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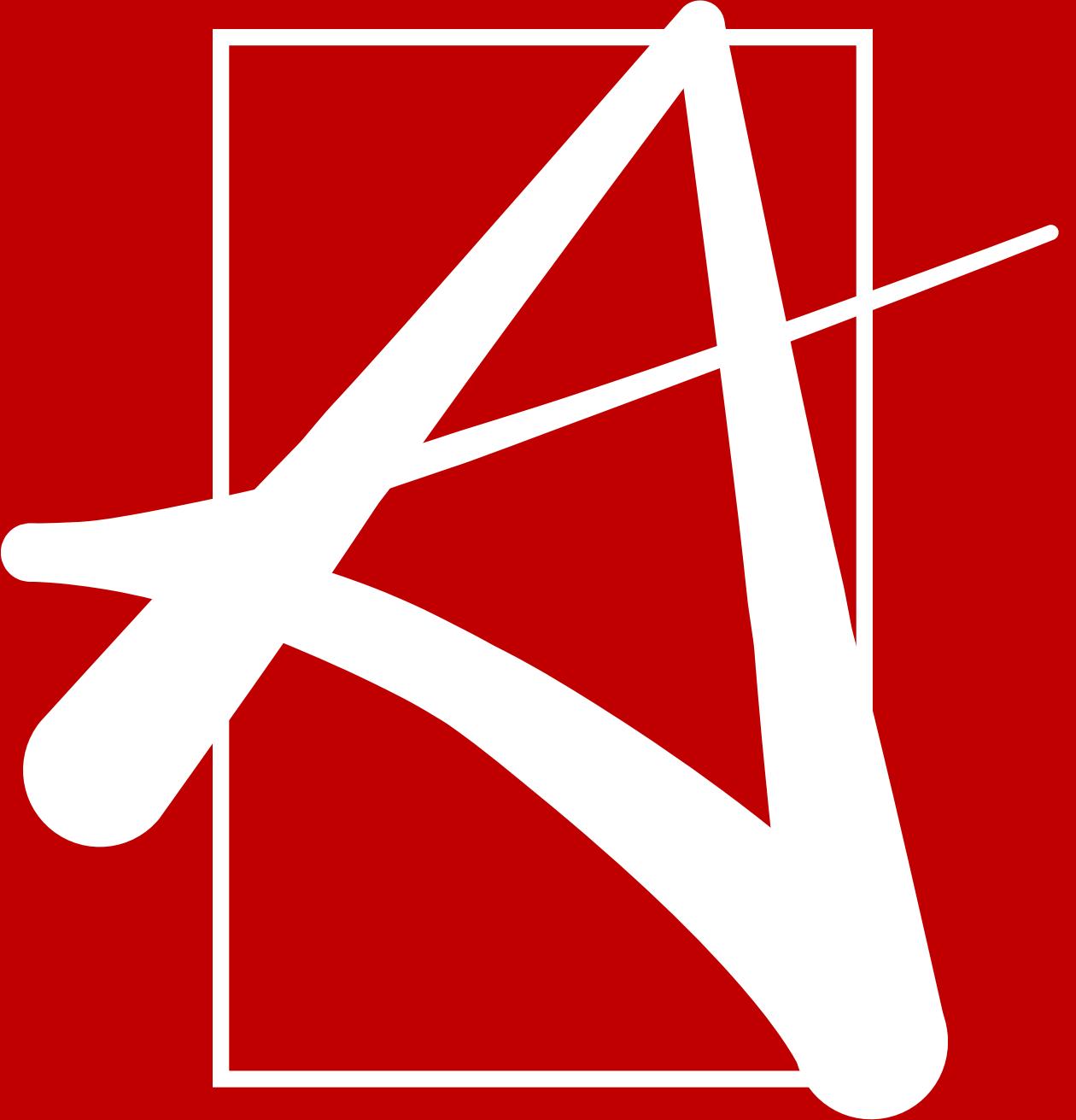
a future sportcar concept for
Vehicle Virtual Design



AER AUTOMOBILES
Centro
Stile



Università di Bologna
Department of
Industrial Engineering



AER Plasmata dal vento.

The future is the breeze that is yet to blow



The Future Sportscar 1 Team

a division of AER Centro Stile



**Giammarco
Costa**

Motoveicolo



**Edoardo
Ferrari**

Motoveicolo



**Francesco
Pontieri**

Motoveicolo



**Daniele
Sgubbi**

Motoveicolo



**Luca
Zappalorti**

Progettazione
Meccanica e
Modellazione

01

Planning and Analysis

02

Product Architecture

03

Styling

Table of
Contents

04

Stylistic Proposal
Choice

05

Chassis

06

Renderings

Table of
Contents

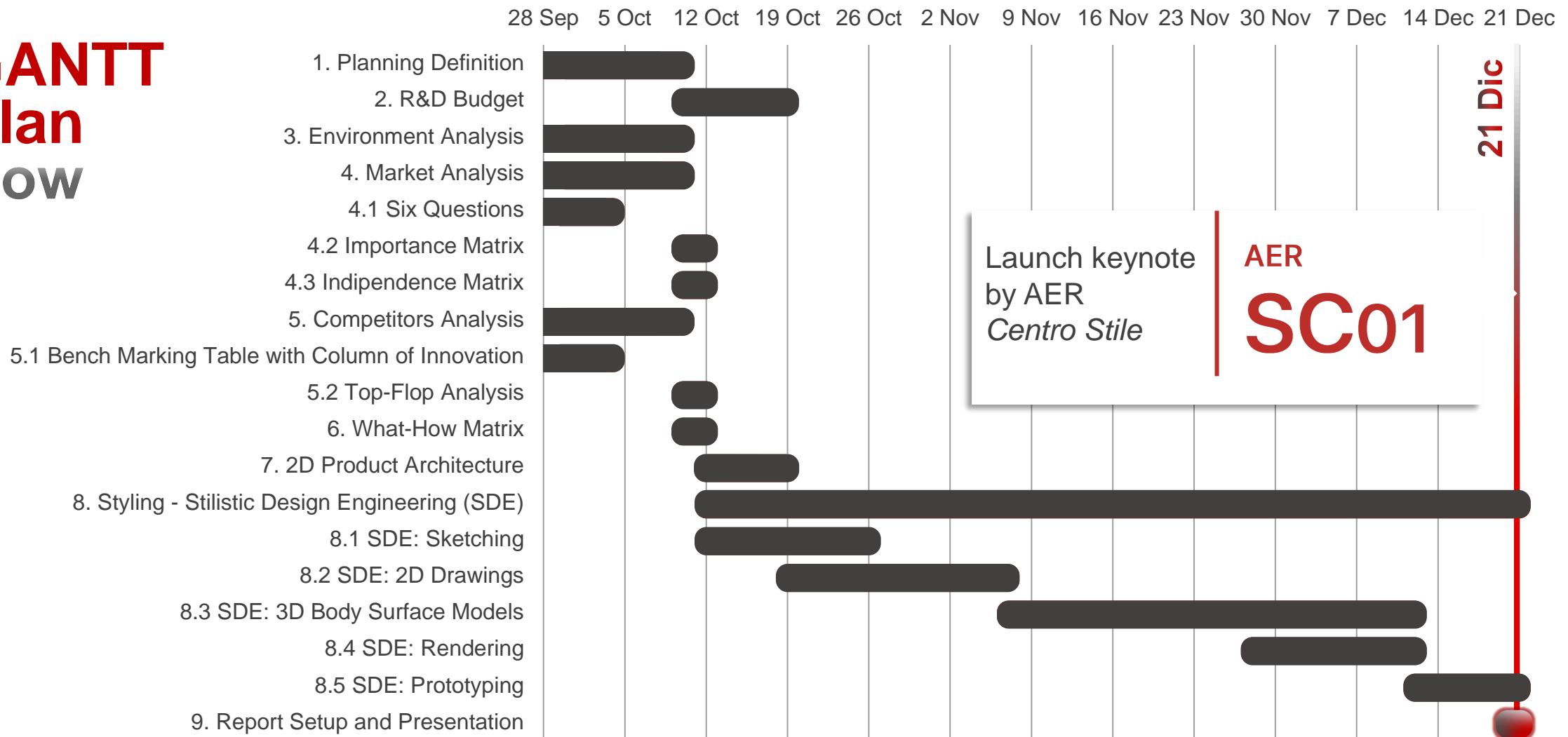
01

Planning and Analysis

- GANTT Plan
- Environmental Analysis
- Six Questions
- Market Analysis
- Competitors Analysis



GANTT Plan Now





Environmental Analysis

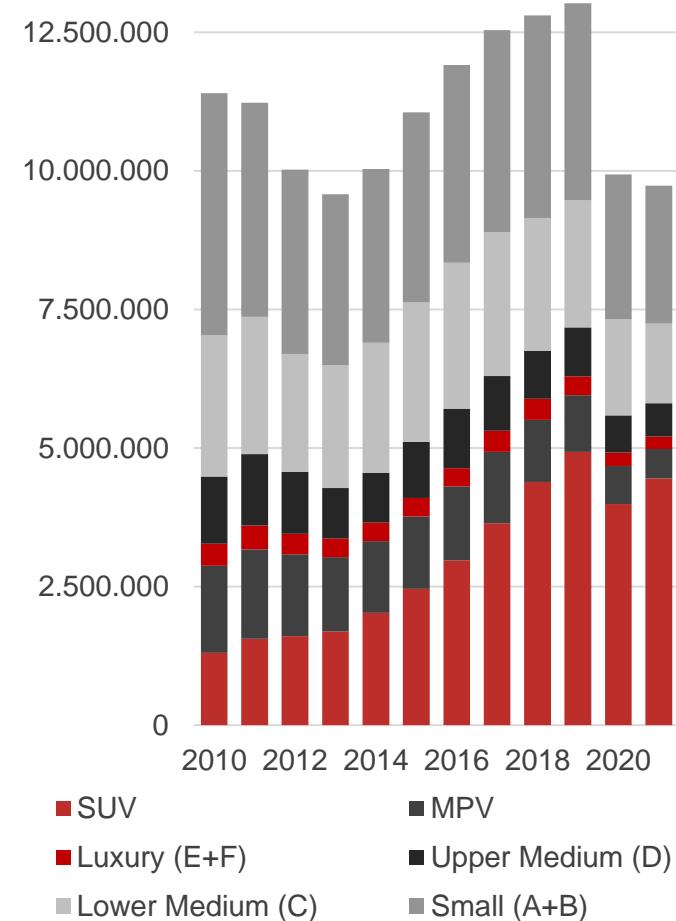
S-Segment

The S-Segment is a European car-classification segment for *sports coupés*, whereby coupe or coupé we mean a passenger car with a sloping or truncated rear roofline and two doors.

Characteristics and requirements

- Superior handling and straight acceleration
- Price: max 100.000 - 150.000 €
- Hybrid PU with sustainable fuel
- GT homologation (GT3 or GT4)

Market share by segment





Levels of Hybridization and Fuel Types

Electric Vehicles



BEVs



PHEVs

Electrically-chargeable vehicles



FCEVs

Fuel cell electric vehicles

Hybrid Electric Vehicles



HEVs

Mild Hybrid
Full Hybrid

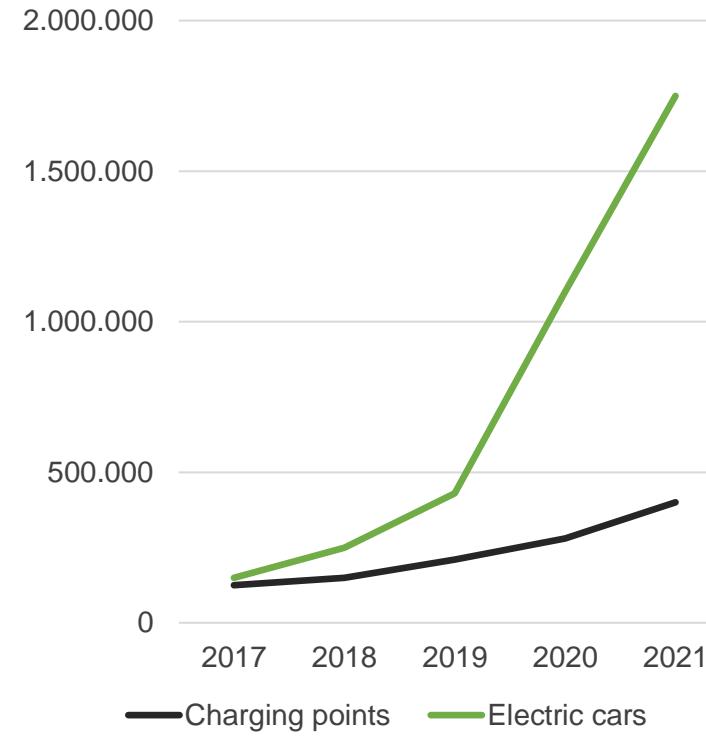
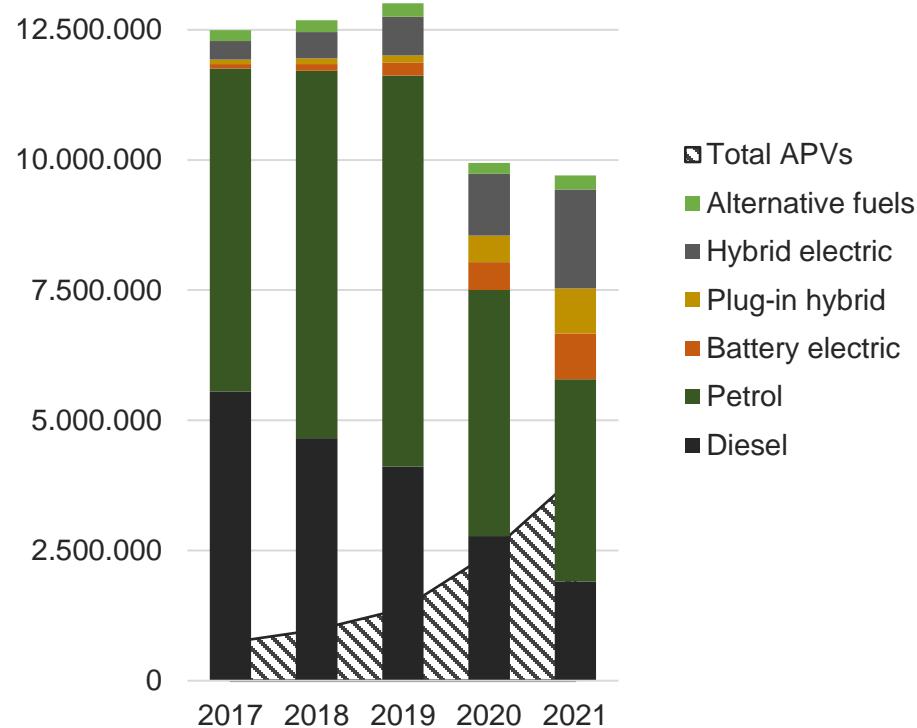
Hybrid Electric Vehicles



E-Fuels
BioFuels



Market share by fuel and infrastructure availability



In the second quarter of 2022 the electrically chargeable vehicles continued to gain overall market share, accounting for almost 1 in every 5 new cars sold across EU.



Market Analysis Flowchart

Quality Function Management

Six Questions

Give a list of quality requirements from a customer perspective

Relative Importance Matrix

Most Important Requirements

Dependence Indipendence Matrix

Most Independent Requirements

Best Requirements

Combination of the previous results



01 Who

Enthusiast seeking an **immersive experience**.

The target group is middle-aged with a good budget and **desire to race**.

02 What

A **track-ready** vehicle that stands out for its **driving involvement** while keeping an eye on **innovation** and environmental issues.

03 Where

Ideal for track days, but enough comfortable on public roads due to the possibility to go full **electric**.

Six Questions



When 04

For every **fun** occasion that the customer will encounter, from the weekend on track to the Sunday tour on the **hills**.

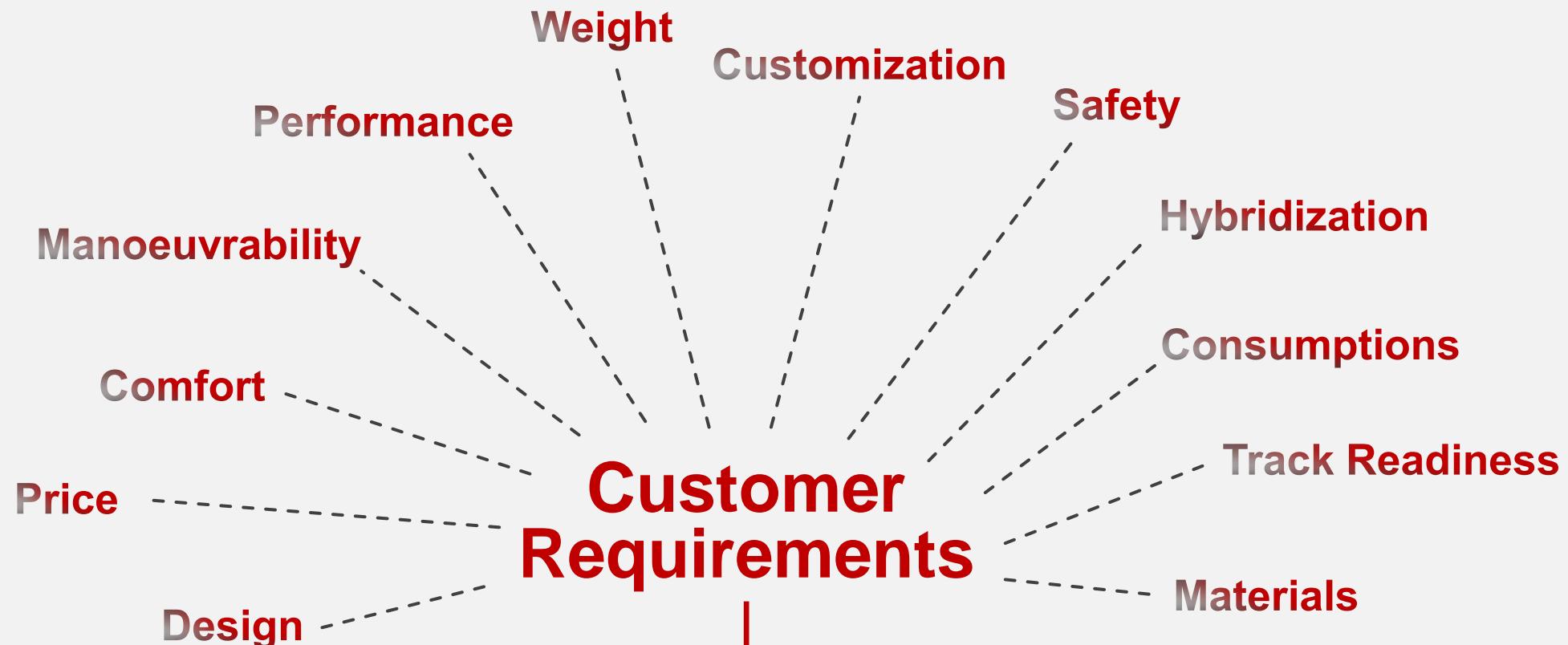
Why 05

The **lightness**, **manoeuvrability** and readiness will ensure an unforgettable experience, while being still usable and free of extreme taxes.

How 06

The product will have track focused design, it will be characterized by attention to **materials** and usage of reliable propulsors.

Six Questions





Relative Importance Matrix

Line element is

more important than	2
important as	1
less important than	0
element in the column	

element in the column

	Design	Price	Comfort	Manoeuvrability	Performance	Weight	Customization	Safety (ADAS)	Hybridization	Consumptions	Track Readiness	Materials	Total
Design	1	2	2	1	1	2	2	2	1	2	1	2	19
Price		1	2				2	1			1	1	7
Comfort			1	1	1	1	1	2	1	2	1	2	13
Manoeuvrability	1	2	1	1	1	1	1	2	1	2	1	2	16
Performance	1	2	1	1	1	1	1	2	1	2	1	2	16
Weight		2	1	1	1	1	2	2		1	1	1	13
Customization			1	1	1		1	1		1		1	7
Safety (ADAS)	1						1	1		1		1	5
Hybridization	1	2	1	1	1	2	2	2	1	2	1	2	18
Consumptions		2				1	1	1		1		1	7
Track Readiness	1	2	1	1	1	1	2	2	1	2	1	2	17
Materials		1				1	1	1		1		1	6



Relative Importance Matrix

1. Design
 2. Hybridization
 3. Track Readiness
 4. Manoeuvrability
 5. Performance

	Design	Price	Comfort	Manoeuvrability	Performance	Weight	Customization	Safety (ADAS)	Hybridization	Consumptions	Track Readiness	Materials	Total
Design	1	2	2	1	1	2	2	2	1	2	1	2	19
Price		1	2				2	1			1	1	7
Comfort			1	1	1	1	1	2	1	2	1	2	13
Manoeuvrability	1	2	1	1	1	1	1	2	1	2	1	2	16
Performance	1	2	1	1	1	1	1	2	1	2	1	2	16
Weight		2	1	1	1	1	2	2		1	1	1	13
Customization			1	1	1		1	1		1		1	7
Safety (ADAS)	1						1	1		1		1	5
Hybridization	1	2	1	1	1	2	2	2	1	2	1	2	18
Consumptions	2					1	1	1		1		1	7
Track Readiness	1	2	1	1	1	1	2	2	1	2	1	2	17
Materials		1				1	1	1		1		1	6



Independence Dependence Matrix

Line element is

totally dependent	9
bit dependent	3
bit independent	1
totally independent	0

from column element

	Design	Price	Comfort	Manoeuvrability	Performance	Weight	Customization	Safety (ADAS)	Hybridization	Consumptions	Track Readiness	Materials	Total
Design	3	1			3		3					3	13
Price	3		1	3	9	3	9	3	9	3	3	9	49
Comfort		3		9	3	1	1	3	3	9	9	1	33
Manoeuvrability		1	9		3	9				9	9	9	31
Performance	3	9	3	3	1			3	3	9	9	3	43
Weight	3			9	3			3	9	3	3	9	39
Customization	3	1										9	13
Safety			3				3			1	3		7
Hybridization	1	1			9					9	3		23
Consumptions	3				9	9		1	9		3	1	35
Track Readiness	3	3	3	9	9	9	1	1	3	3	3	3	47
Materials	3	9					9				3		24
Total	22	30	20	33	45	29	26	11	36	21	46	38	



Independence Dependence Matrix

1. Track Readiness
2. Performance
3. Materials
4. Weight

	Design	Price	Comfort	Manoeuvrability	Performance	Weight	Customization	Safety (ADAS)	Hybridization	Consumptions	Track Readiness	Materials	Total
Design	3	1			9	3	3				3	3	13
Price	3		1	3	3	1	9	3	9	3	3	9	49
Comfort	3			9	3	1	3	3	3		9	1	33
Manoeuvrability		1	9		3	9	1			9	9	9	31
Performance	3	9	3	3	3	1			3	9	9	3	43
Weight	3			9	3	1		3	9		3	9	39
Customization	3	1						3				9	13
Safety			3				3			1	3	7	
Hybridization	1	1			9	9				9	3		23
Consumptions	3				9	9	1	9			3	1	35
Track Readiness	3	3	3	9	9	9	1	1	3	3	3	3	47
Materials	3	9					9				3		24
Total	22	30	20	33	45	29	26	11	36	21	46	38	



Best
Requirements





Combining the results of the two matrices we obtain the best requirements that the product must meet

Best Requirements

			Sum
Design	19	22	41
Price	7	30	37
Comfort	13	20	33
Manoeuvrability	16	33	49
Performance	16	45	61
Weight	13	29	42
Customization	7	26	33
Safety	5	11	16
Hybridization	18	36	54
Consumptions	7	21	28
Track Readiness	17	46	63
Materials	6	38	44

1. Track Readiness
2. Performance
3. Hybridization
4. Manoeuvrability
5. Materials



Benchmark Analysis Flowchart

Innovation vs Bench Marking

The Bench Marking results allow us to identify which of the technical characteristics must be improved to arrive at the most innovative product in the segment.



F-Type

Jaguar



TT - S

Audi



A 110

Alpine



4C

Alfa Romeo



Supra GR3

Toyota



Z4 M40i

BMW



Cayman S

Porsche



GT-R

Nissan



911 Carrera

Porsche



Evora S GT

Jaguar



Rc 350 F

Lexus

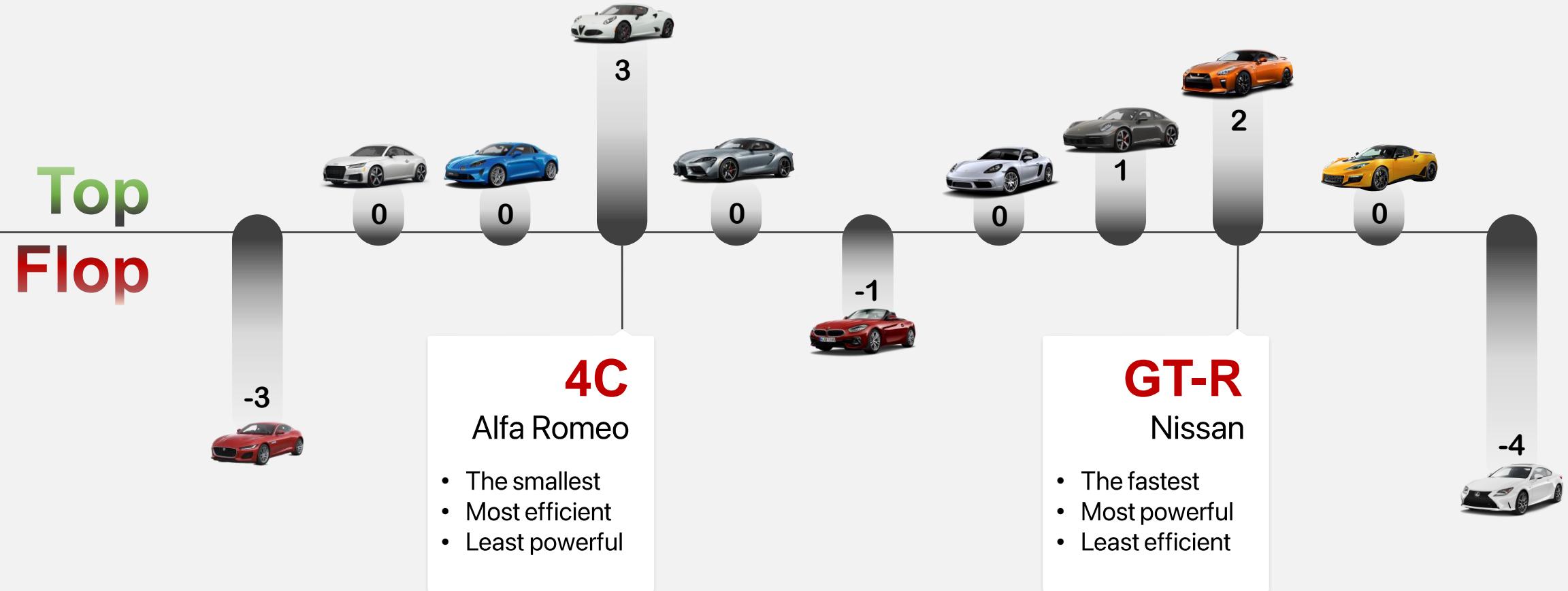


Competitors Choice



	Jaguar F-Type	Audi TT S	Alpine A110	Alfa Romeo 4c	Supra GR 3.0	BMW Z4 M40i	Cayman s	911 Carrera 4	Nissan GT-R	Lotus Evora Sport GT	Rc 350 F Sport
Engine type	In line 4				In line 6		Boxer 4	Boxer 6	V6		V8
Charge system			Turbocharged					Bi turbocharged	Superch.		Aspirato
Traction type	RWD	RWD	RWD	RWD	RWD	RWD	RWD	AWD	RWD	RWD	RWD
Length [mm]	4470	4199	4180	3989	4379	4324	4379	4519	4710	4394	4705
Width [mm]	1885	1832	1798	1864	1854	1864	1801	1852	1895	1972	1845
Height [mm]	1311	1366	1248	1183	1292	1304	1284	1298	1370	1223	1390
Wheelbase [mm]	2622	2505	2419	2380	2470	2470	2475	2450	2780	2575	2730
Curb weight [kg]	1520	1815	1365	920	1570	1860	1385	1555	1746	1331	1765
Consumption [l/100km]	8.1	7.3	8.9	6.8	7.2	7.2	9.2	9.2	13.9	12.9	11.8
Displacement [cm³]	1997	1984	1798	1742	2998	2998	2497	2981	3799	3456	4969
Hp/liter	148.2	158.8	160.2	136.1	113.4	113.4	138.2	127.5	147.9	118.6	68.6
Power [kW]	220.5	235	215	176.5	250	250	257.5	283	419	305.7	254
Max Torque [Nm]	400	400	320	350	500	500	420	450	637	420	530
Top Speed [km/h]	261	274	261	256	281	281	290	299	321	301	270
0-100 [km/h]	5.4	4.5	4.4	4.5	4.6	4.5	4.4	4.1	3.5	4.5	4.5
Weight/Power [kg/kW]	6.9	6	5.2	5.2	6.17	6.2	5.4	5.5	4.2	4.4	6.9
Price [k€]	68.970	63.900	60.882	65.550	66.500	73.710	75.774	126.056	105.450	135.000	97.000

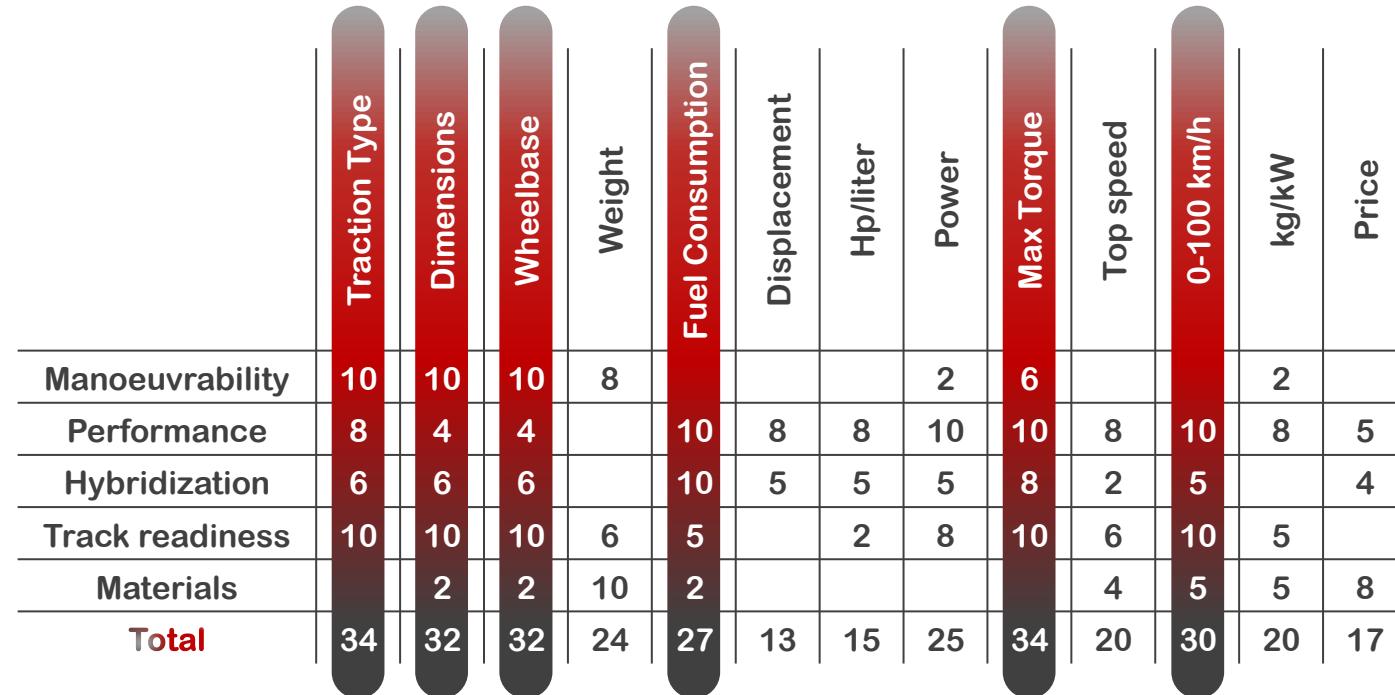
Benchmark Table





What – How Matrix

Performances satisfy customers requirements	
	0
none	0
a little	2
enough	5
a lot	10





What – How Matrix

1. Traction Type
2. Max Torque
3. Dimensions and Wheelbase
4. 0-100 km/h
5. Fuel Consumption

The aim of the W-H matrix is to merge QFD with Bench Marking to individuate what technical characteristics must be improved to obtain an innovative product

02

Product Architecture

- Dimensions and Wheelbase
- Fuel Consumption
- Traction
- Torque
- Acceleration (0-100)



Dimensions and Wheelbase

Our car of the future needs the right size compromise to beat competitors and meet customer requirements.

- **Compact but enough width for a good roadway**
- **Tight wheelbase for agility and track readiness**



Alfa Romeo 4C

The Smallest

Length x Width x Height
3989 x 1864 x 1183

The Shortest Wheelbase
2380 mm



Lotus Evora

The Widest

Length x Width x Height
4394 x 1972 x 1223

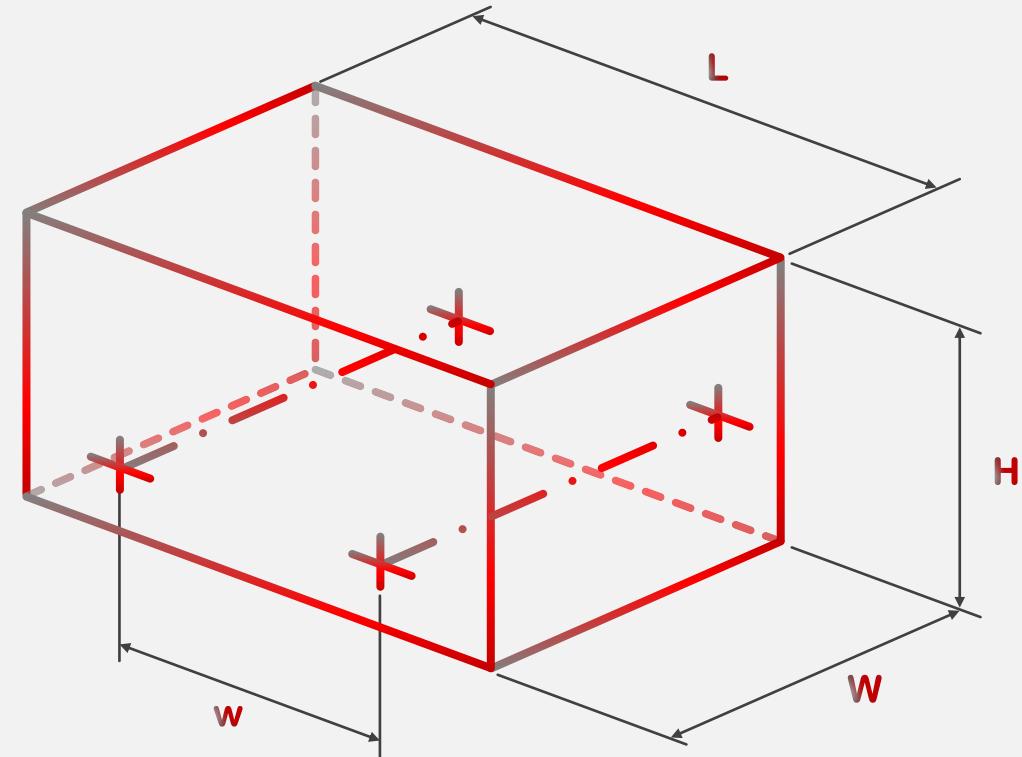
Wheelbase
2575 mm



Dimensions and Wheelbase

Our car of the future needs the right size compromise to beat competitors and meet customer requirements.

- Compact but enough width for a good roadway
- Tight wheelbase for agility and track readiness



The Future
Sportscar
The Optimum

Height H	≈ 1100 mm
Width W	≈ 1900 mm
Wheelbase w	≈ 2380 mm



— Fuel Consumption



E-Fuel

Circular emission fuels can extend ICE technology life and also have a greater energy density compared to full electric PUs.

— **Plug-In Hybrid**

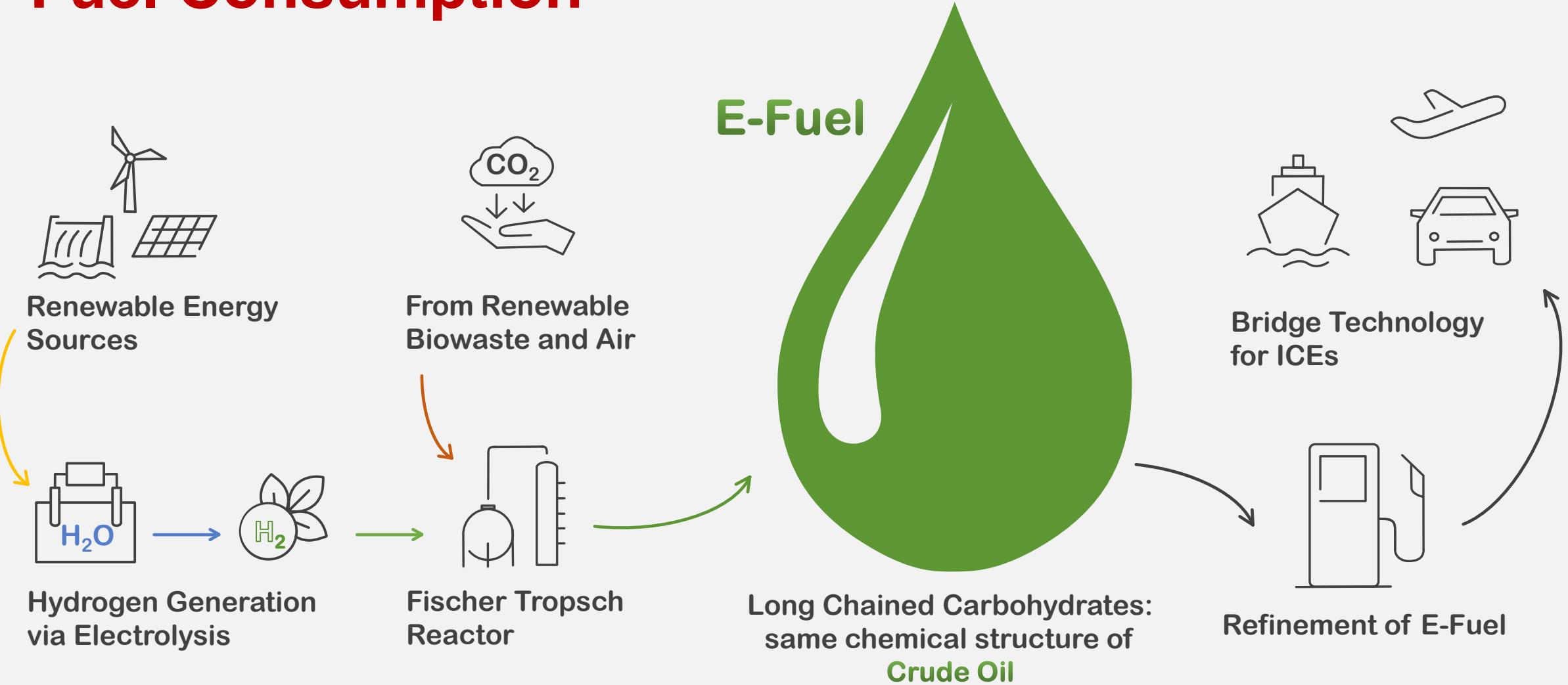
The hybridization increases the range and allows the recovery of energy: the plug-in solution is perfect for driving even in the city with a green footprint

**Power Unit
Arrangement**

Based on the Rally1 ICEs and the LMH electric motors displacement (AWD)



Fuel Consumption





Fuel Consumption

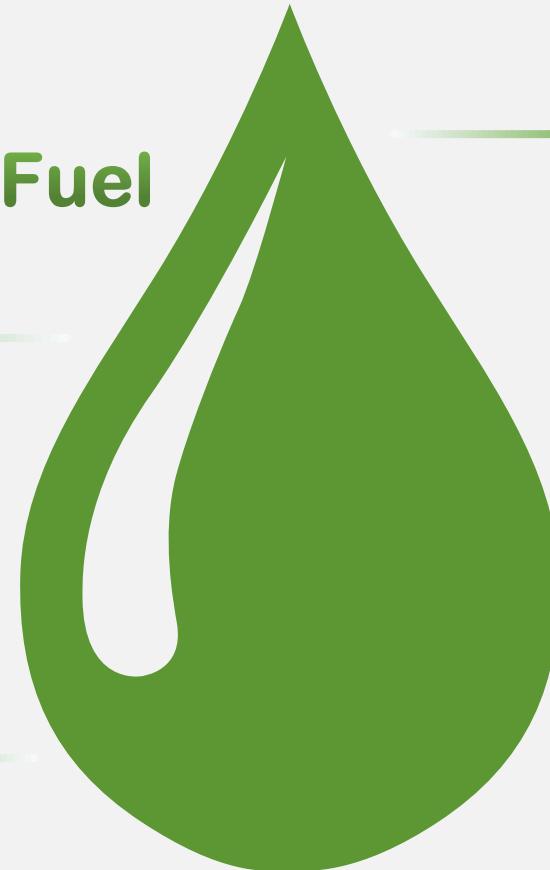
Converting CO₂

CO₂ has a cyclical life: it is captured to produce e-fuels and is generated by the combustion of e-fuels. For the balance to be neutral, it is mandatory that the energy sources be of renewable origin

More Efficient

E-fuels are more efficient than fuel refined from oil

E-Fuel

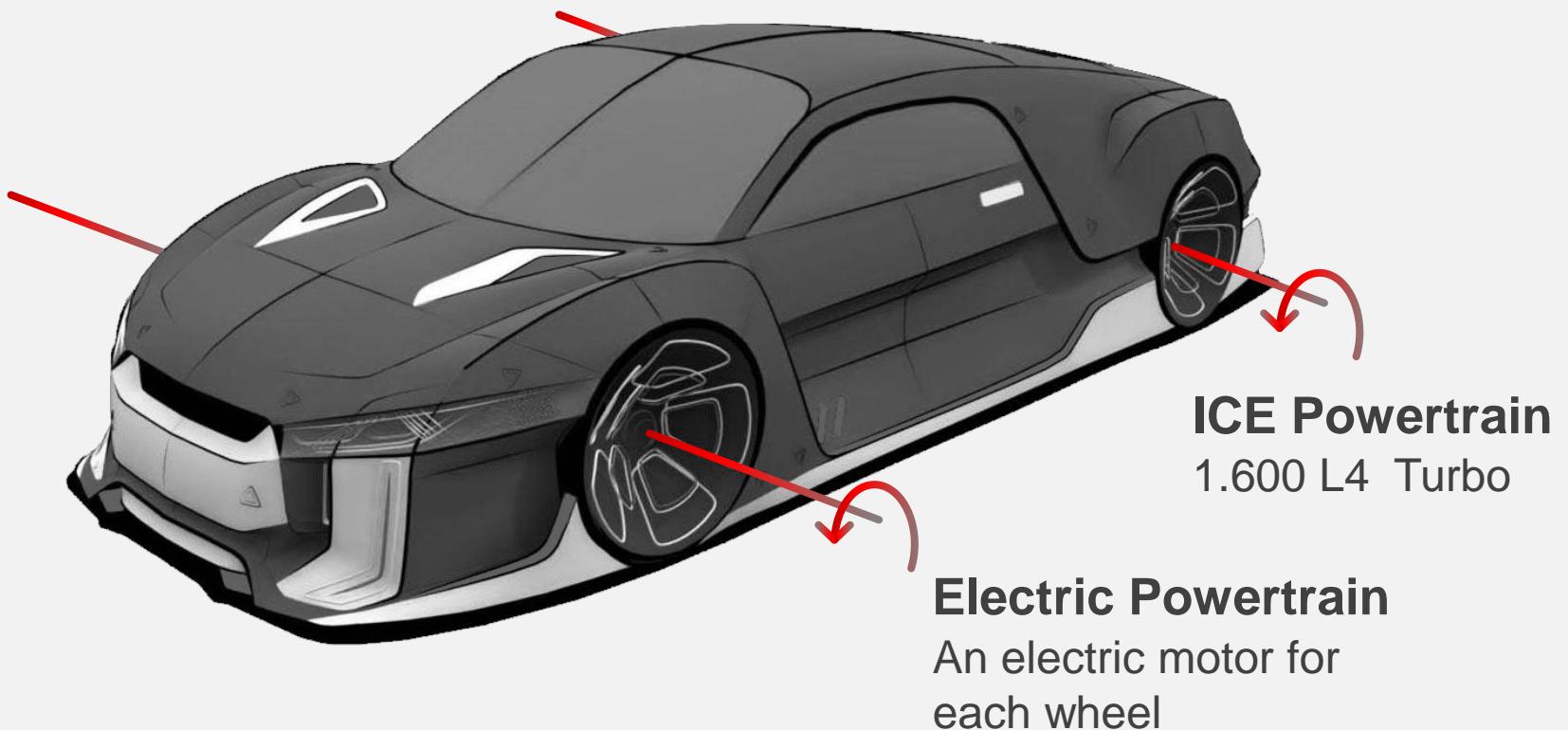


Energy Density

E-fuels have the same energy density of petrol, diesel and kerosene: that means more energy packed in the same weight compared to batteries



Traction

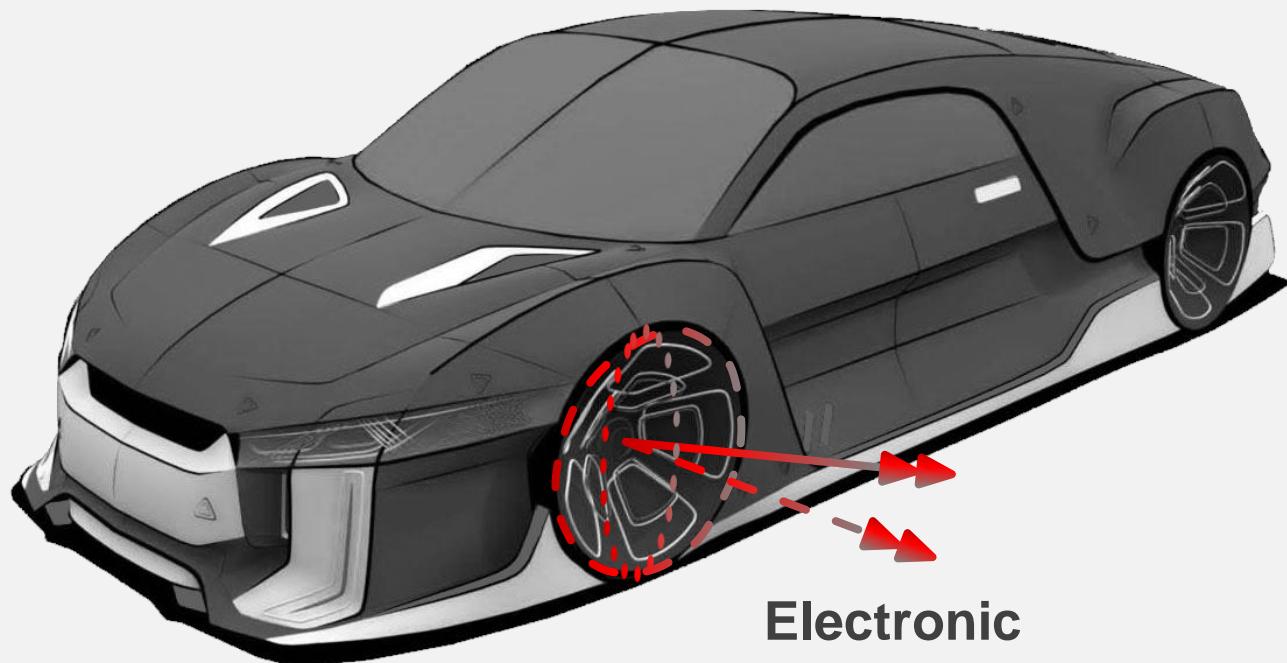


Hybrid AWD

The combination of the front EMs with the Turbo ICE allows a better exit from the turns, anticipating the throttle, and a reduction of the turbo lag.

All Wheel Drive

Traction



Electronic
Torque Vectoring

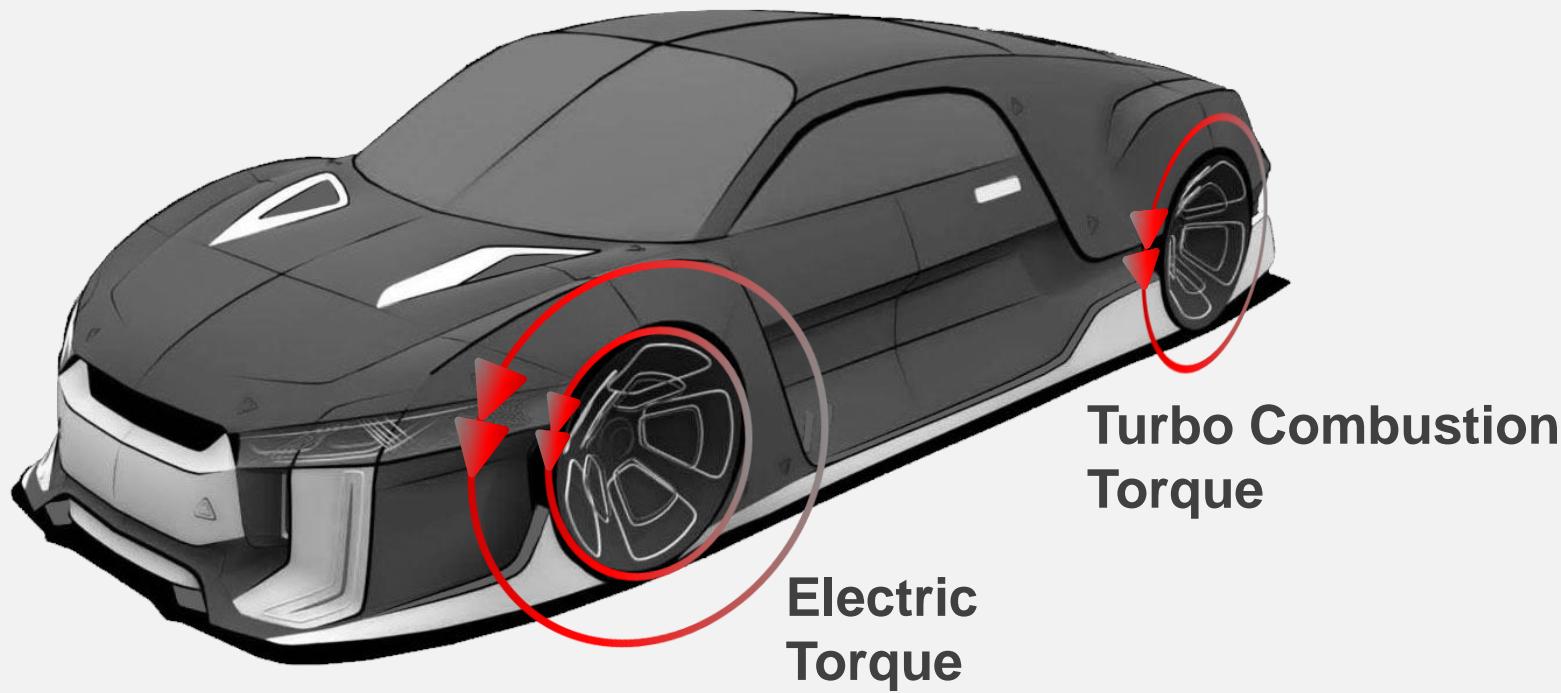
Electronic Torque Vectoring

The front EMs, one for each wheel, allow an independent management of the torque without using an electronic mechanical differential

Torque Vectoring



Torque and Acceleration



A **superb** acceleration

The front EMs, one for each wheel, allow an additional contribution to the acceleration from standstill and exiting a curve.

Hybrid AWD



Product Layout

Arrangement of the mechanical components

Space Management

Management of the overall dimensions of mechanical parts

Occupant Safety Environment

Spaces defined by standards

Occupant Driving Position

Racing driving position

Data Sheet

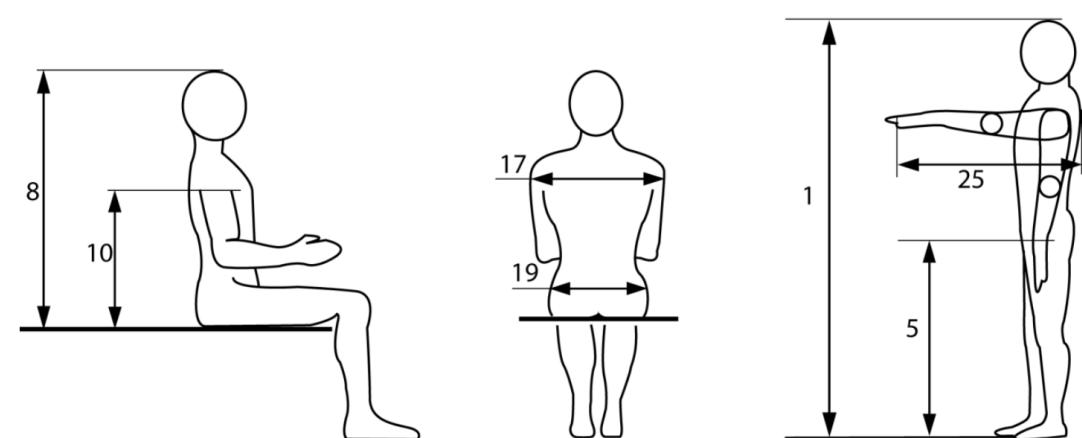
Technical specs of technologies used



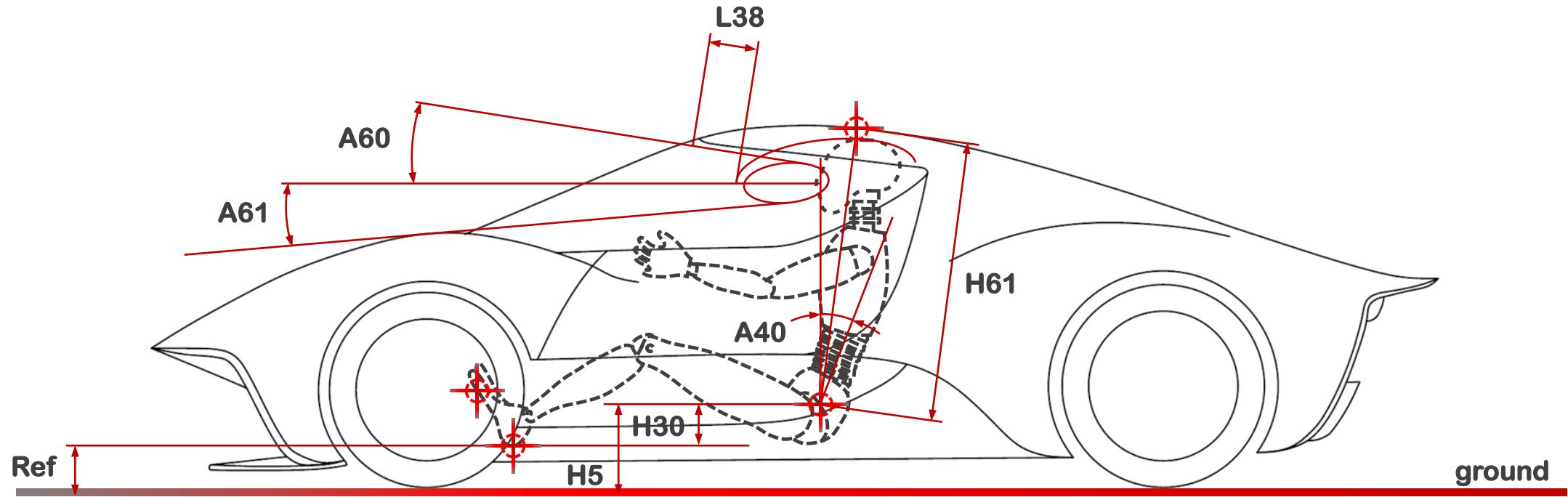
Anthropometric Reference Data

#	Dimension	Measurements	
		95th Percentile Male	5th Percentile Female
	Weight	102 kgs	49 kgs
1	Standing Height	186,5 cm	151,5 cm
5	Hip Height	100,0 cm	74,0 cm
8	Erect Sitting Height	97,0 cm	79,5 cm
10	Sitting Shoulder Height	64,5 cm	50,5 cm
17	Sitting Shoulder Width	50,5 cm	37,5 cm
19	Hip Width	140,5 cm	31,0 cm
25	Shoulder Grip Length	71,5 cm	55,5 cm
30	Foot Length - bare	28,5 cm	22,0 cm
31	Foot Width – bare	11,0 cm	8,5 cm

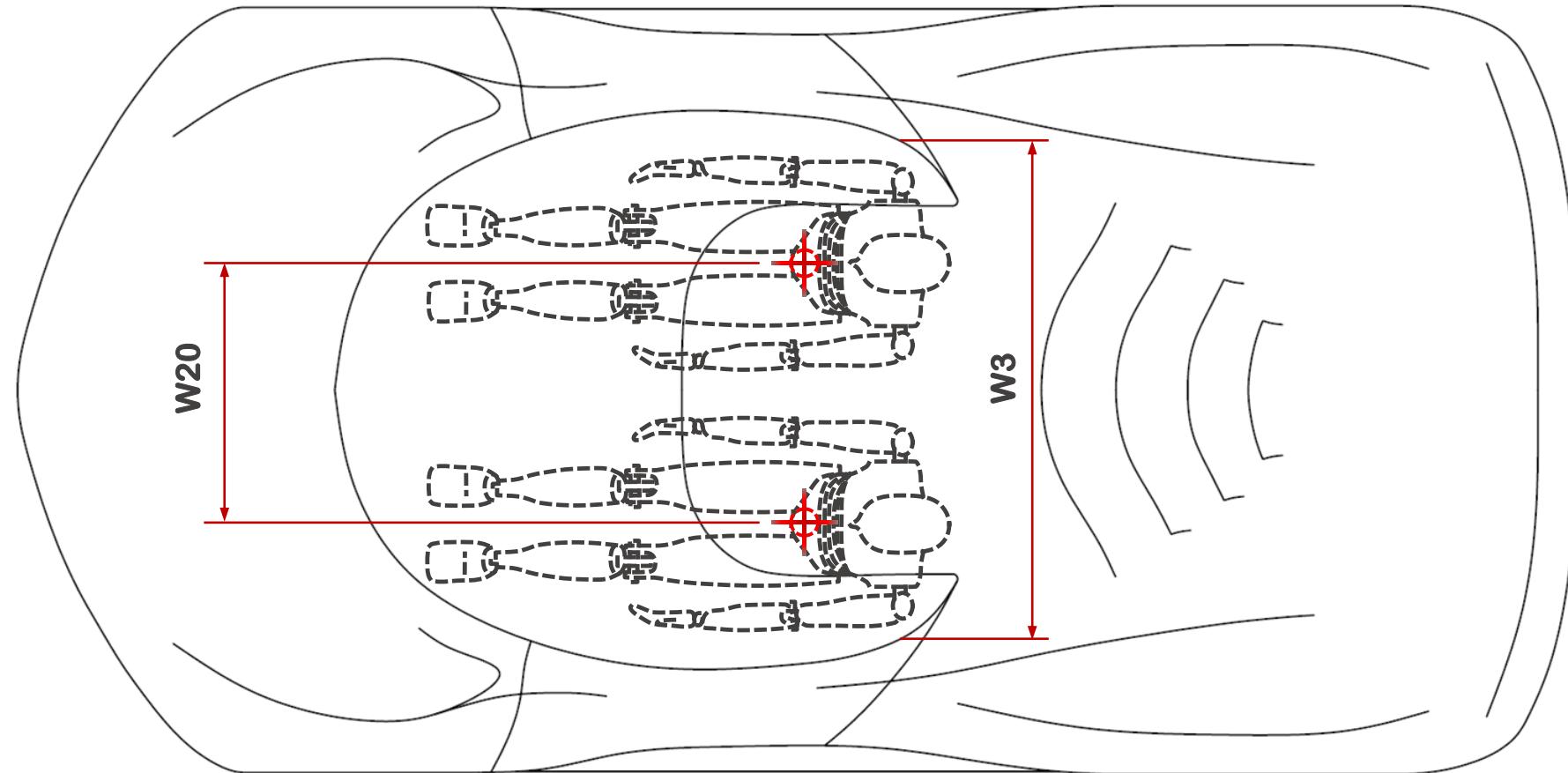
One basic car design should be able to accommodate, and hence be saleable to, drivers of a range of statures from the 5th percentile female to the 95th percentile male



Source: Formula SAE Rules



Occupant Environment Dimensions



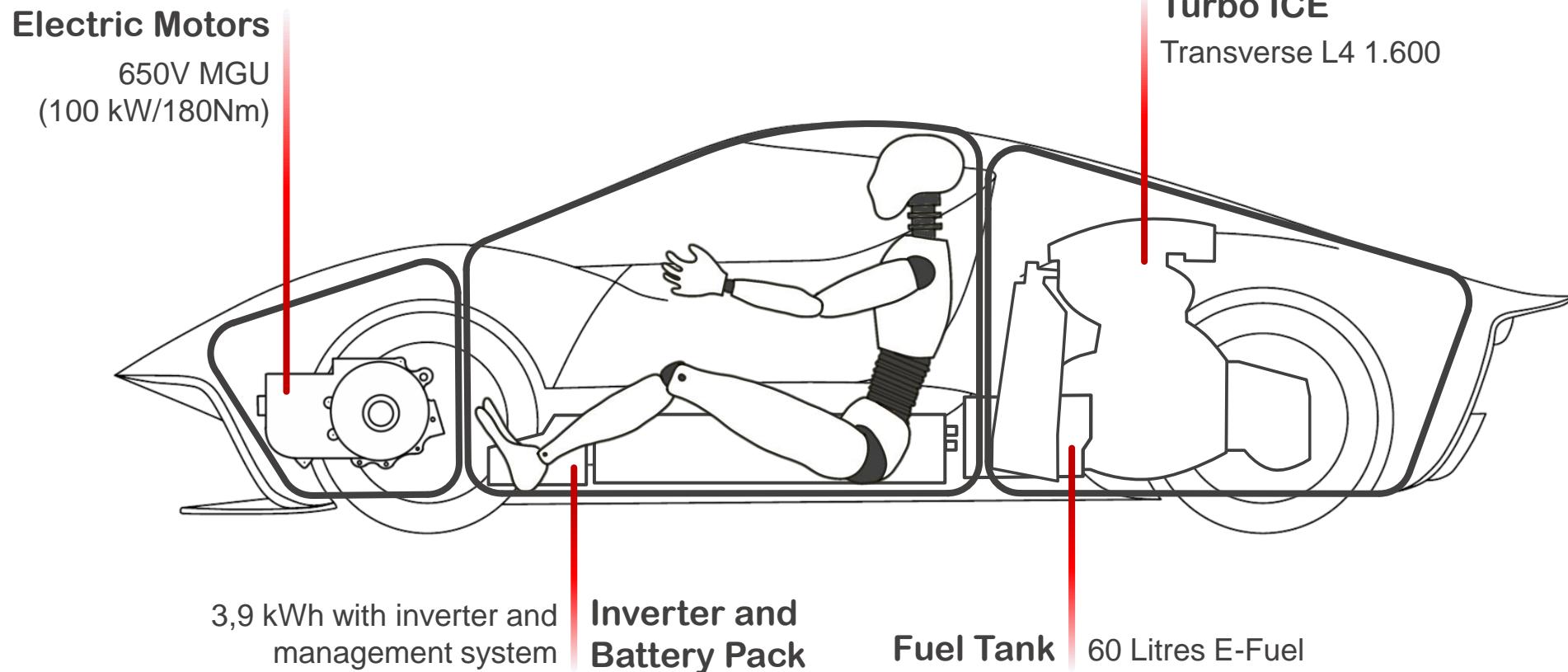
Occupant Environment Dimensions



Sports Car	Heel to Ground	Chair Height	H point to ground	Back Angle	Effective Head Room	Upward Vision Angle	Downw'd Vision Angle	Shoulder Room	Lateral Location
(Ref)	H30	H5	A40	H61	A60	A61	W3	W20	
175	150	325	28.0	950	8.0	5.0	1350	700	

Source: H-Point

Occupant Environment Dimensions

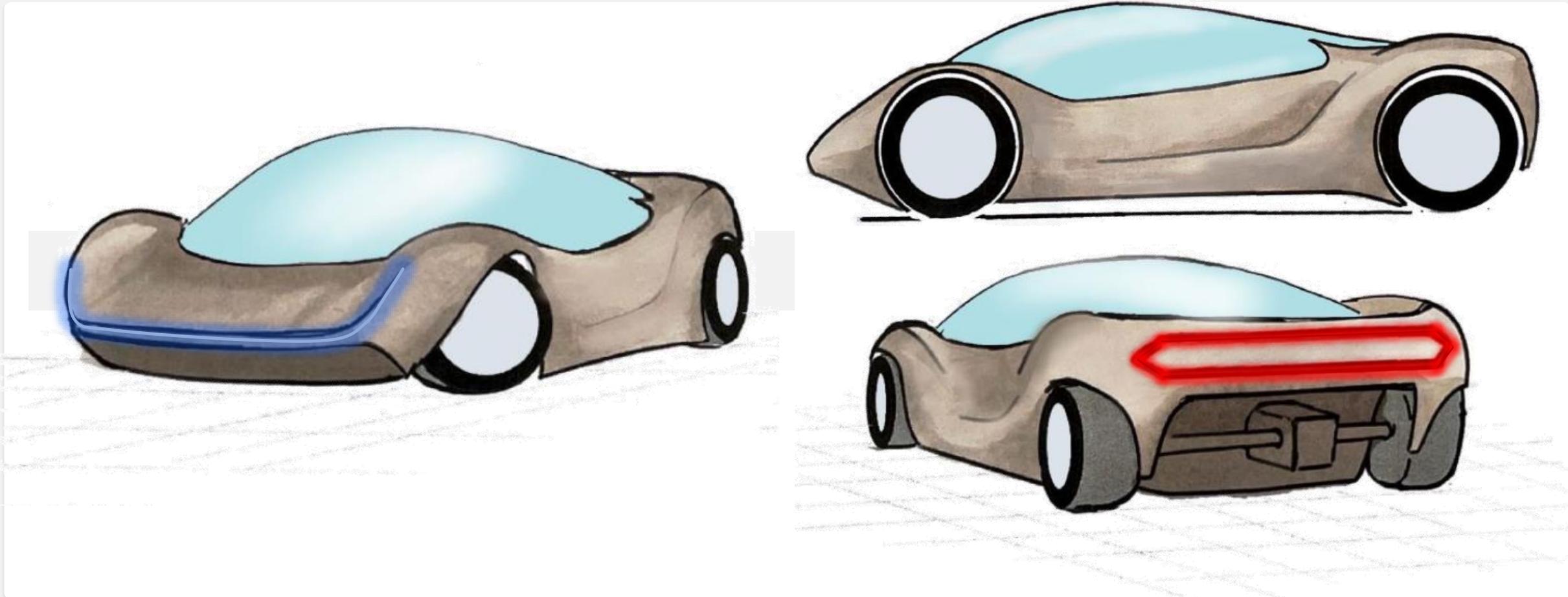


Architecture Arrangement

03

Styling

- Sketches
- Blueprints
- Style Comparison
- Virtual Model
- Render



Natural

The side is inspired by a swooping hawk and by the B2 stealth bomber: among the rounded curves stands out the glass dome in a forward position, like the hawk and the fighter plane.

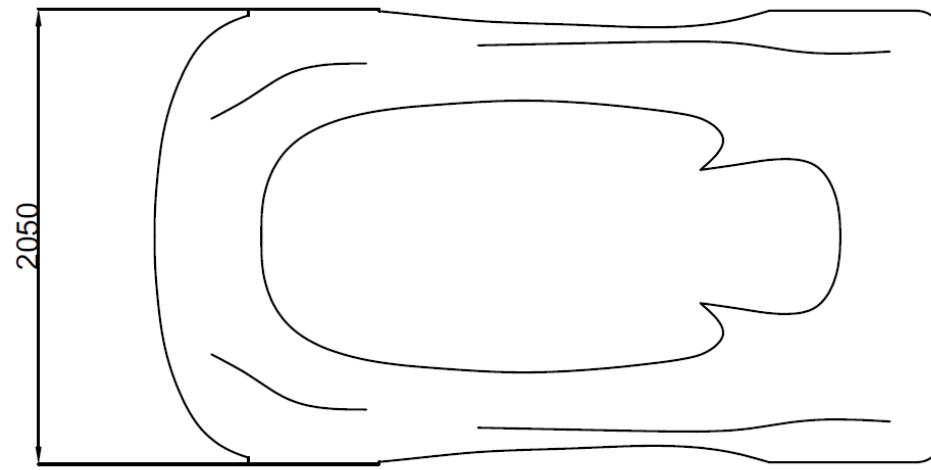
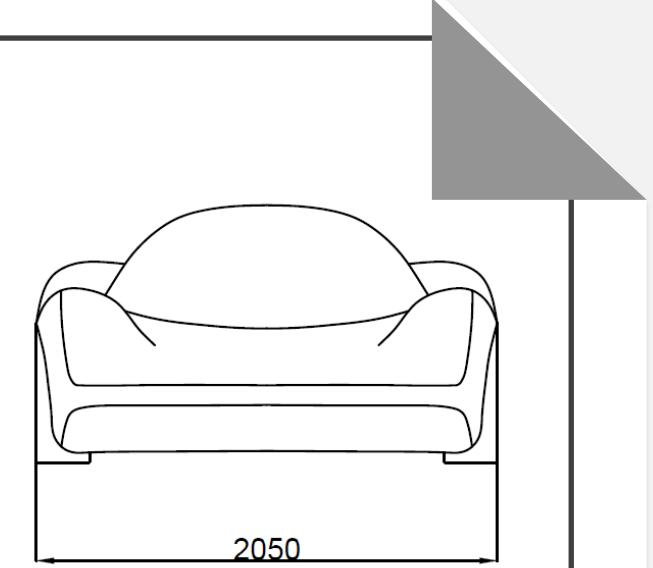
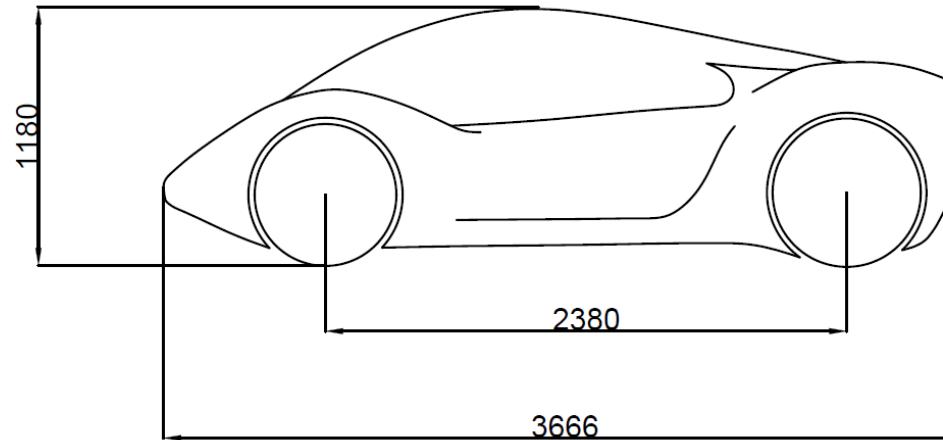
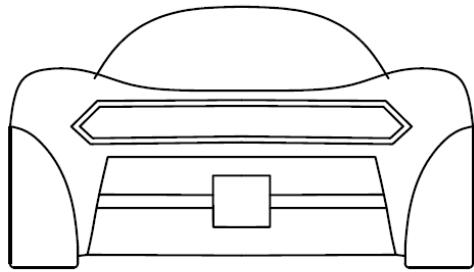


AER AUTOMOBILES

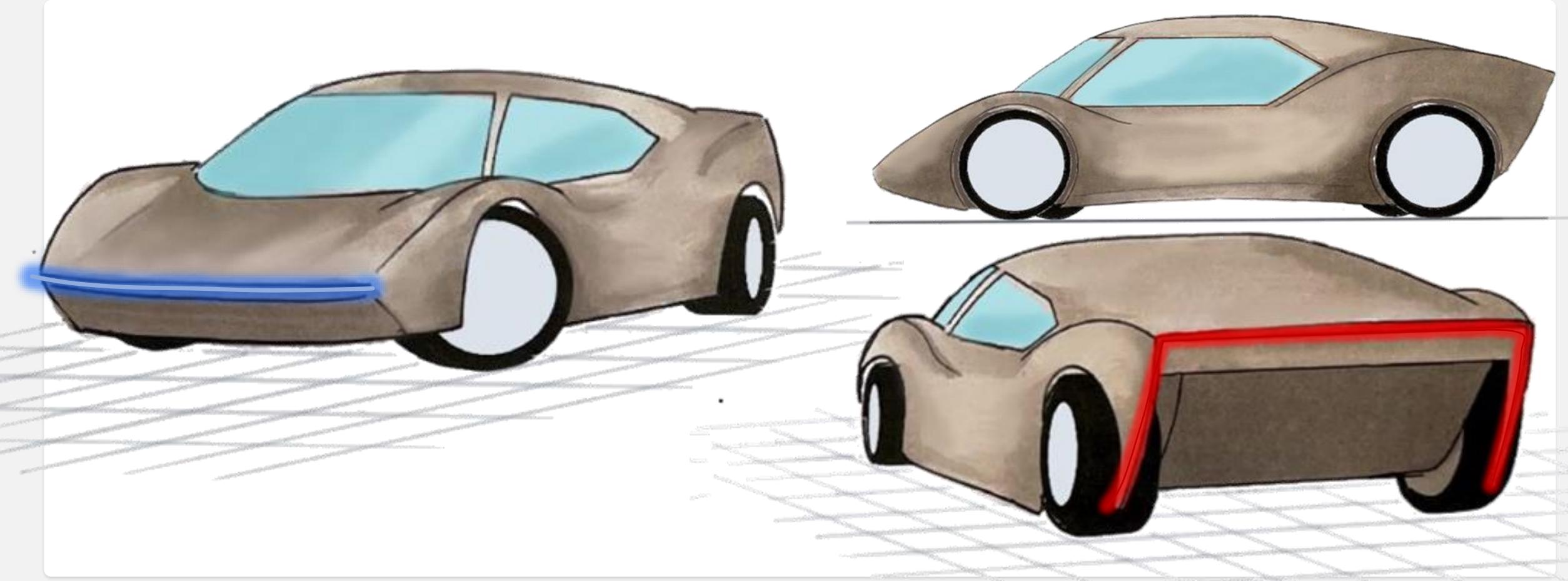
Centro Stile

03 STYLING

44

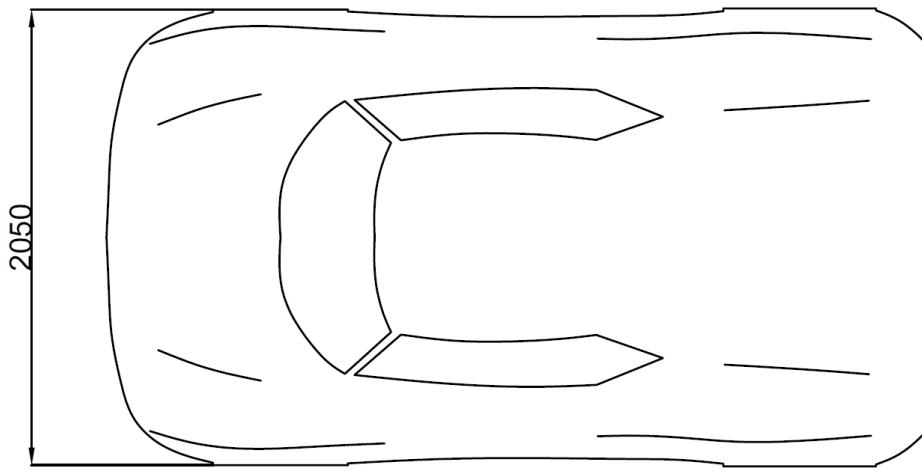
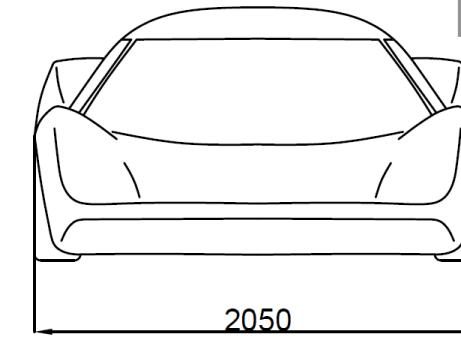
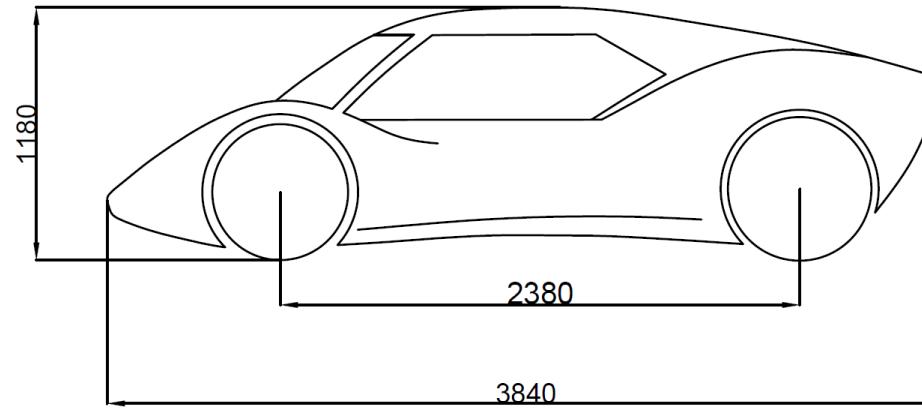
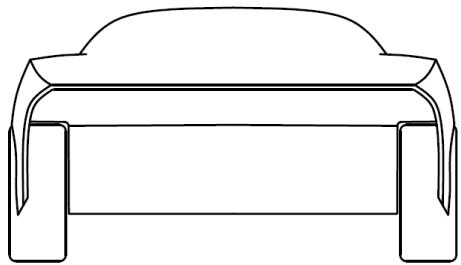


Natural

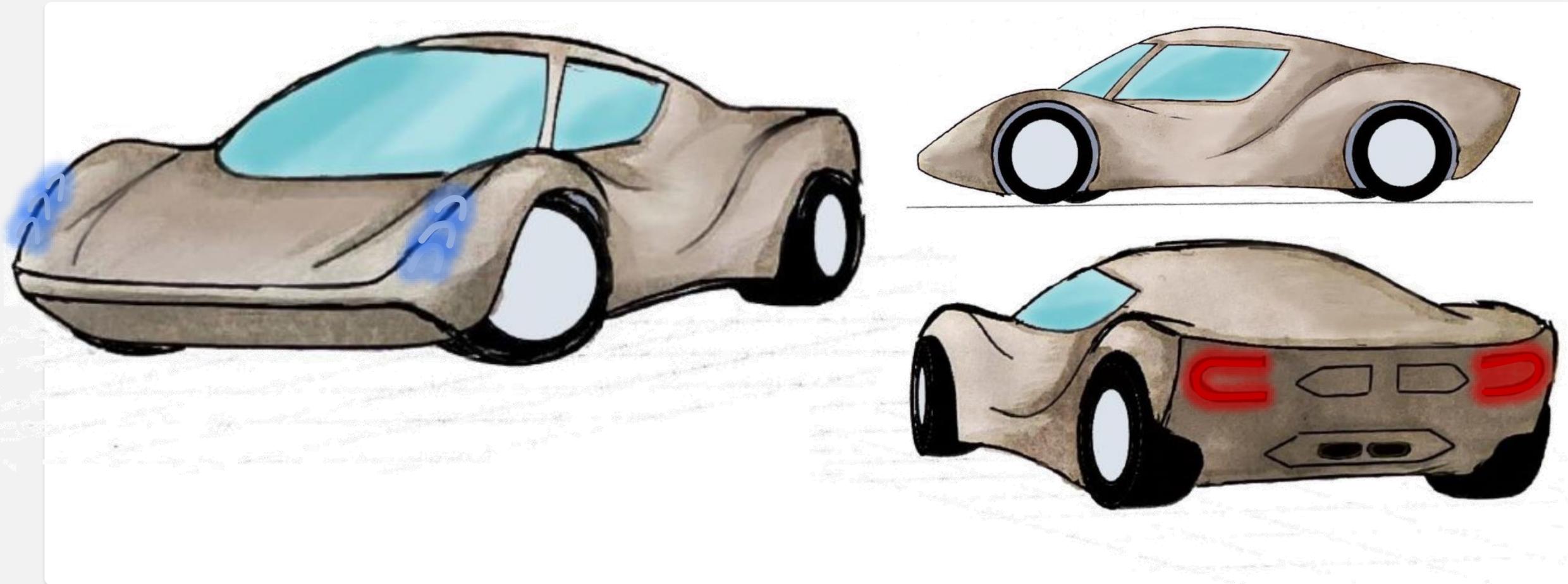


Stone

The stone styling has massive volumes and sharp lines, as if carved from rock

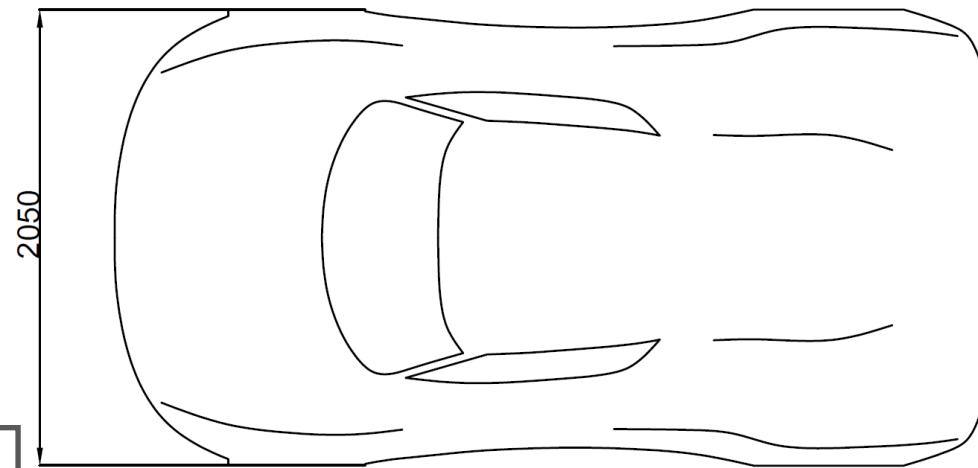
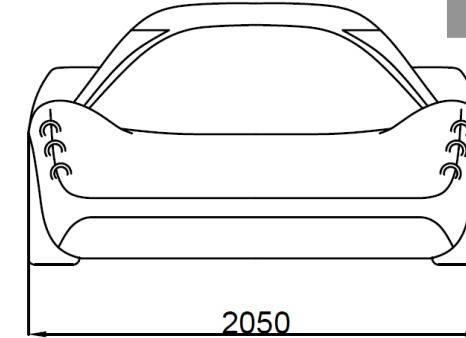
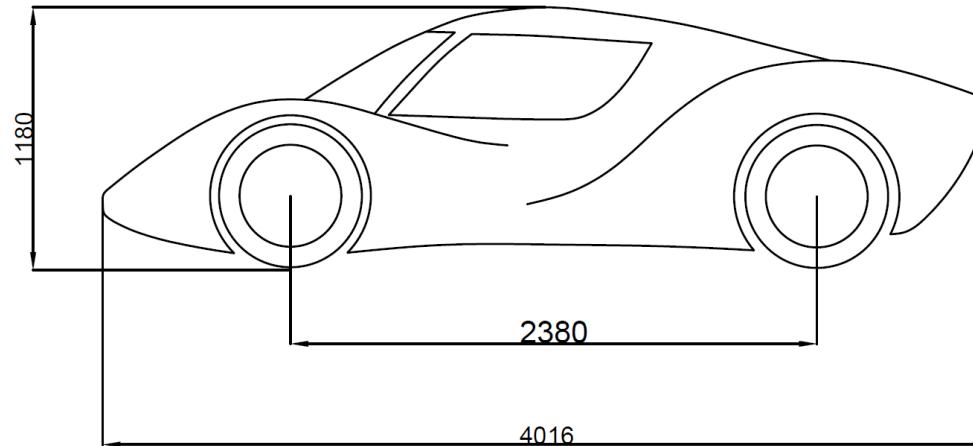
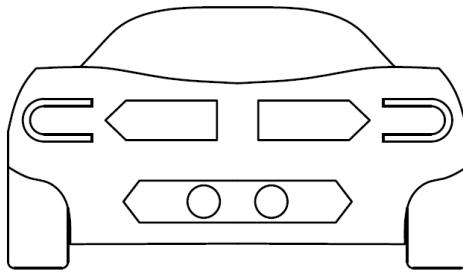


Stone

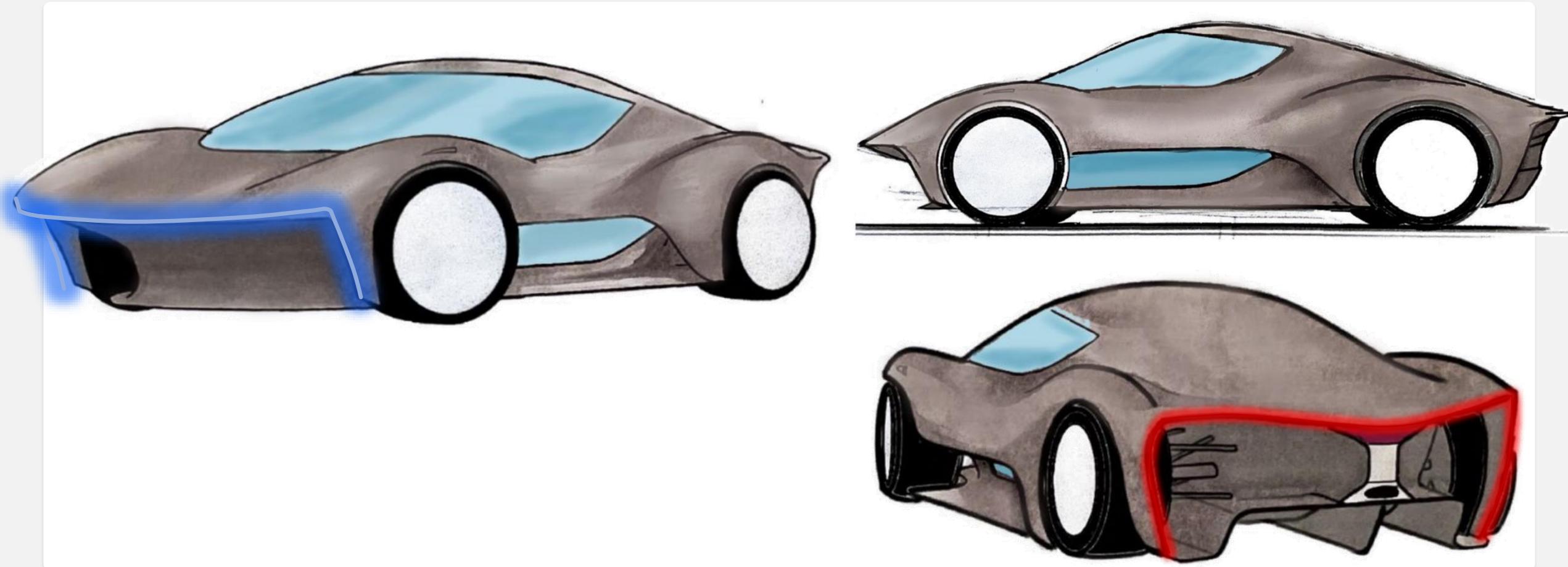


Retrò

It is inspired by the sports cars of the 60s and the first aerodynamic concepts of the time. The lateral lines are flowing through the fenders while the rear tail is neatly truncated.

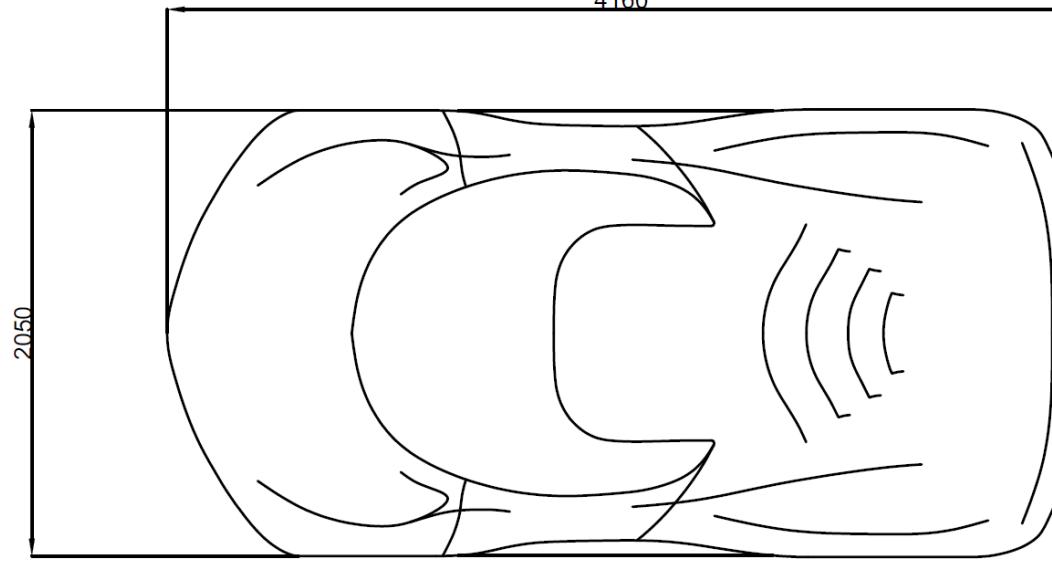
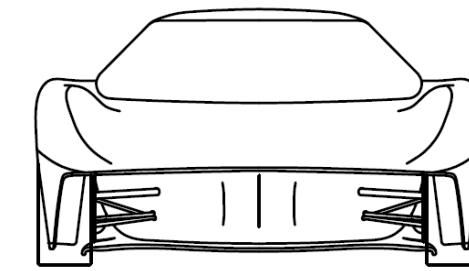
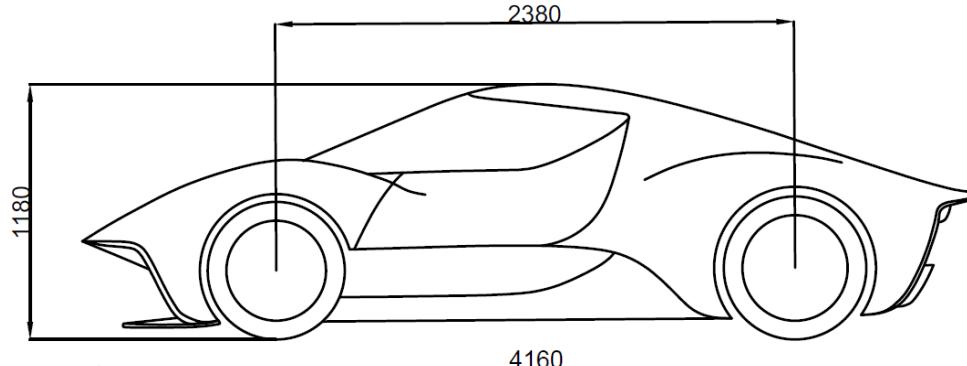
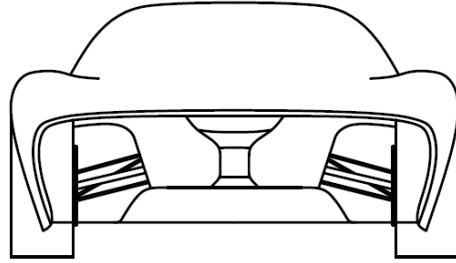


Retrò

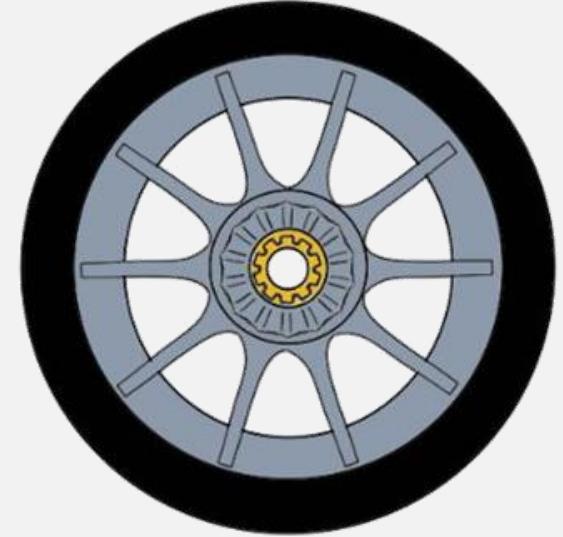
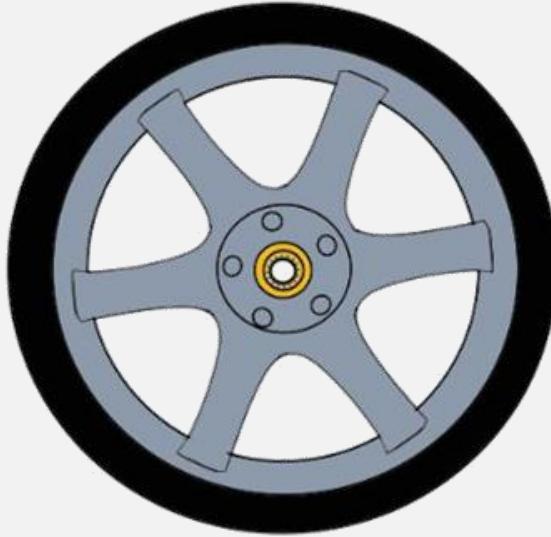
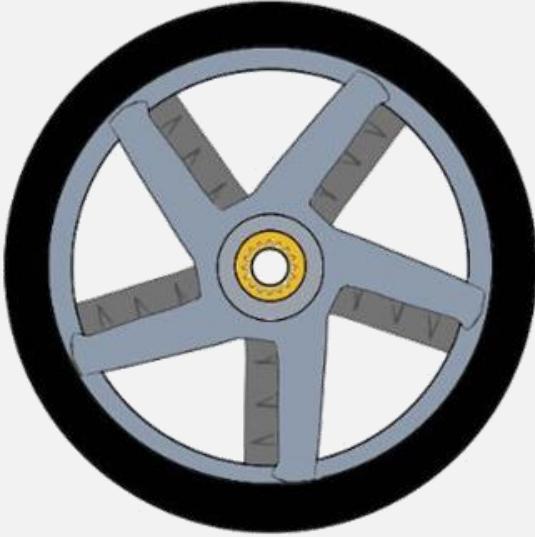


Advanced

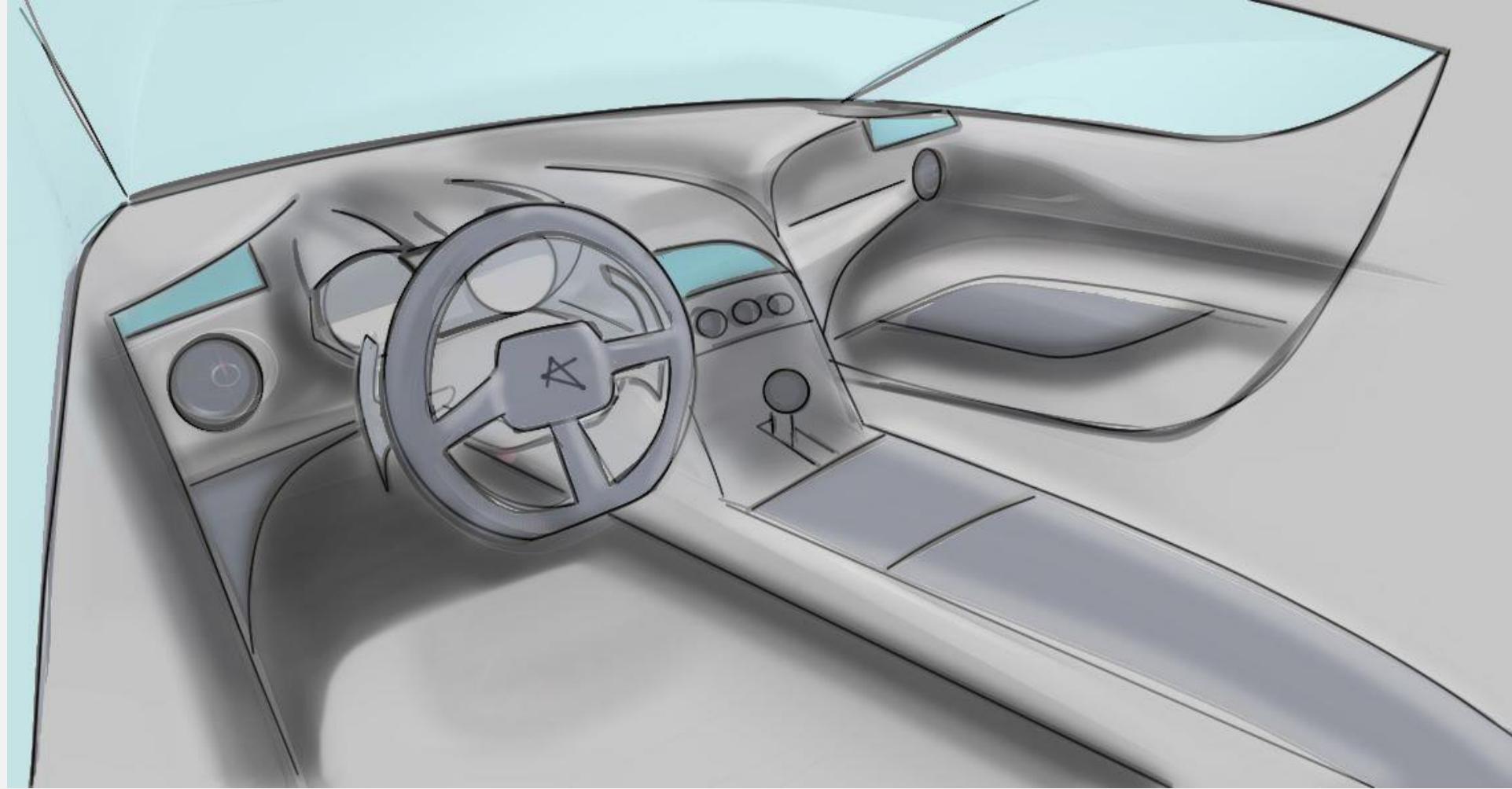
The key is less is more: the unnecessary body volumes have been removed to exasperate the aerodynamics and the flows under and above the car. The side is profiled to show the passenger seat



Advanced



Rims Proposals



Interiors Proposal

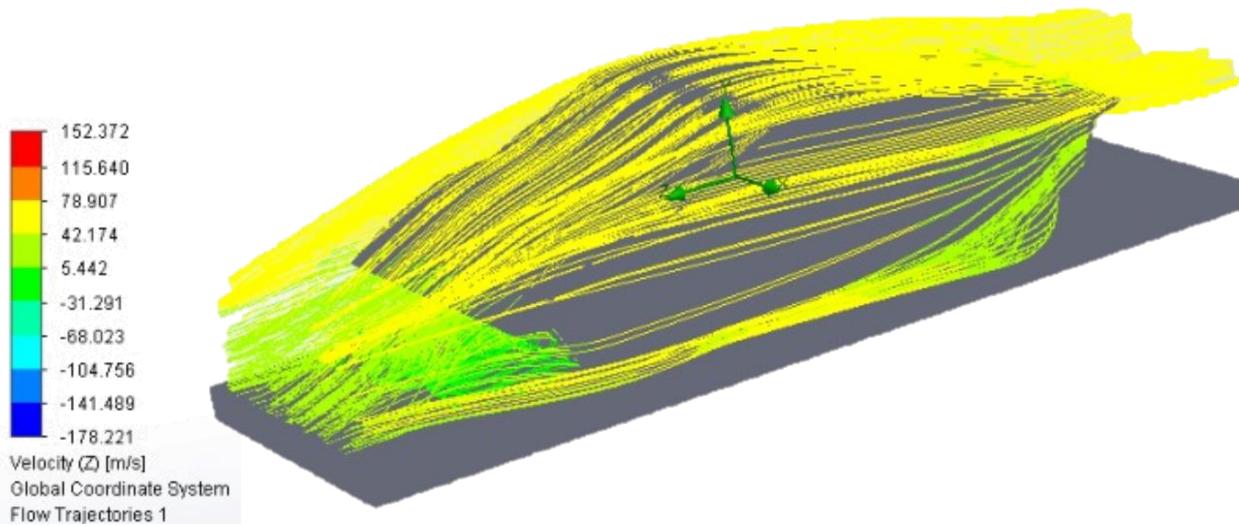
04

Stylistic Proposal Choice

- CFD Analysis
- Front Section
- Interior Space
- Visibility
- Proportions



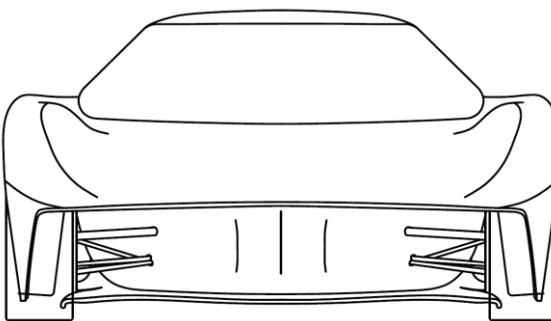
CFD Analysis



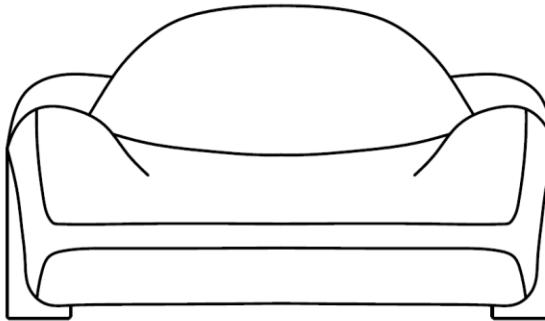
	Advanced	Natural	Retro	Stone
CX	0,313169	0,41544	0,4917825	0,289086
Best CX			0,289086	
Ratio	108,33%	143,71%	170,12%	100,00%
Surplus%	8,33%	43,71%	70,12%	0,00%
CX%	91,67%	56,29%	29,88%	100,00%



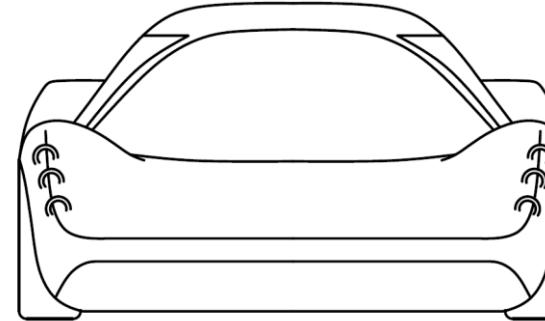
Front Section Analysis



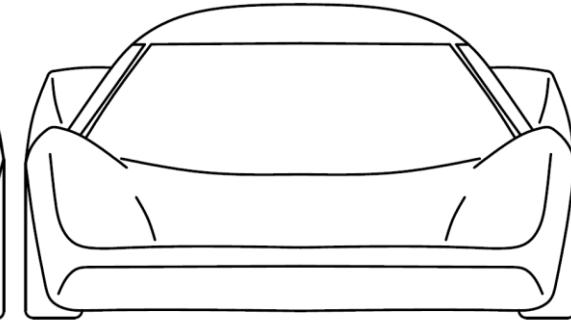
Advanced



Natural



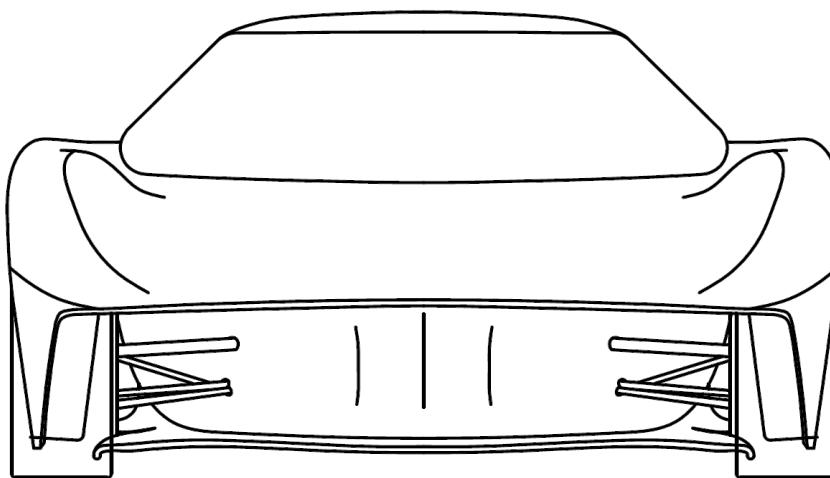
Retrò



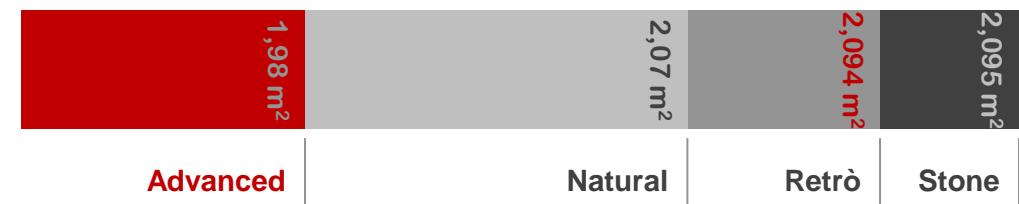
Stone



Front Section Analysis

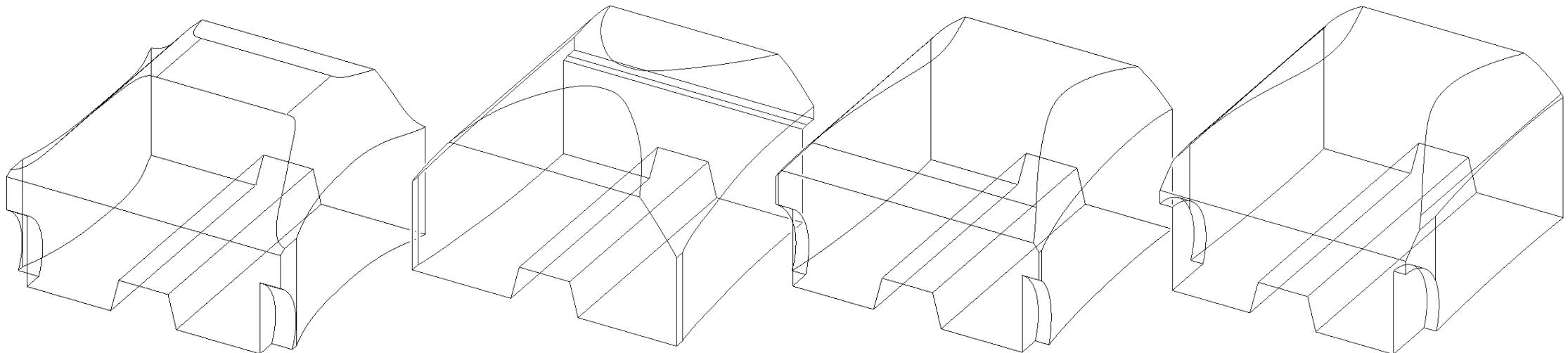


	Advanced	Natural	Retro	Stone
Area [m ²]	1,982964	2,074864	2,094676	2,095102
Best Section	1,982964			
Ratio	100,00%	104,63%	105,63%	105,66%
Surplus%	0,00%	4,63%	5,63%	5,66%
SP%	100,00%	95,37%	94,37%	94,34%





Interior Volumes Analysis



Advanced

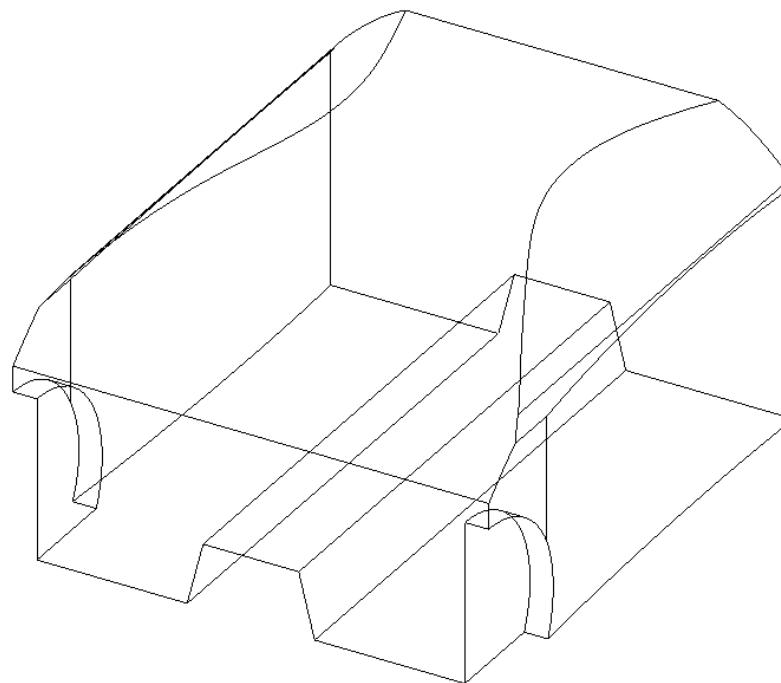
Natural

Retrò

Stone



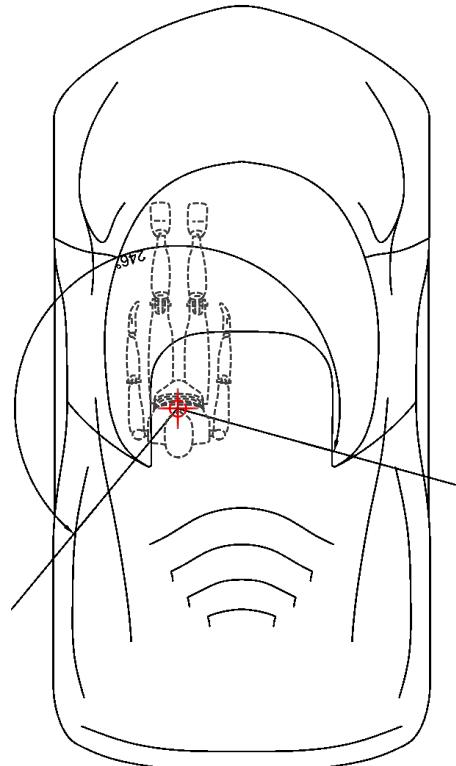
Interior Volumes Analysis



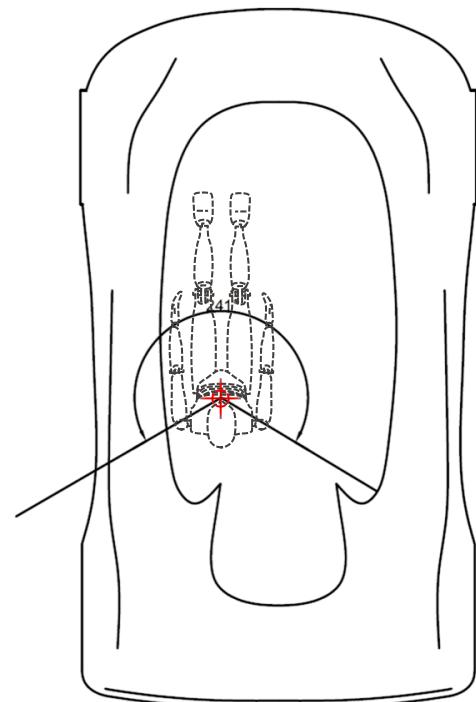
	Advanced	Natural	Retro	Stone
Real Volume	1,85674	1,8005	1,73965	2,00392
Ideal Volume	2,486176	2,446808	2,244154	2,349325
Real/Ideal Ratio	74,68%	73,59%	77,52%	85,30%
Width	1669	1575	1560	1493
Int/Ext Ratio	81,41%	74,89%	75,73%	73,08%
Length	1555,58	1545,8	1480	1692
Int/Ext Ratio	37,48%	42,17%	36,85%	44,11%
Heighth	957,598	1005	972	930
Int/Ext Ratio	81,15%	85,17%	82,37%	78,81%
Max Volume	2,003919916			
Ratio	92,66%	89,85%	86,81%	100,00%



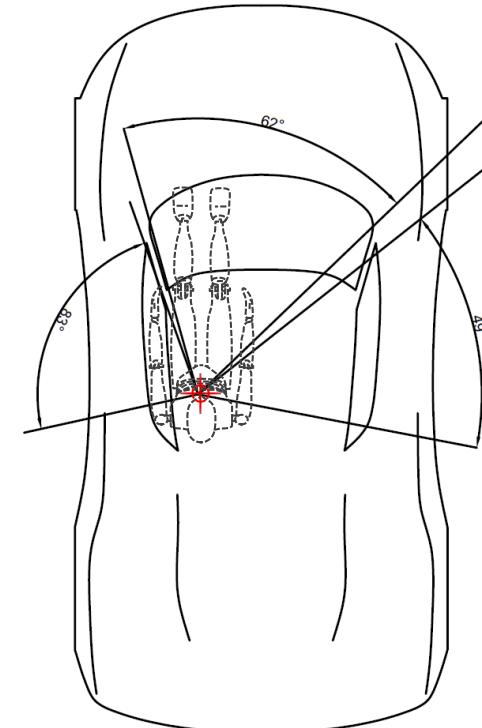
Visibility Analysis



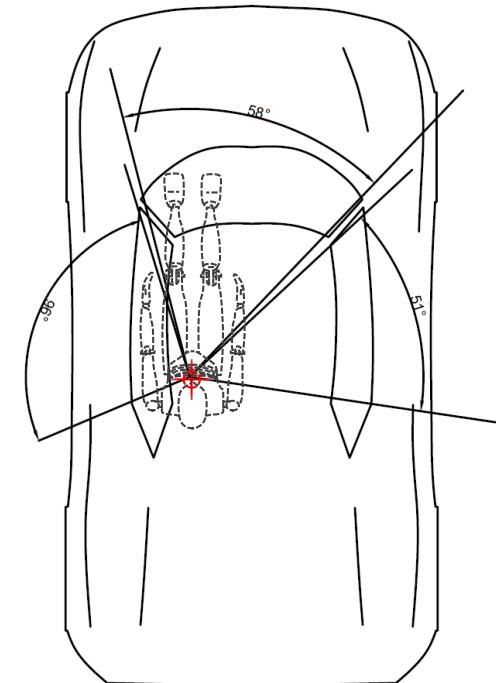
Advanced



Natural



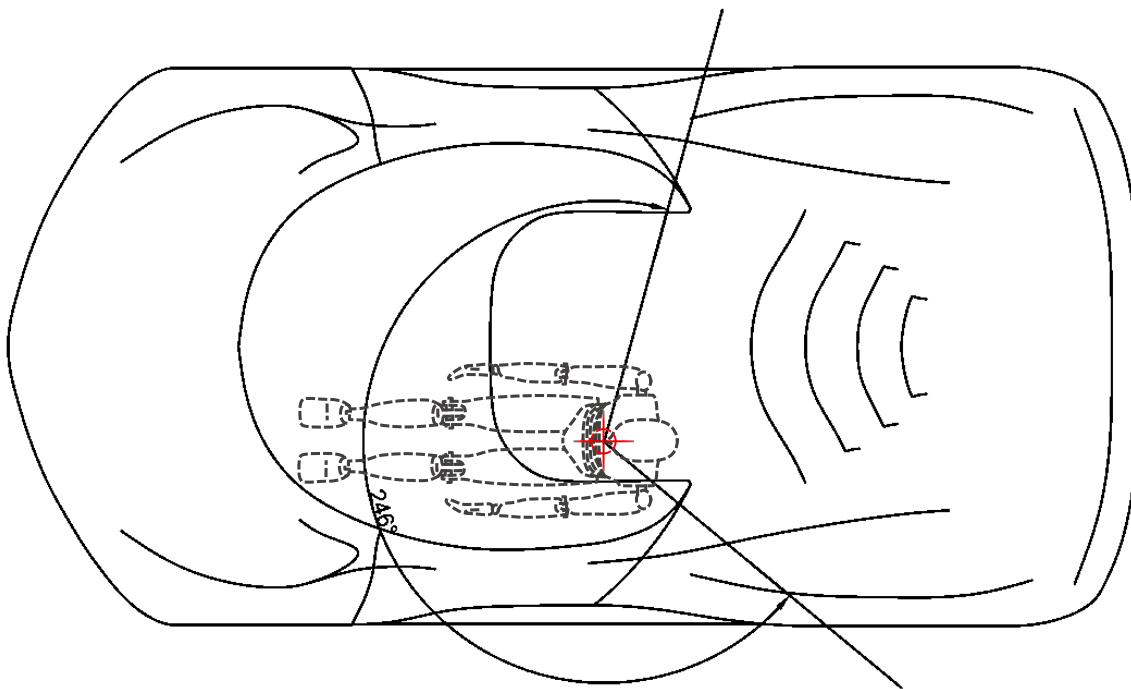
Retrò



Stone



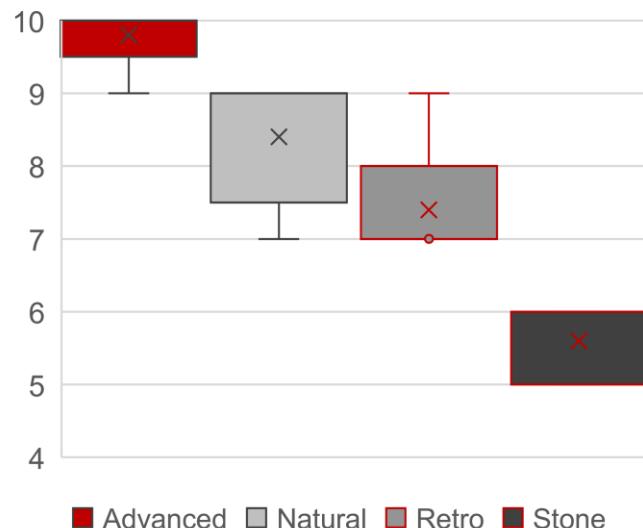
Visibility Analysis



	Advanced	Natural	Retro	Stone
α°	246	240	204	164
Max α°			246	
Ratio	100,00%	97,56%	82,93%	66,67%



Proportions Evaluation

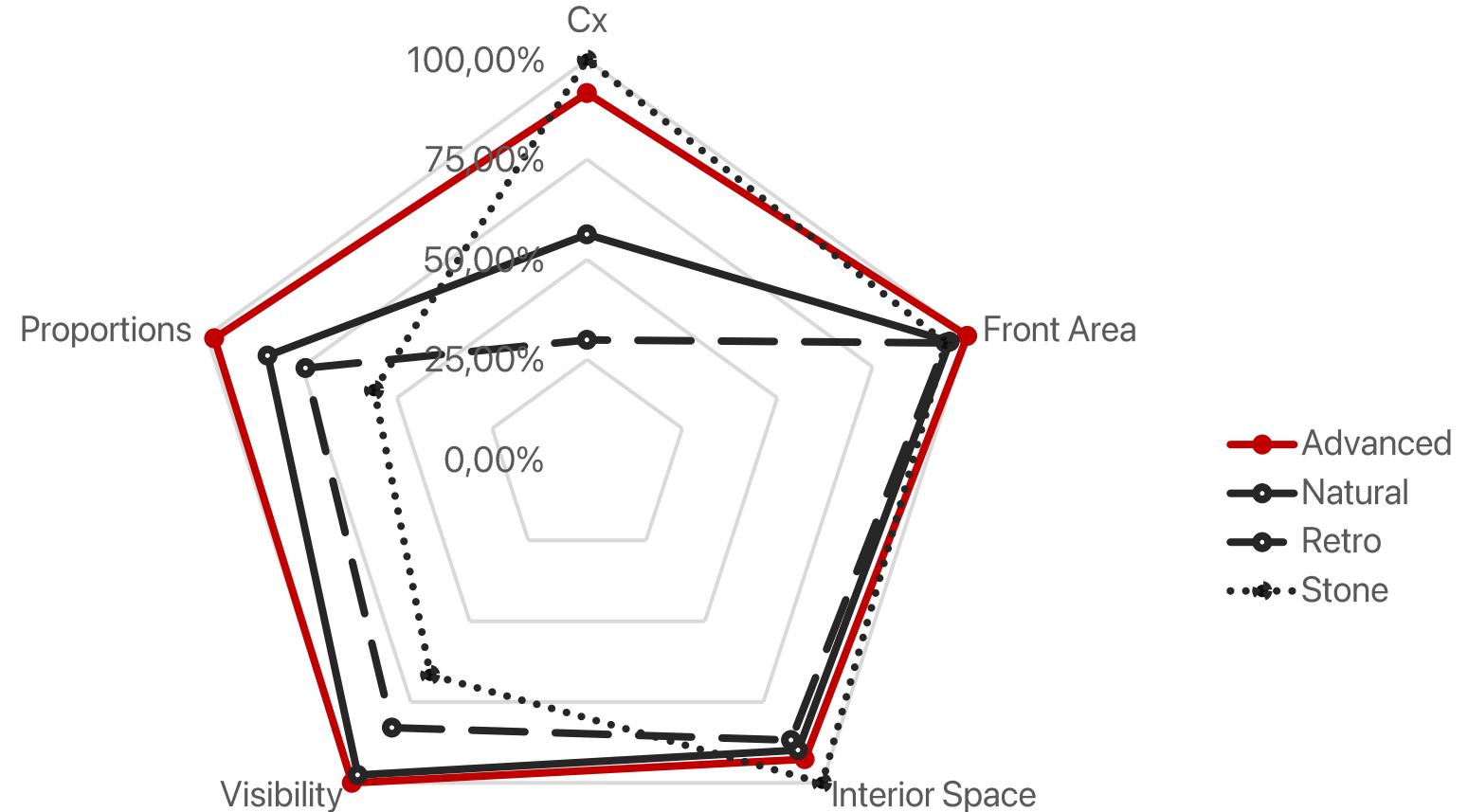


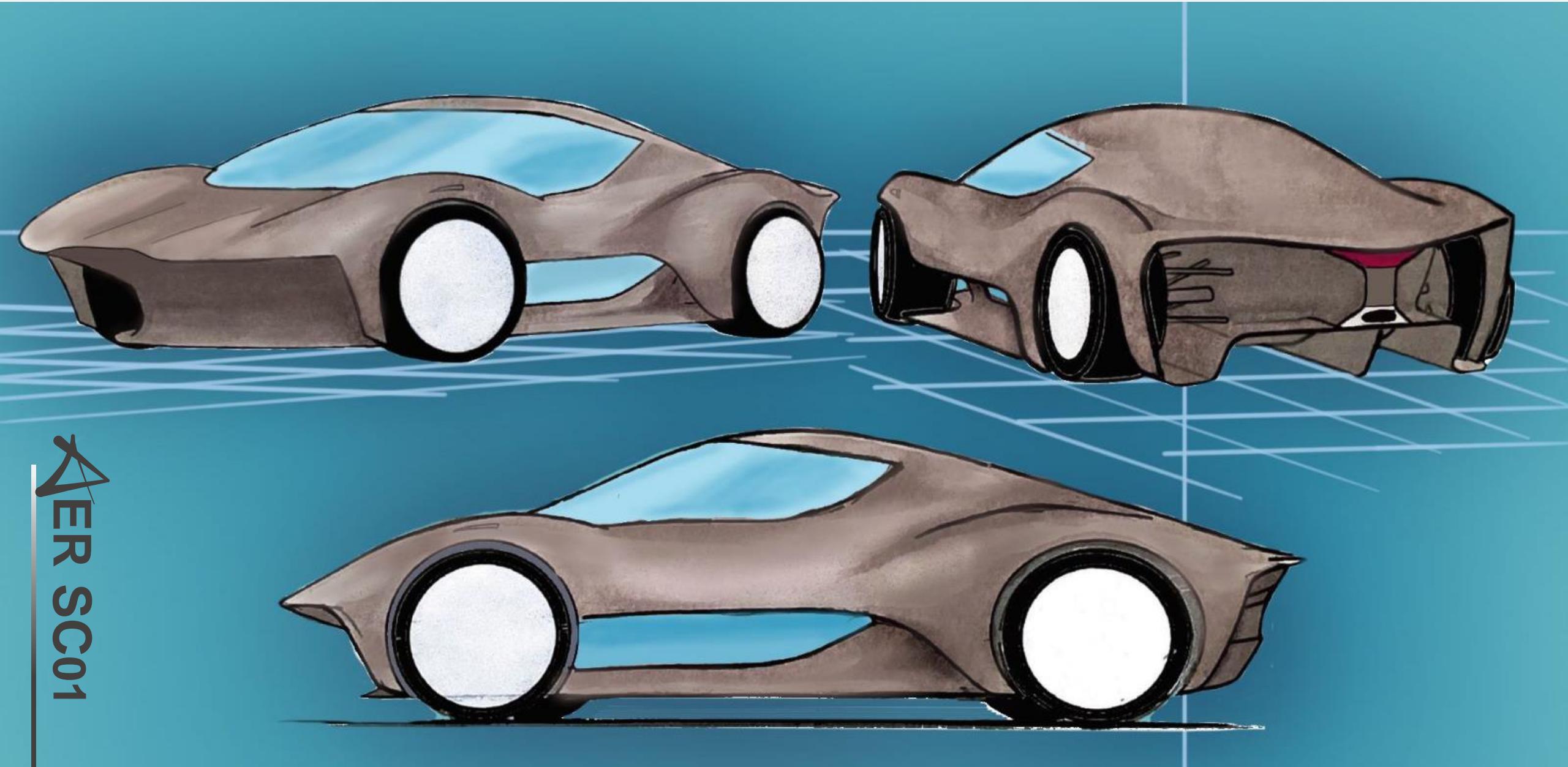
	Advanced	Natural	Retro	Votes
V1	10	9	9	5
V2	10	9	7	6
V3	9	7	7	5
V4	10	8	7	6
V5	10	9	7	6
Average	9,8	8,4	7,4	5,6
Avg%	98,00%	84,00%	74,00%	56,00%



5 Properties

Let's compare the scores obtained by each stylistic proposal in each evaluation category

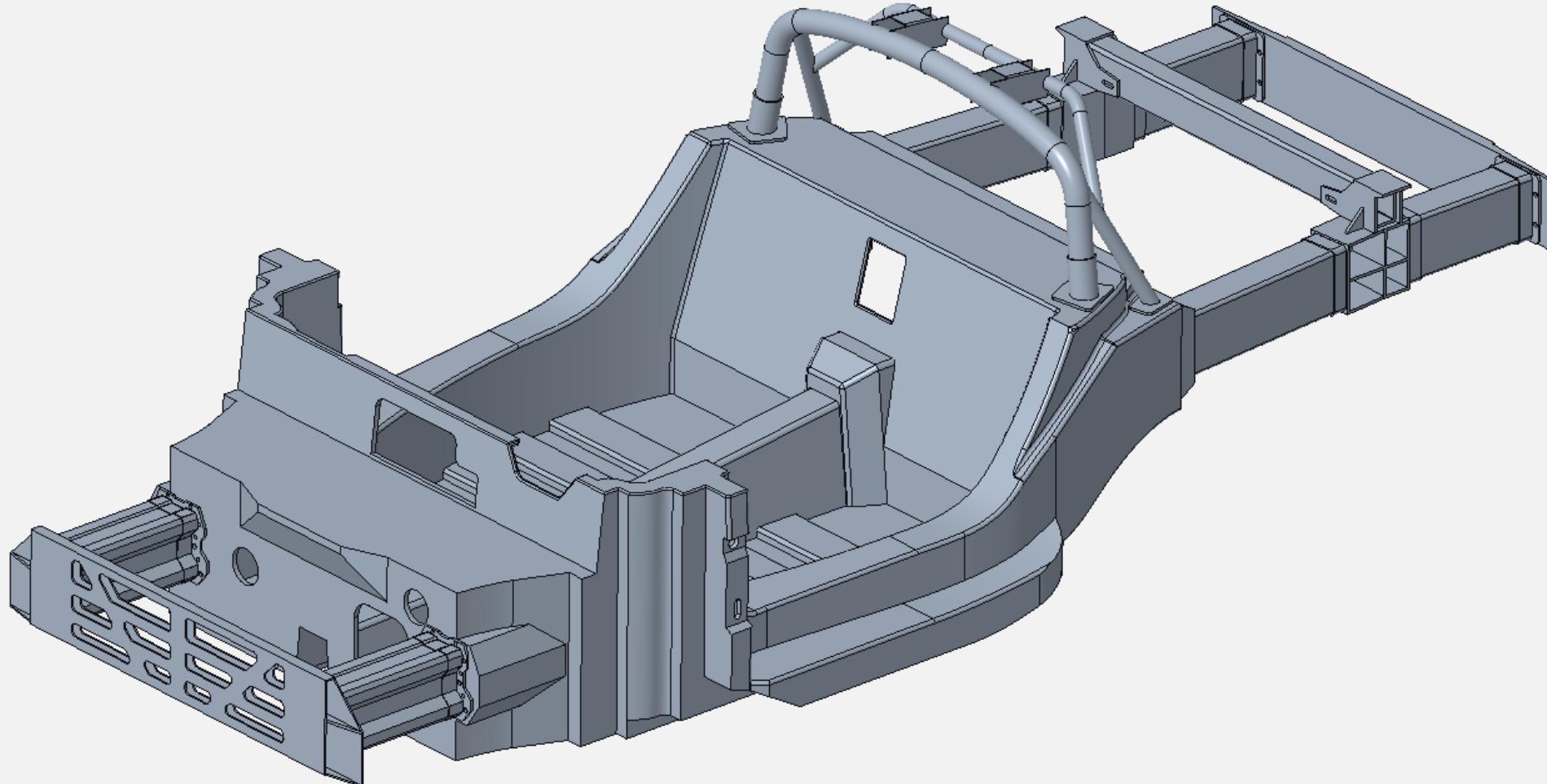




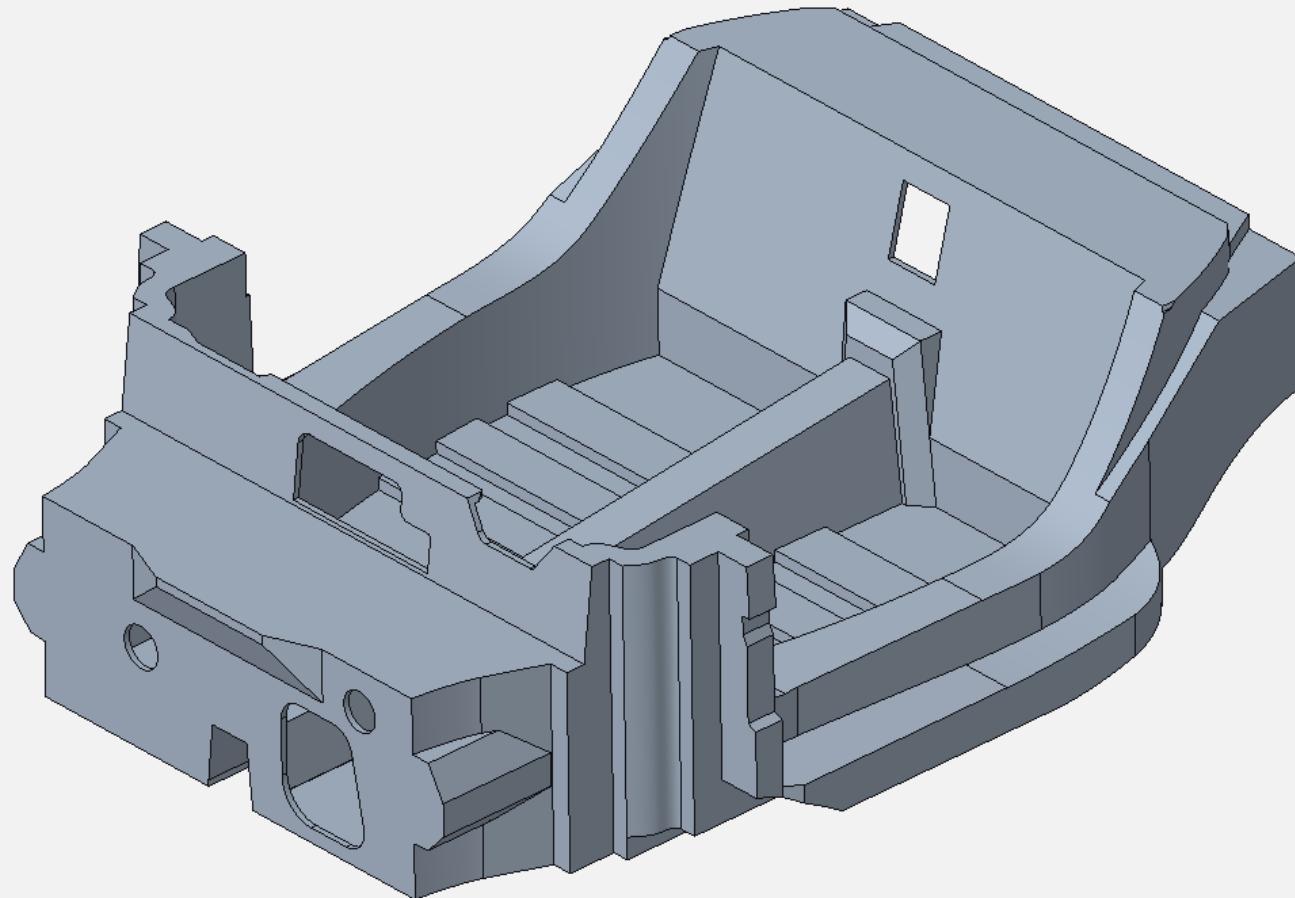
05

Chassis

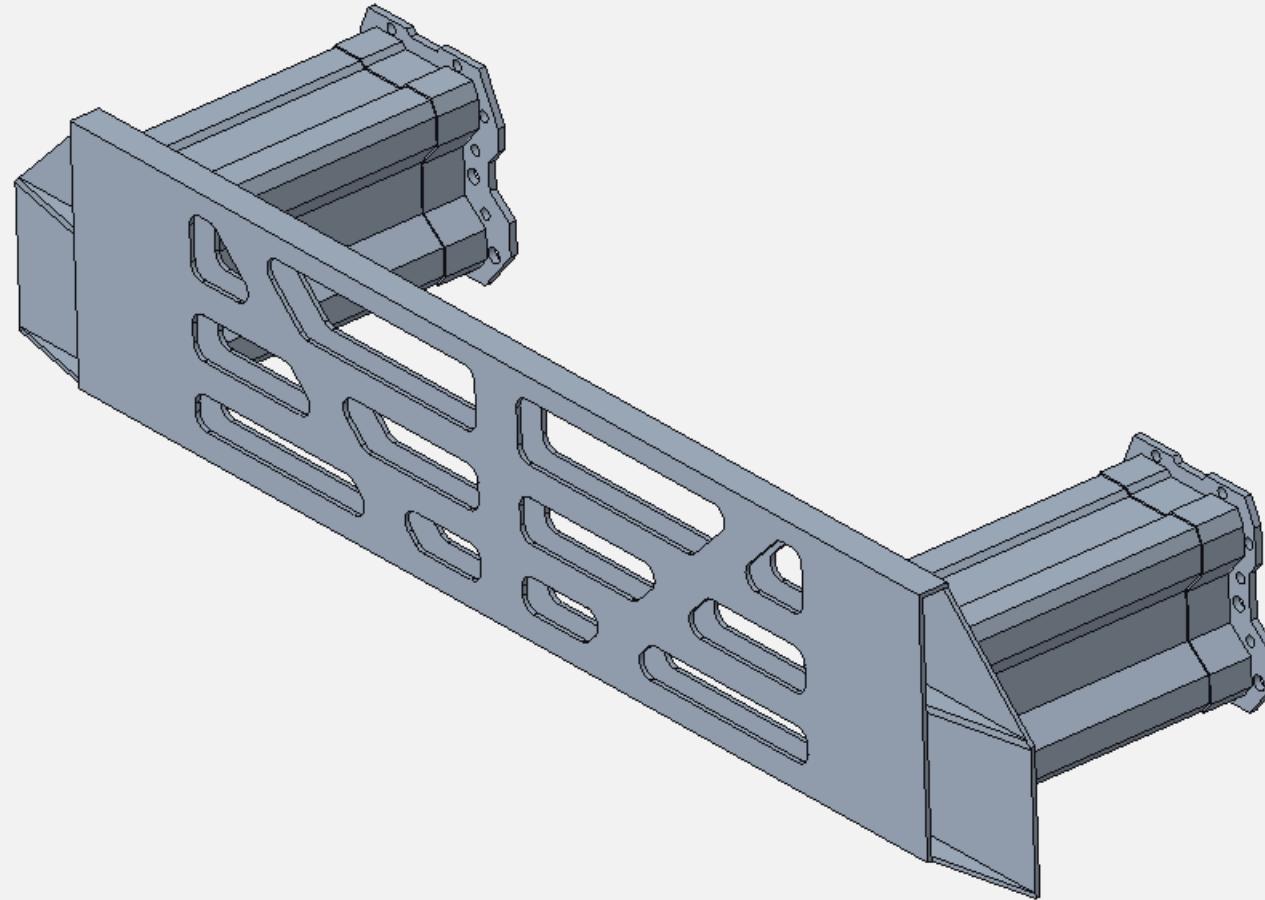
- Monocoque
- Front Frame
- Rear Frame
- Roll-bar



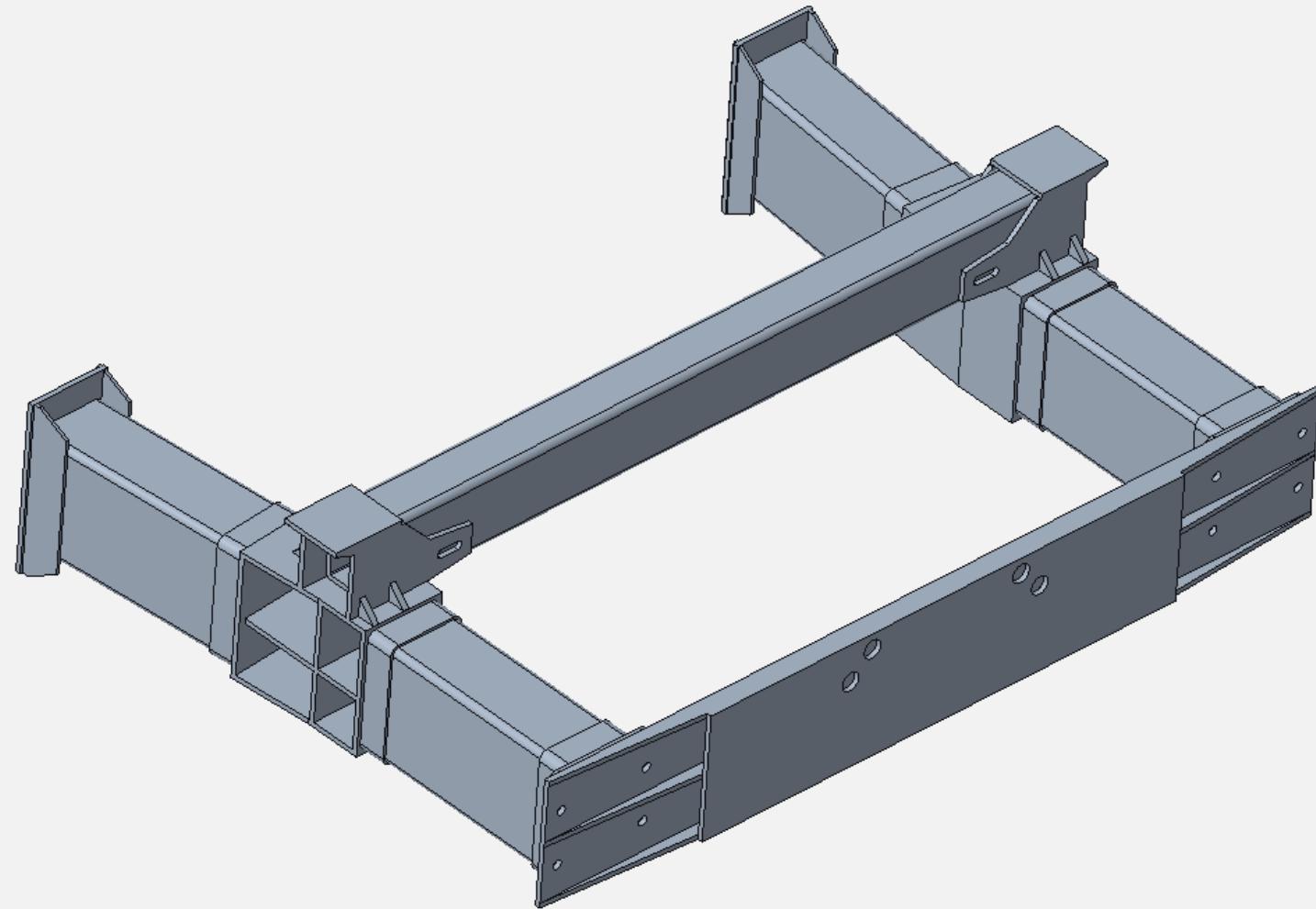
Monocoque and Frames



Alluminium Monocoque



Front Frame



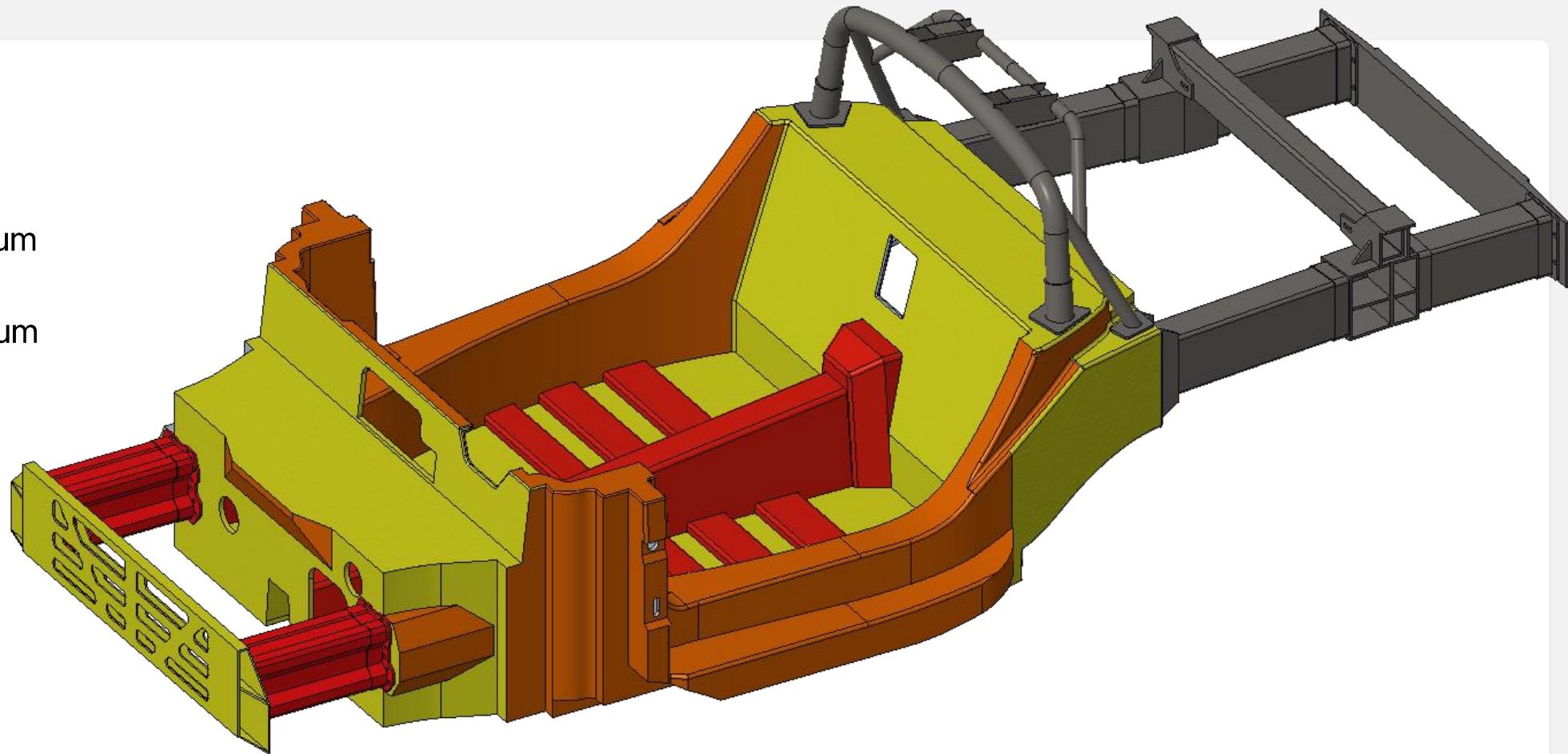
Rear Frame



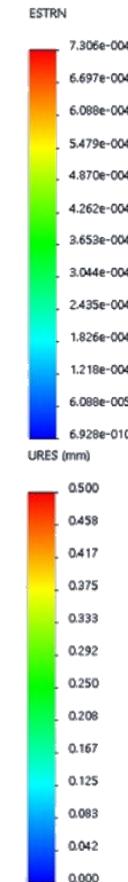
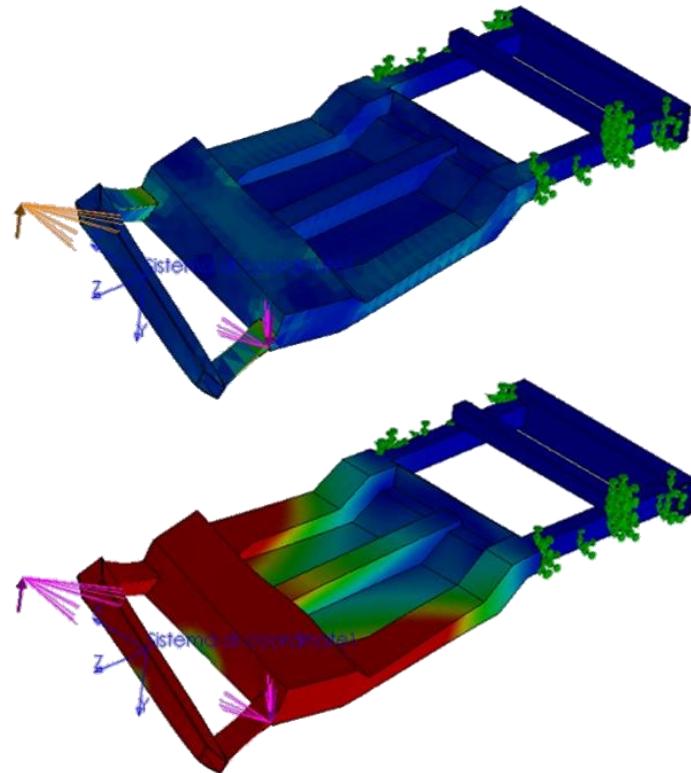
Roll Hoop



- Aluminum Sheet
- Extruded Aluminum
- Stamped Aluminum
- Extruded Steel



Chassis Manufacture

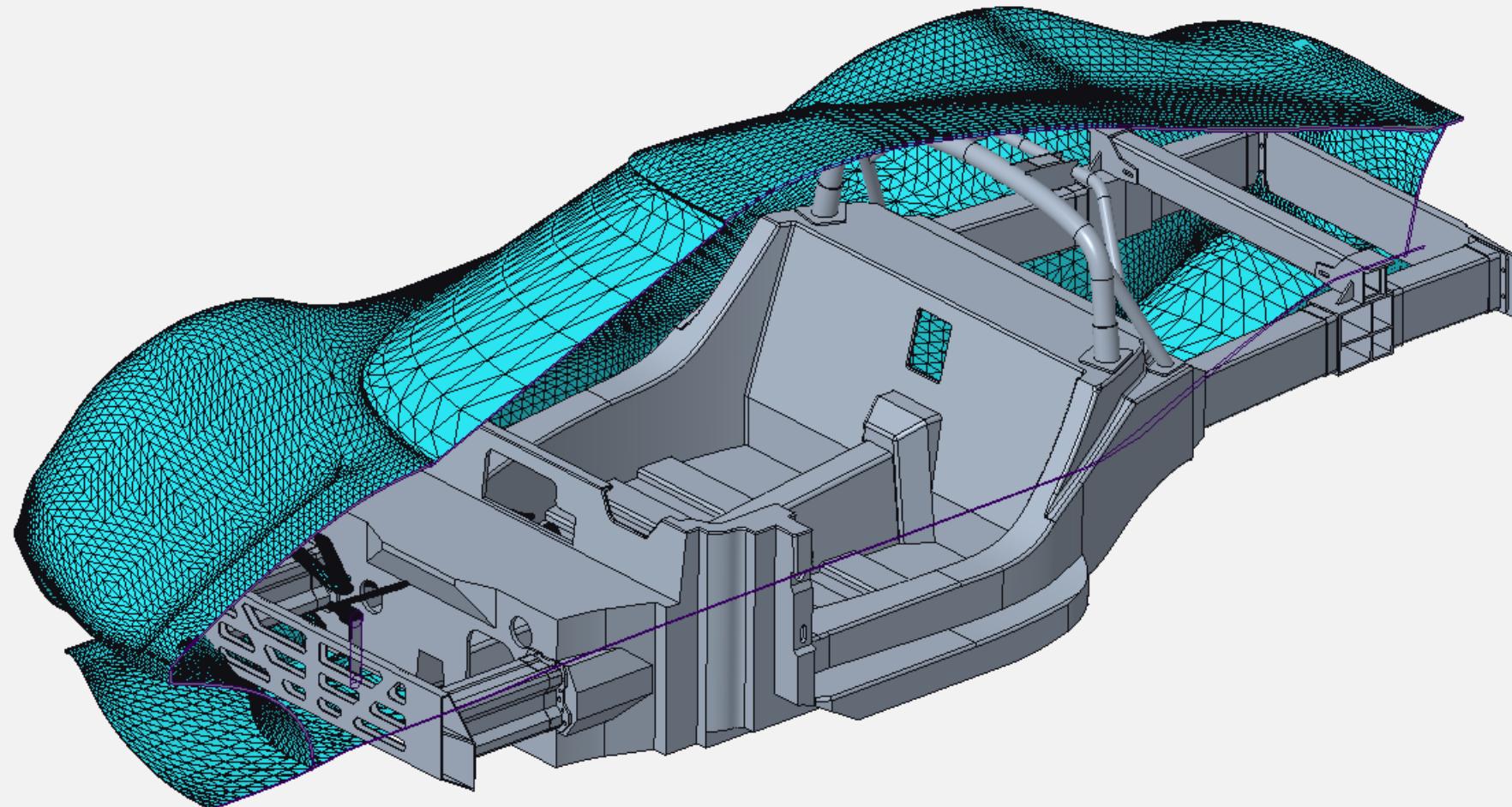


Torsional Stiffness

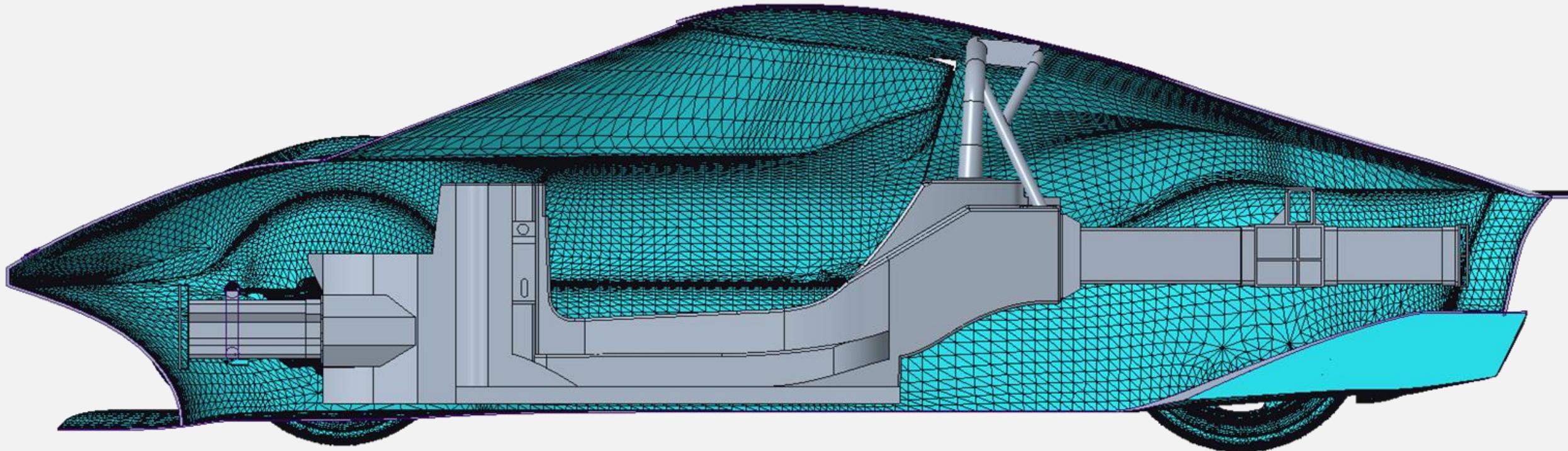
$$\alpha = \left[\frac{\delta_a + \delta_b}{d} \right] \left(\frac{180}{\pi} \right) = 0,13^\circ$$

$$K_t = \frac{M_t}{\alpha} = 8150 \frac{\text{Nm}}{\text{°}}$$

FEM Simulations



Installing the bodywork

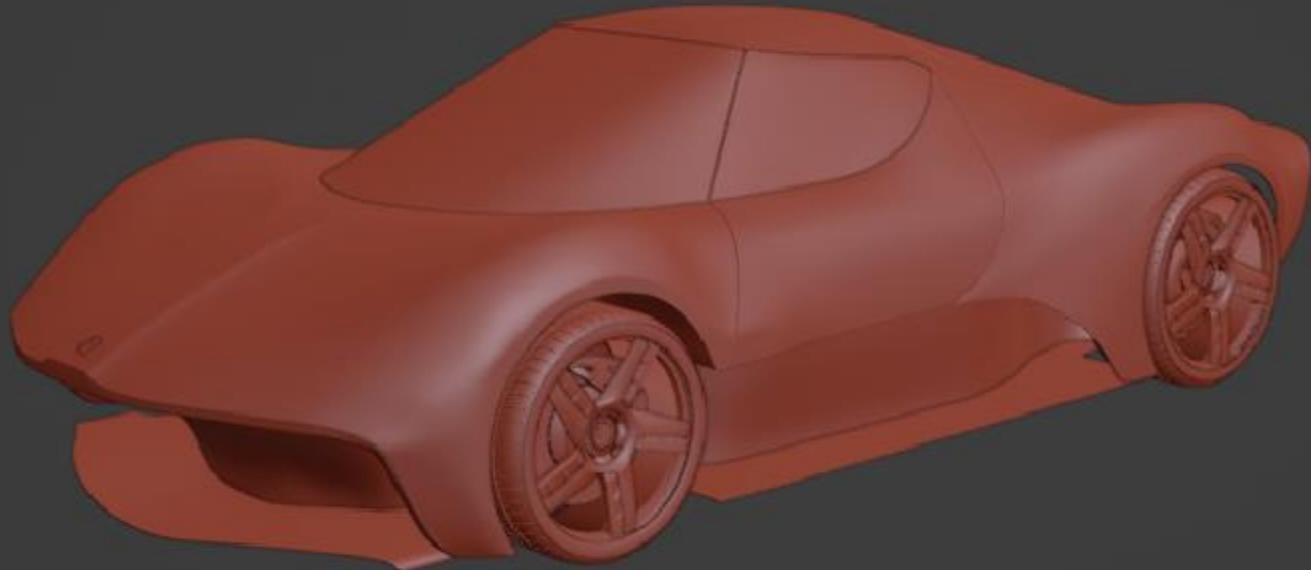


Installing the bodywork

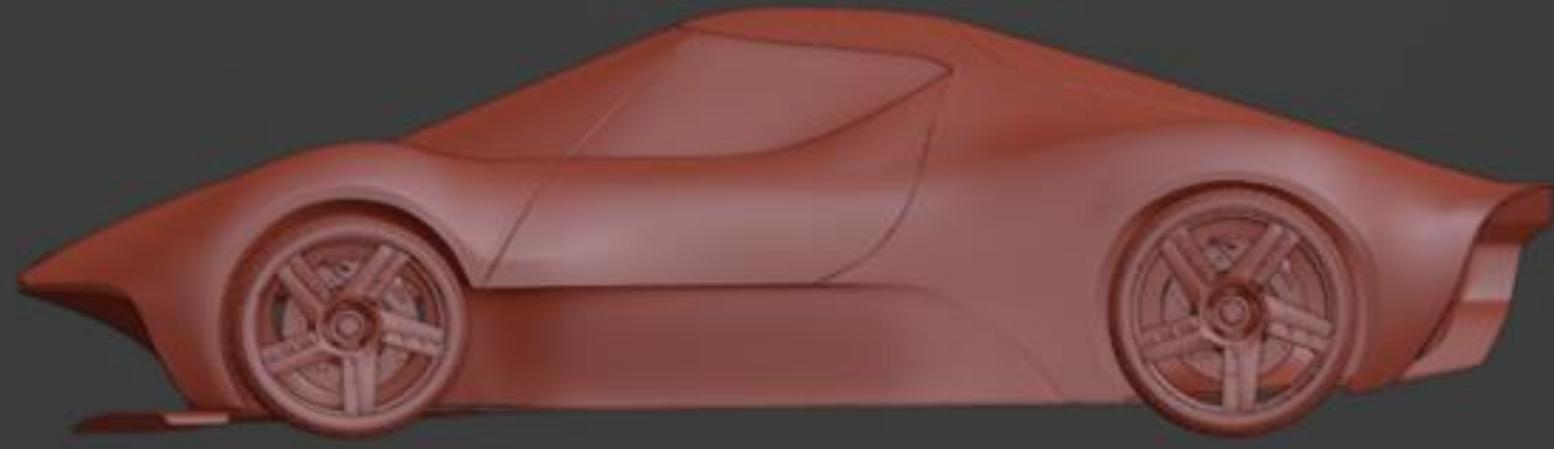
06

3D Model

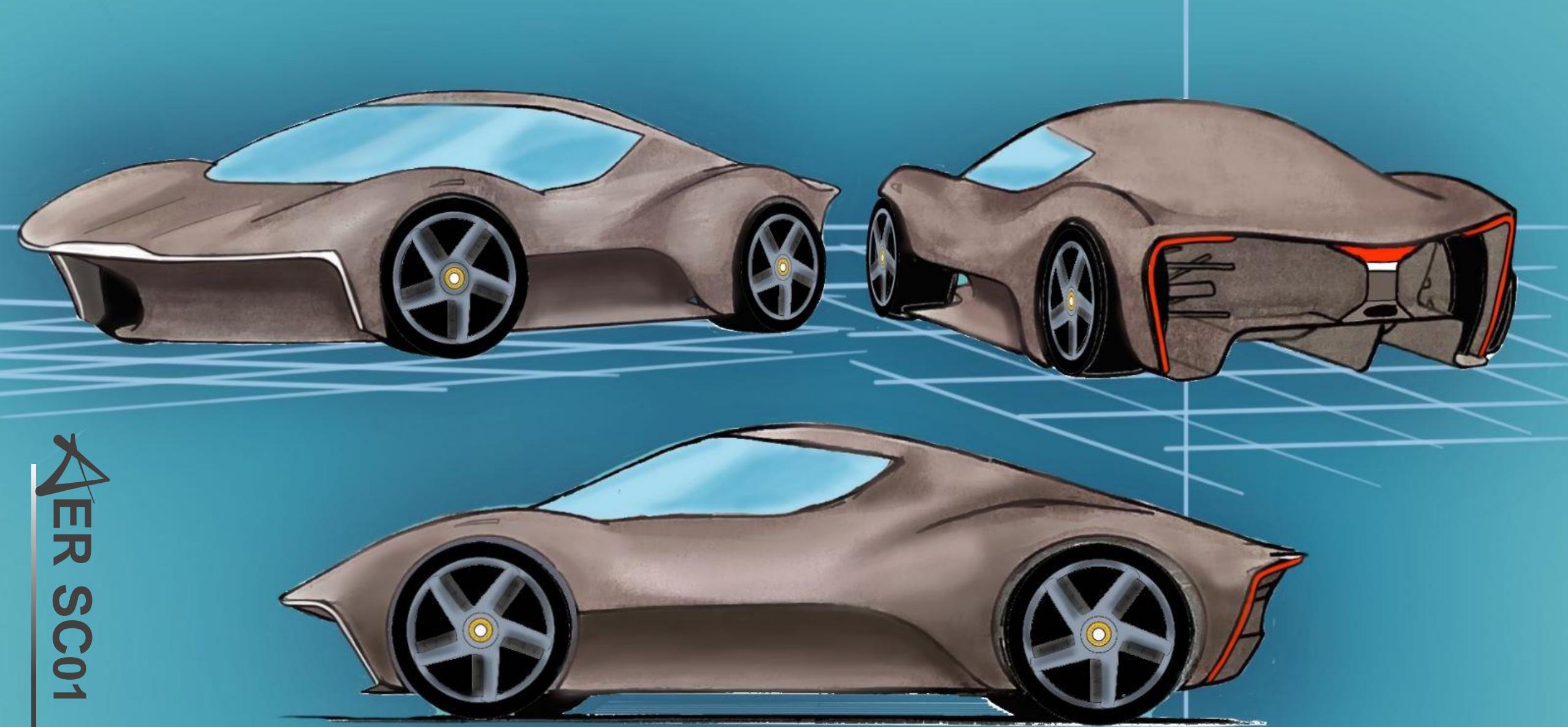
- Starting Sketch
- Blender Model
- Renders

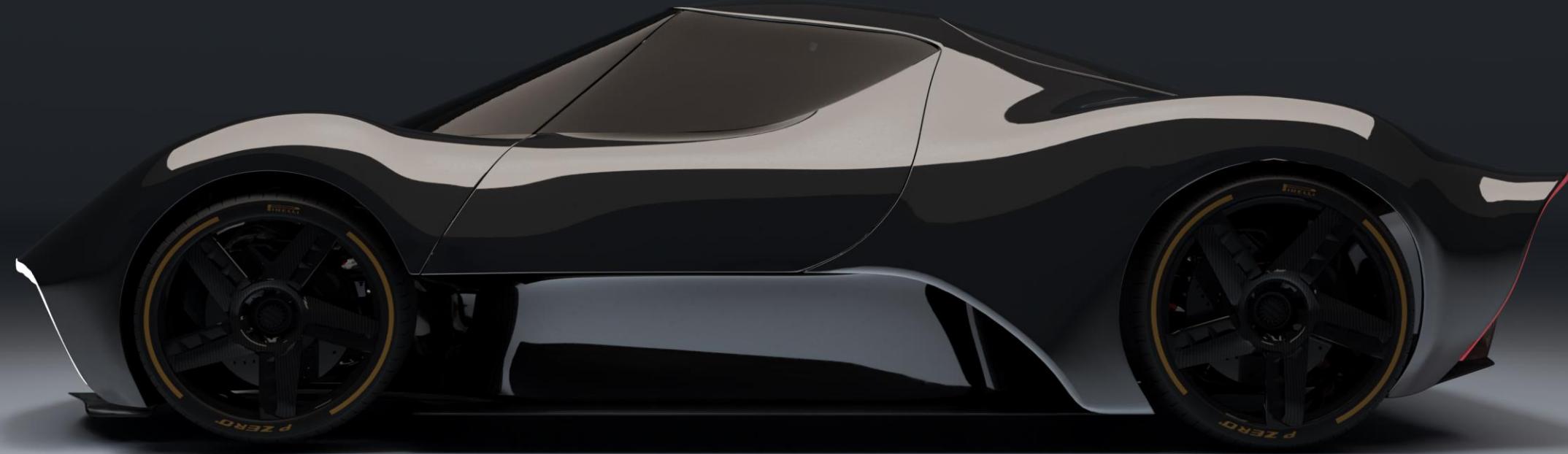


Clay Model – Blender Model

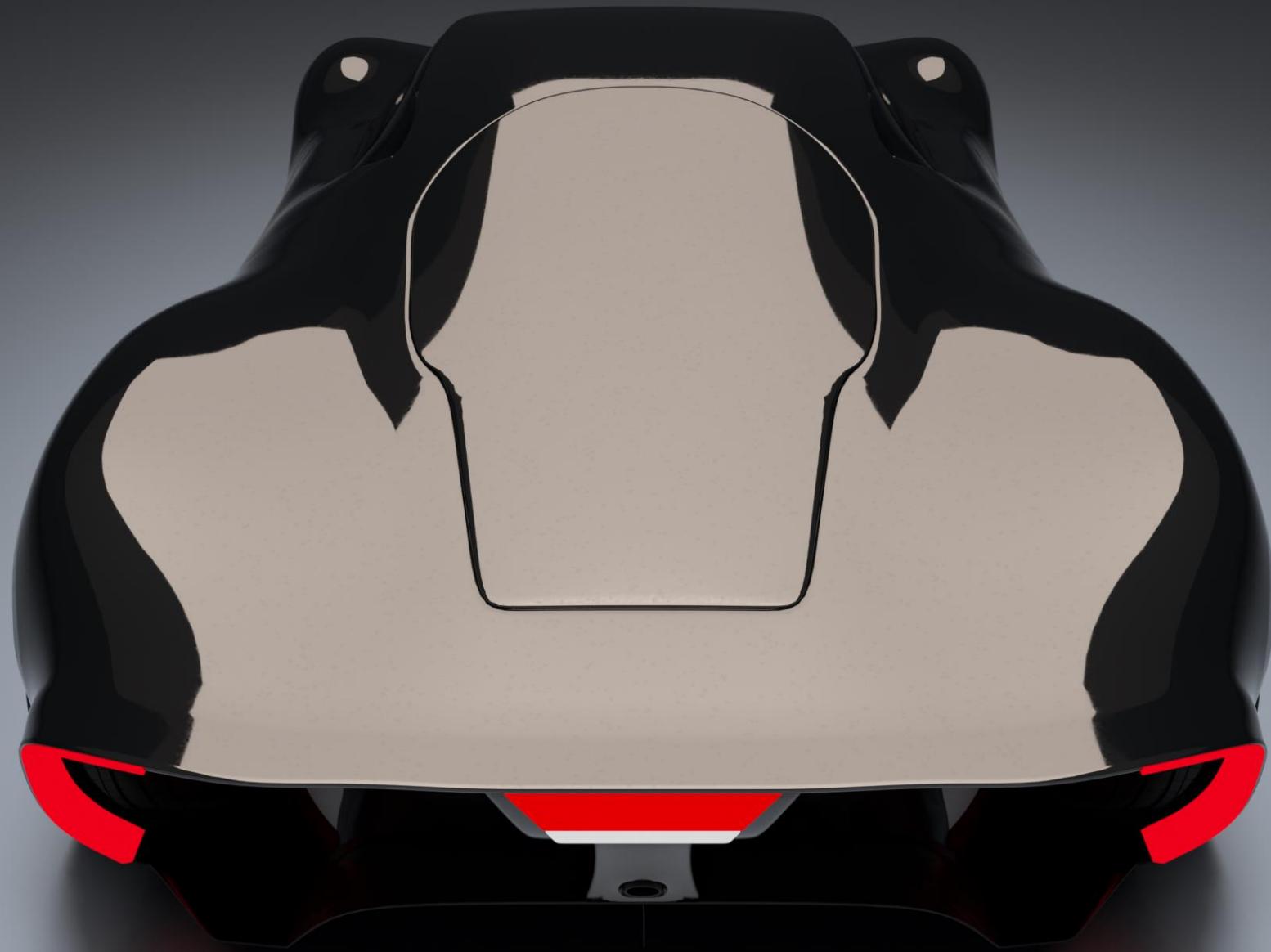


Clay Model – Blender Model





AER SC01



AER SC01



AER SC01



AER SC01



AER SC01



AER SC01



AER SC01

AER SC01



AER SC01



AER SC01



AER SC01



AER SC01





AER SC01

AER SC01





The future is the breeze that is yet to blow

