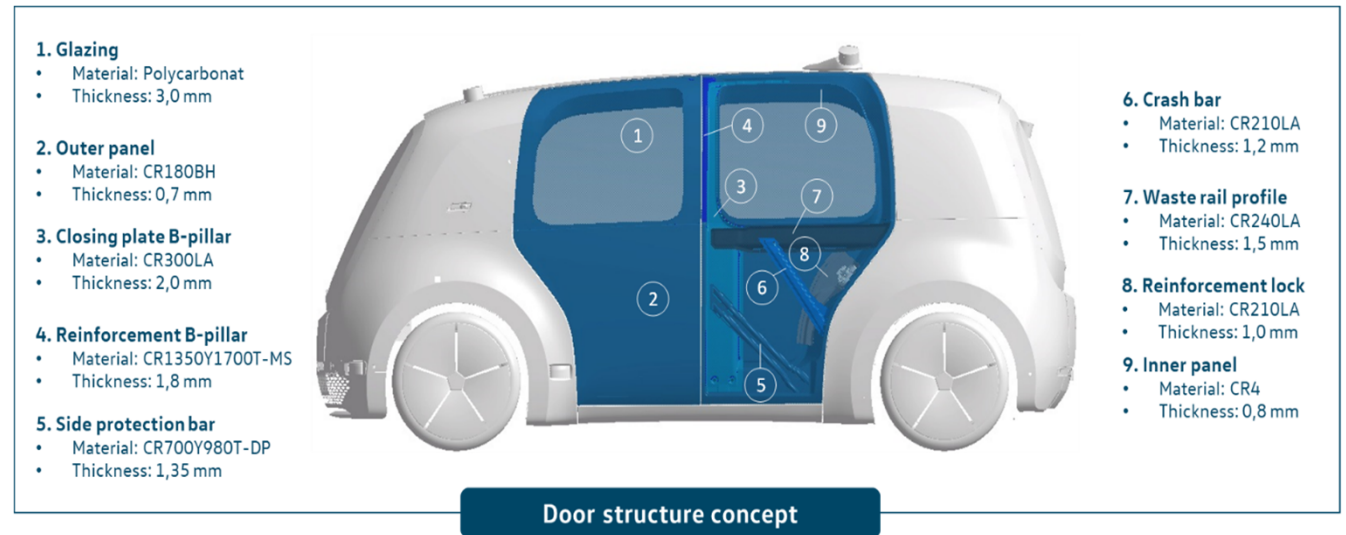
# Overall objectives of physical demonstrators

- European carmakers (CRF, Daimler, Opel, TME, Volvo, VW) and suppliers (Batz, Benteler, Novelis, tkse) have joined forces to commonly develop innovations in vehicle lightweighting (mass reduction of ~25%) focusing on costs (3 €/kg @100,000 u.p.a.) and global warming potential (LCA impact -6%).
- In work package WP5 the ALLIANCE consortium was working on eight different demonstrators of real vehicle models. The demonstrators “Integrated rails, wheel house and strut tower” by Opel and the “Rear bumper reinforcement” by TME are virtually demonstrated only. This presentation encompasses design, optimization and prototyping of the following physical demonstrator parts:



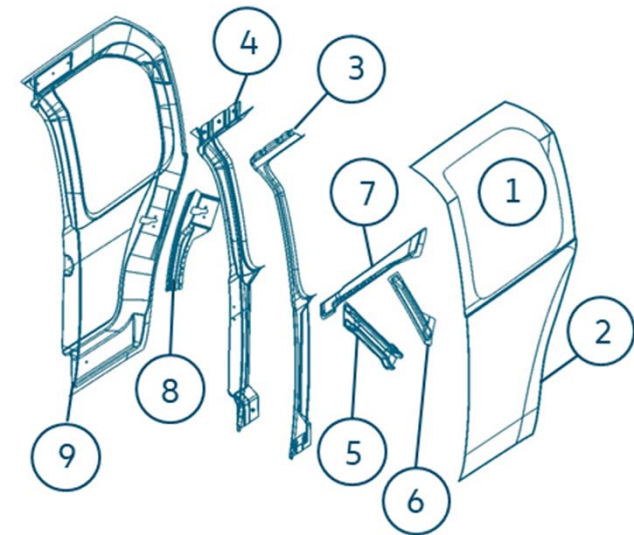
# Front door hybrid structure for an automatically driven electric vehicle / VW

- Reference door steel concept
- Lightweighting by multi-material approach
- Quantity 100.000 p.a.
- Comparison life cycle 200.000 km vs. 600.000 km
- Door prototype as demonstrator only (no testing)



# Front door hybrid structure for an automatically driven electric vehicle / VW

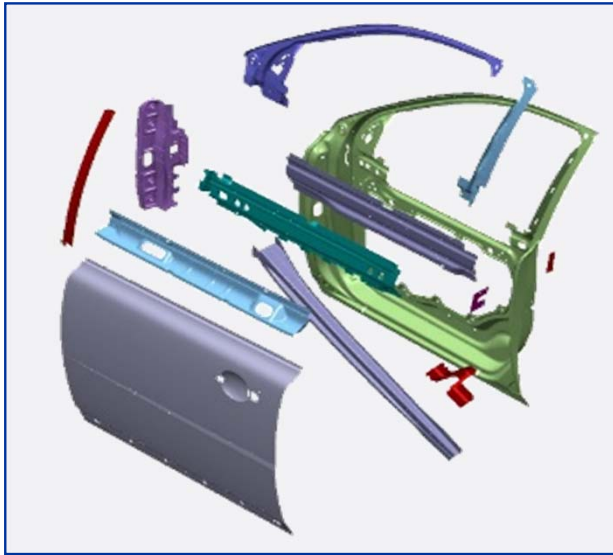
Nr. Part	Conventional steel design			Lightweight design			CO <sub>2</sub> -emissions [kg <sub>CO2-eq.</sub> ]*	
	Material	t [mm]	m [kg]	Material	t [mm]	m [kg]	200 tkm	600 tkm
1 Glazing	Polycarbonate	3,0	3,5	Polycarbonate	3,0	3,5	0,0	0,0
2 Outer panel	CR180BH	0,7	6,5	TL094 T6	1,0	3,2	1,6	-24,8
3 Closing plate B-pillar	CR300LA	2,0	5,8	CR300LA	2,0	5,8	0,0	0,0
4 Reinforcement B-pillar	CR1350Y1700T-MS	1,8	7,9	CR1350Y1700 T-MS	1,8	7,9	0,0	0,0
5 Side protection bar	CR700Y980T-DP	1,35	1,3	CR900Y1180T-DH	1,0	1,0	-6,1	-8,9
6 Crash bar	CR210LA	1,2	0,7	TL094 T6	1,2	0,2	-1,4	-4,9
7 Waste rail profile	CR240LA	1,5	2,0	TL114 T6	1,4	0,6	-4,9	-16,2
8 Reinforcement lock	CR210LA	1,0	0,7	CR210LA	1,0	0,7	0,0	0,0
9 Inner panel	CR4	0,8	10,7	GFRP woven fabric	1,8	5,1	-30,9	-76,1
*CO <sub>2</sub> -emissions in comparison to conventional steel design		<b>Abs.</b>	<b>39,1</b>	<b>Abs.</b>	<b>28,1</b>		<b>-41,7</b>	<b>-130,8</b>
							<b>-28%</b>	



**Weight saving achieved:** - 27 %  
**Achieved reduction in GWP:** - 42 kg CO<sub>2</sub> equ.  
**Additional costs in €/kg-saved:** + 1,56 € / kg saved (determined by BaxCo)

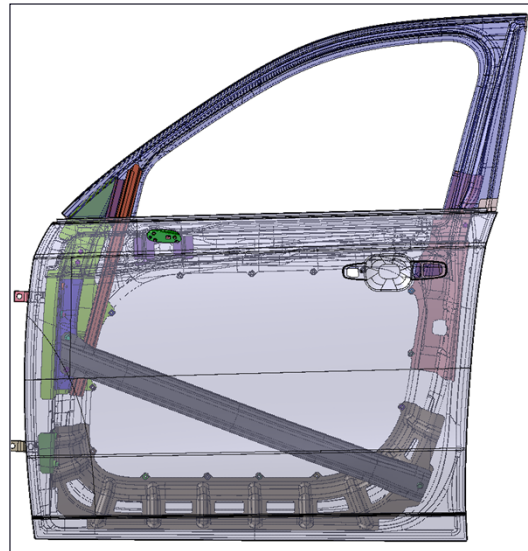
# Front door aluminium structure / Volvo

## ■ Comparison of reference and ALLIANCE final design



### Initial concept

- One piece inner panel
- 3 piece ringframe for material yield
- Hinge & lock reinforcements c/o steel design



### Developed concept

- One piece inner panel
- 1 piece ringframe for assembly & geometry
- Hinge & lock reinforcements extended for frame stiffness
- Lower reinforcement for increased stiffness



# Front door aluminium structure / Volvo

Main features of the final design: BoM, foreseen/applied manufacturing technologies, weight saving achieved, achieved reduction n GWP, additional costs in €/kg-saved + picture(s)

MODEL TYPE	PART NO LHS	PART NO RHS	PART	QTY	MTLR	T	PART WT(G) CATIA	BLANK WT	PART WT(G) STEEL
GEOM-INST	33381103-AL	33381110-AL	RING FRAME FR DR	1	ALU	1,8	1574	3950	1700
STD	30624596		PIERCE NUT M5 (for modele)	2		12	24		
GEOM-INST	33381000-AL	33415054-01	INNER PANEL FR DR	1	ALU	1,2	3006	6100	6050
GEAN-PROD	33381131-AL	33381130-AL	OUTER PANEL FR DR	1	ALU	1,0	2634	5500	5200
GEAN-PROD	33381133-AL	33381000-AL	DIAGONAL MEMBER FR DR	1	DP1000	1,5	1634	2550	1634
STD	30624280		PIERCE NUT M6	1		12	12		
GEAN-PROD	33381001-AL	33381002-AL	OUTER BELT REINF FR DR	1	ALU	1,2	477	950	970
GEAN-PROD	33381003-AL	33381004-AL	OUTER MIRROR REINF	1	ALU	3	292	610	580
GEAN-PROD	33381003-AL	33381010-AL	HINGE REINF UPPER FR DR	1	ALU	2,4	452	350	300
STD	30640642		PIERCE NUT M6 (for belt)	2		12	24		
GEAN-PROD	33381003-AL	33381010-AL	HINGE REINF LOWER FR DR	1	ALU	3,0	35	200	170
STD	30624280		PIERCE NUT M6 (for Upper Hinge)	2		12	24		
GEAN-PROD	33381013-AL	33381018-AL	SPEAKER BRACKET LOWER FR DR	1	ALU	1,5	187	450	330
STD	30624596		PIERCE NUT M5 (for modele)	2		12	24		
GEAN-PROD	33381015-01	33381016-AL	DIAGONAL BEAM REINF BRACKET FR DR	1	ALU	1,2	225	500	405
STD	30624596		PIERCE NUT M5 (for modele)	2		12	24		
			GLASS CHANNEL		ALU	1	100	150	200
			UPPER BRACKET		ALU	1,5	10	20	
			LOWER BRACKET		ALU	1,5	10	20	



## Manufacturing

### Forming Panels, reinforcements, sidemember

Cold deep/stretch drawing

Hot forming considered but not applied

### Joining

Rivet & adhesives

Laser welding

Bolting

Reinforcements to panel

Ringframe to window frame

Side member

## Material highlights

Inner panel	6016 High formability "Advanz™ 6HF – e200"	t 1.2 mm
Outer panel	6016 Strength & hemming perf "Advanz™ 6F – e170"	t 1.0 mm
Reinforcements	6451 High strength "Advanz™ 6F – s600SPX"	t 1.2 – 3.0
Sidemember	UHSS DP1000	t 1.5

## Achievements for design equivalent to steel

Weight saving :

35 % or 6kg / frt door

Reduction in GWP:

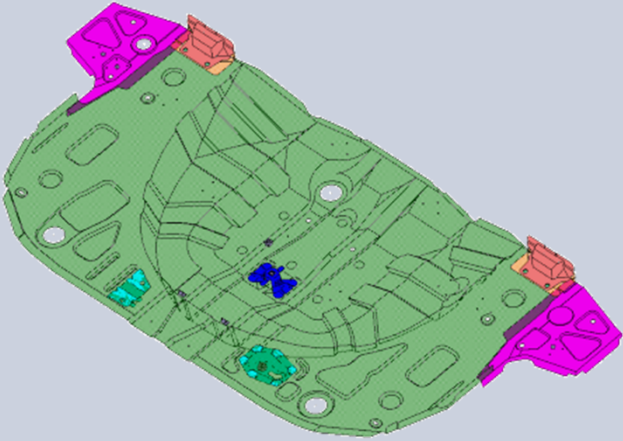
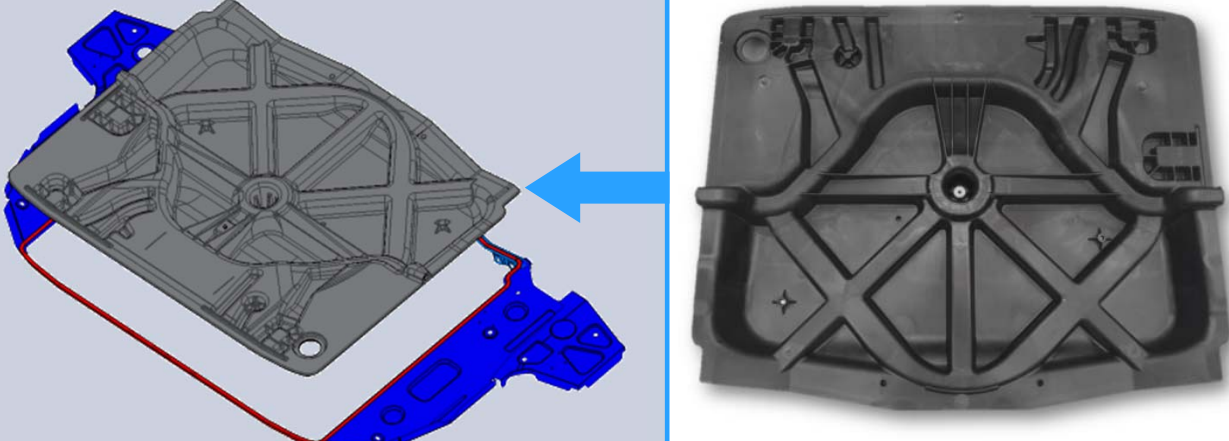
- 57.0 kg CO2 equ (scaling XC90 design)

Additional costs in €/kg-saved:

+ 4,5 € / kg saved (est from calculations BaxCo)

# Rear floor pan / Toyota Motor Europe

- Lightweight through use of alternate materials and joining technology.

Reference (Steel rear floor pan)	Concept (Plastic PP + 40% long glass fibre)
 <p>Drawn galvanized steel sheet joint by spot weld</p>	 <p>Injected LGF-PP bonded to E-coated steel sheet</p>

- Shape optimization using BATZ technology: IMC (Injection Molding Compound) + WIT (Water Injection Technology)
- Initial geometry developed using topology simulation
- Full vehicle & cut body demonstrators produced to validate production feasibility and performance



# Rear floor pan / Toyota Motor Europe

## WIT: Water Injection Technology

1. Resin injection



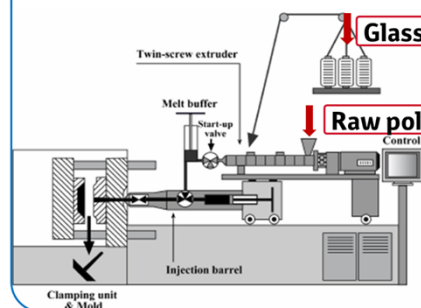
2. Water injection



3. Water removal



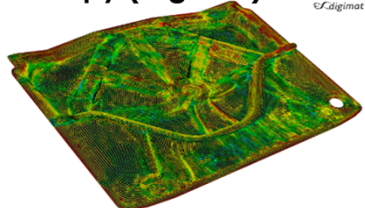
## IMC: Injection Molding Compounding



• compounding directly from raw material

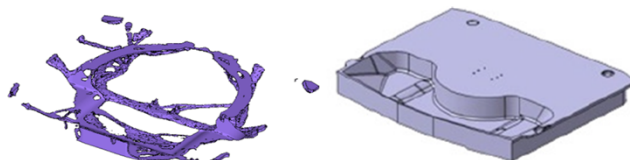
• 30% lower material cost

## Anisotropy (Digimat)



• Anisotropic material properties mapped from process simulation\*

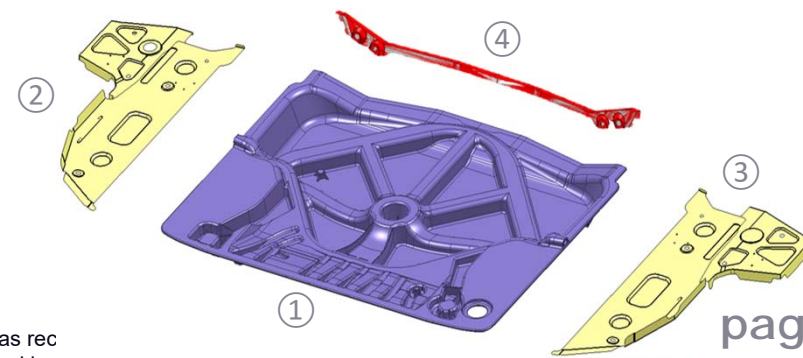
## Topology optimisation



• Definition of main structure layout  
• Selection of WIT path

- Weight saving achieved: -25%
- Achieved reduction in GWP: -20.2% kgCO<sub>2</sub> eq.
- Additional cost in €/kg-saved: +4.6 € / kg saved (determined by BaxCo)

Nr.	Part	Material		Manufacturing technology
		Current	New	
1	LGFRP floor pan	Steel t0.7	PP LGF40%	IMC and WIT
	- Nut & bolt insert	CuMnPb	CuZn38pb	Overmoulded
	- Bracket (Spare wheel)	Steel t1.2	-	Integrated in floor
	- Bracket (Fuel canister)	Steel t2.0	-	Integrated in floor
2	Steel support (RH)	Steel t0.7	Steel t0.7	-
3	Steel support (LH)	Steel t0.7	Steel t0.7	-
4	Steel support (RR)	Steel t0.7	Steel t0.7	-
	NV & Body sealer	Asphalt/PU	-	Integrated in floor design
	Joining	Spot welding	1C polyurethane adhesive	-

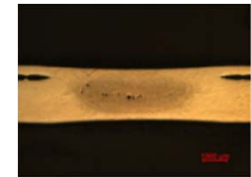


# Hood / Centro Ricerche Fiat

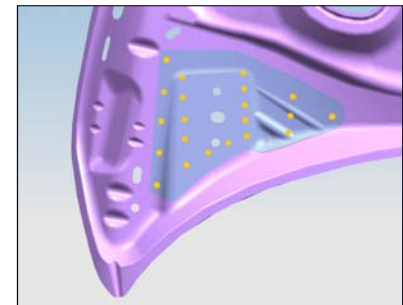
- Reference Fiat 500 steel concept
- Lightweighting approach by light alloy introduction and reinforcement integration exploiting multi-thickness patchwork solution
- Quantity 100'000 vehicles per year
- Physical demonstrator is manufactured



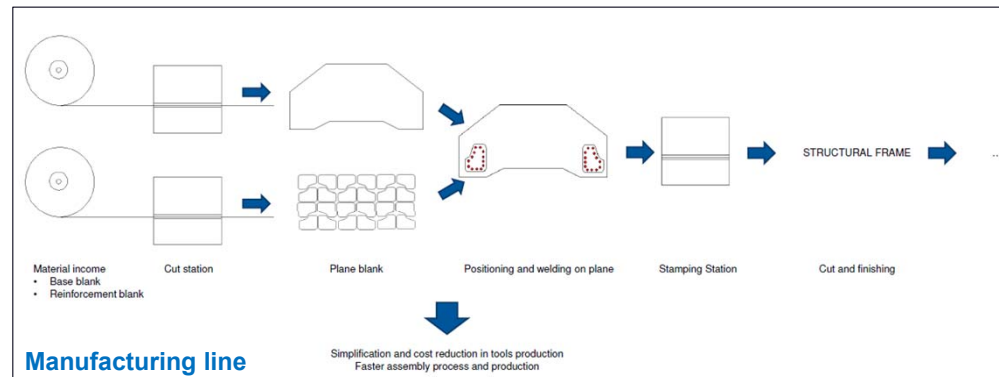
Patch after structural panel stamping operations



Spotweld between 0.6-2.0 mm Al sheets section micrography



Spotweld optimized position



# Hood / Centro Ricerche Fiat

Part AP FIAT 500	#	Material	Thickness
External panel	1	Steel	0.7 mm
Internal panel	1	Steel	0.65 mm
Lock reinforcement	1	Steel	1.8 mm
Hinge reinforcement Left	1	Steel	1.2 mm
Hinge reinforcement Right	1	Steel	1.2 mm
Lock	1	Steel	Ø 5 mm

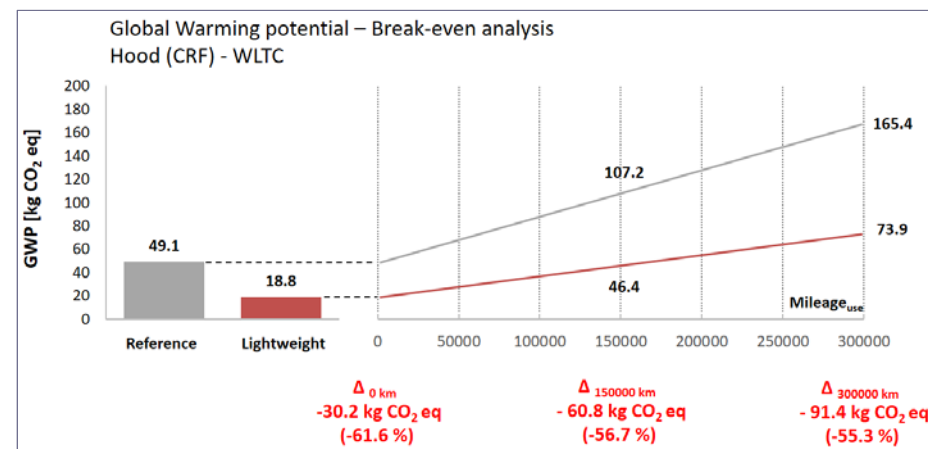
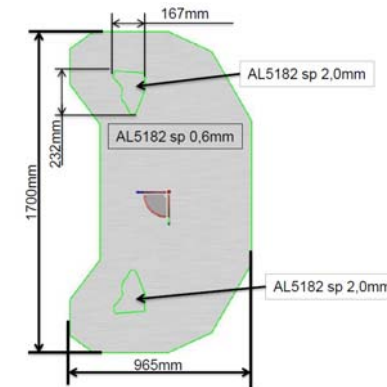
Part Lightweight FIAT 500	#	Material	Thickness	Weight
External panel	1	AA6111 NOVELIS	0.8 mm	1.85 kg
Internal frame patchwork	1	AA5182 NOVELIS	0.6 mm	1.23 kg + 0.280 kg
Lock reinforcement	1	FeE340	1.8 mm	0.320 kg
Lock	1	Steel	1.8 mm	38 g
Glue	-	Polymer	-	80 g
			TOT	3.80 kg

	AP	Lightweight	Delta
Weight	7.4 kg	3.6 kg	-52 %
GWP	REF	NEW	-56.7 % @ 150'000km
Cost	20.45 €	28.65 €	+40 %
dCost/dWeight			2.15 €/kg

Part Brakedown:



Plane blank:



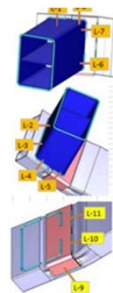
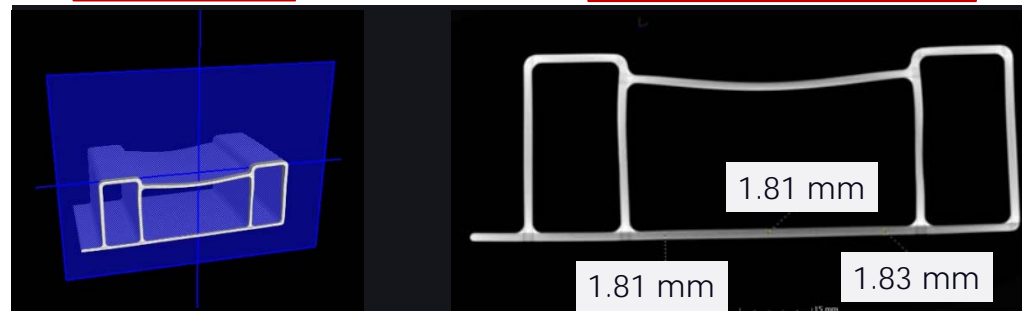
# Front bumper beam (aluminium) / CRF / BENTELER

- Reference Jeep Renegade aluminum 6000 class design
- Lightweighting approach by light alloy introduction of class AA-7003
- Proved feasibility of low thickness extrusion of aluminum alloy 7003 at 1.8 mm wall thickness (Novelty!)
- Weight reduction design with local reinforcement optimization



Section A - A

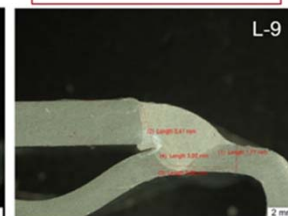
Thickness measurement



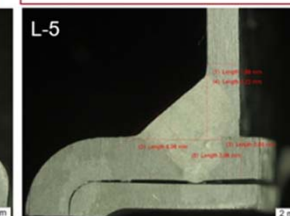
Crashbox to Beam



Reinforcement to Beam



Crashbox to Reinforcement

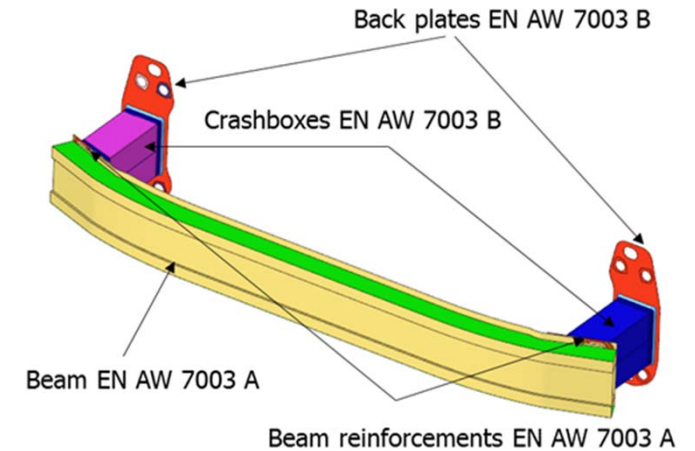









# Front bumper beam (aluminium) / CRF / BENTELER

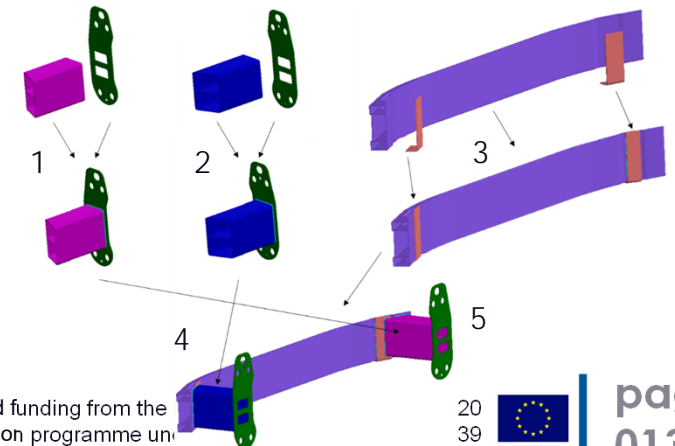
Part Brakedown

	n	Reference			Lightweight design		
		Thickness	Material	Weight	Thickness	Material	Weight
Flange plates	2	2.5 & 5.0	AW6082	0.5	3.5	AW7003 B	0.32
Crash boxes	2	2.3 to 2.7	AW6060	0.87	2.4	AW7003 B	0.88
Beam	1	2.2 to 2.7	AW6082	3.16	1.8 to 2.0	AW7003 A	2.01
Reinforcements					3.0	AW7003 A	0.12
Total weight				4.56			3.33



 <b>21-33% Weight</b> <b>-28 %</b>	 <b>- 6% GWP</b> <b>(Global Warming Potential)</b> <b>-22 % @ 150000km</b> determined by 	 <b>3€/Kg Saved</b> <b>(compared to benchmark vehicle)</b> ~ determined by 
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Assembly operations – welding sequence



This project has received funding from the research and innovation programme un

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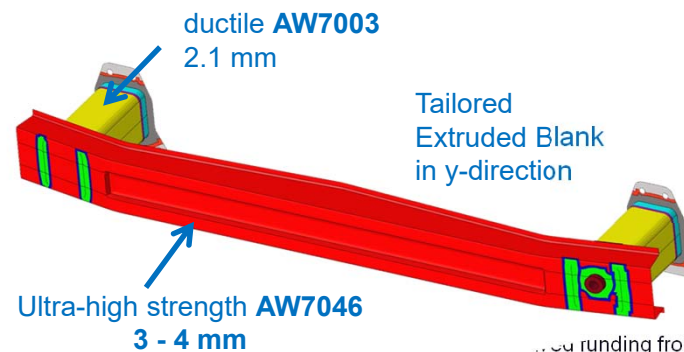
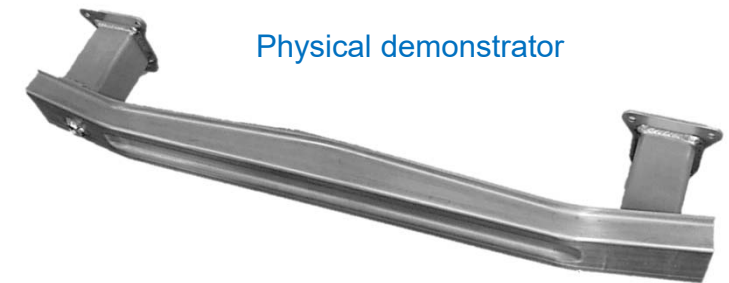
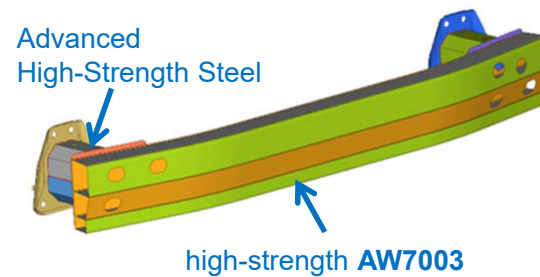


# Rear bumper beam (aluminium) for US / BENTELER

- Reference: 7000 series aluminium beam; steel crash boxes  
Toyota C-HR
- Lightweighting approach by
  - Ultra-high strength AW7046 aluminium material
  - Material allocation where needed
  - Open Beam with more forming
- Quantity 25.000 p.a.
- Mainly designed for high speed rear crash



- TME / BENTELER Proposal: 7000 series aluminium component





# Rear bumper beam (aluminium) for US / BENTELER



		Reference US			Lightweight design		
	n	Thickness	Material	Weight	Thickness	Material	Weight
Flange plates	2	2.0 & 2.6	HCT600X	0.791	4.0	AW7003 B	0.296
Crash boxes	2	1.2 & 2.0	HCT600X	1.888	2.1	AW7003 B	0.796
Beam	1	2.5 to 3.5	AW7003 A	4.02	3.0 to 4.0	AW7046	2.56
Towing Nut	1	2.0 to 2.6	HSLA	0.218	2.4 to 8	AW6082	0.134
Total weight				6.917			3.786



21-33% Weight

-45 %



- 6% GWP  
(Global Warming Potential)

-44 % @ 150000km

determined by  UNIVERSITÀ  
DEGLI STUDI  
FIRENZE  
 DIF  
DIPARTIMENTO  
DI INGEGNERIA  
INDUSTRIALE

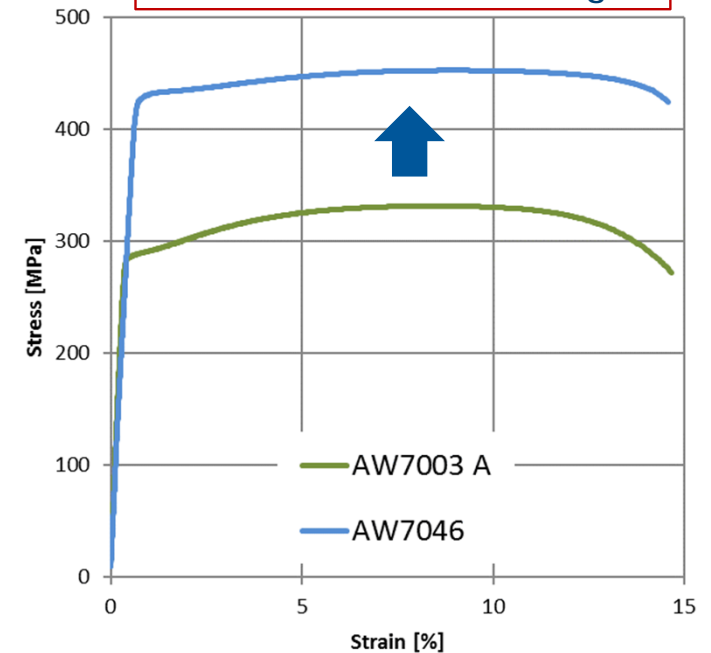


3€/Kg Saved  
(compared to benchmark  
vehicle)

-5 €/kg saved

determined by  BAX  
& COMPANY  
VALUE FROM SCIENCE AND TECHNOLOGY

Stress – strain curves  
for reference and new design



# Front bumper beam (steel) / Daimler

1. Absorber, upper left
2. Absorber, lower left
3. Absorber, upper right
4. Absorber, lower right
5. Bumper Beam
6. Closing plate
7. Console, left
8. Console, right
9. Reinforcement, left
10. Reinforcement, right



Variant	Beam	Weight [kg]	Plate	Weight [kg]	Weight [kg]
					Total Beam & Plate
Physical Demonstrator / Variant 2.2KU	DP-K850Y1180T -DH 1,50 mm	3,51	DP-K850Y1180T -DH 1,00 mm	1,63	5,79
Virtual Demonstrator / Variant 2.1KU	DP-K850Y1180T -DH 1,30 mm	3,04	DP-K850Y1180T -DH 1,20 mm	1,78	4,82
Reference	PSC950Y1300T 1,35 mm	3,16	CR330Y590TDP GI50/50-U / 1,75 mm	2,85	6,01

## Front bumper beam: Comparison of physical, virtual demonstrator and reference

		Weight Saving		GWP		Costs	
		absolute [kg]	relative [%]	absolute [kg CO <sub>2</sub> eq]	relative [%]	Δ Costs [€]	[€ / kg saved]
Rear bumper system	Reference	3,99 / 6,92	-	56,3 / 112,9	-	10,01	-
	ALLIANCE	2,42 / 3,82	- 39,3 / - 44,8	61,3	+ 8,9 / - 45,7	6,38 / 3,23	
Rear floor panel	Reference	6,93	-	106,7	-	7,44	-
	ALLIANCE	5,31	- 23,4	85,2	- 20,1	4,59	
Door concept 1	Reference	35,2	-	765,2	-	61,04	-
	ALLIANCE	24,6	- 30,1	628,7	- 17,8	5,76	
Door concept 2	Reference	19,69	-	345,9	-	33,84	-
	ALLIANCE	11,91	- 44,1	195,0	- 43,6	5,61	
Bumper beam	Reference	13,06	-	215,4	-	3,06	-
	ALLIANCE	11,87	- 9,1	194,1	- 9,9	2,57	
Hood	Reference	3,58	-	61,0	-	4,68	-
	ALLIANCE	3,58	- 52,6	61,0	- 55,8	1,17	
FCB	Reference	4,53	-	80,5	-	-0,17	-
	ALLIANCE	3,33	- 26,5	62,1	- 22,9	-0,14	
Strut tower & Int. Rail	Reference	18,62	-	-	-	-1,66	-
	ALLIANCE	11,29	- 39,37	-	- 37,2	-0,21	
Total	Reference	109,58 / 112,51	-	1.708,3 / 1.764,9	-	118,24	-
	ALLIANCE	73,41 / 74,81	- 33,00 / - 33,51	1.287,4	- 24,6 / - 27,1	3,26 / 3,13	

This project is part of the research

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