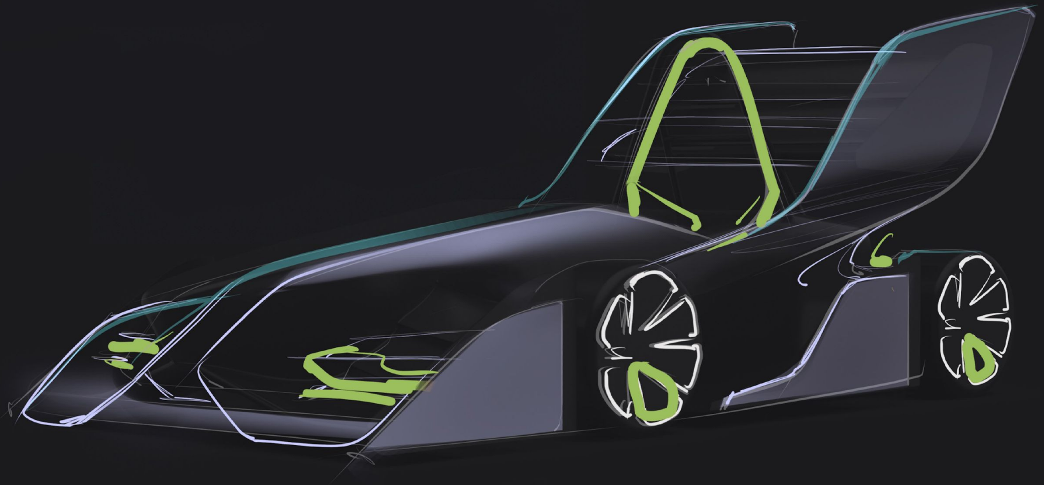
Advanced PLM course
CDMM, 2020

Formula Student



Skoltech
Skolkovo Institute of Science and Technology

moscow
polytech

Skoltech Racing

15 people

8 subteams

6 mentors

1 goal

1000 hours

Introduction to PLM

Teams assembly

Rules management

Simulations

First digital twin

Advanced PLM

Optimisation of Chassis

Powertrain simulations

Battery simulations

Design verification

Advanced PLM 2

Finalization of the digital car

Purchases

Start of Assembly

Detailing

Assembly & Racing

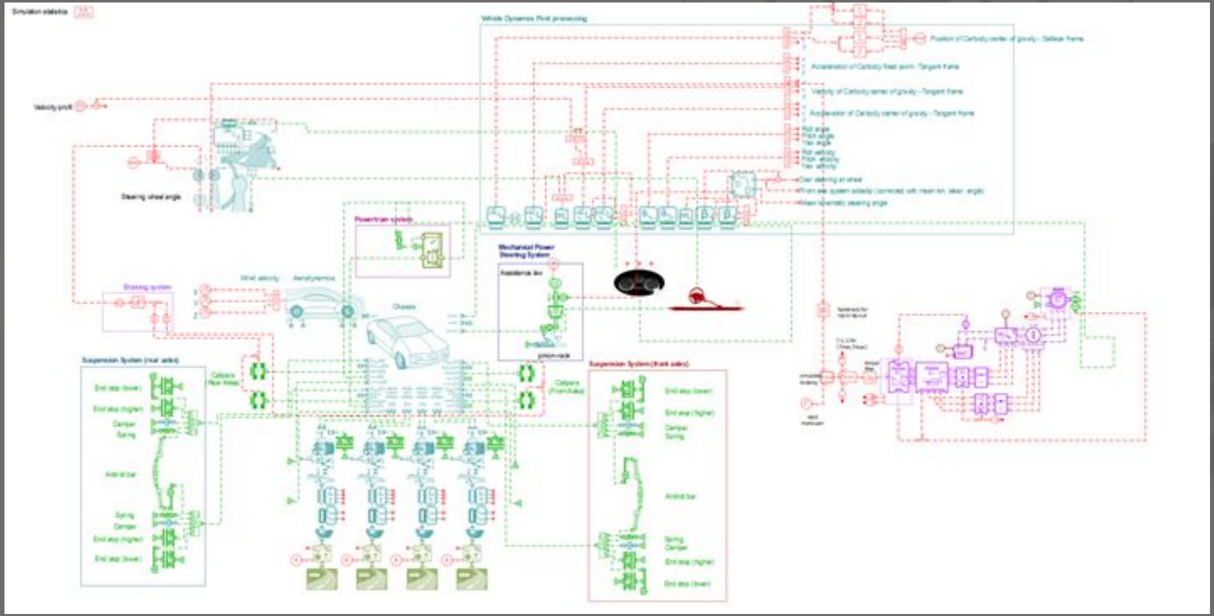
Assembly

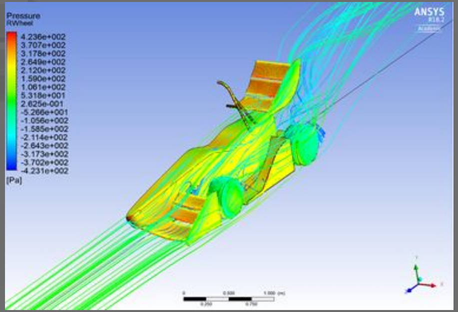
Testing

Adjustments

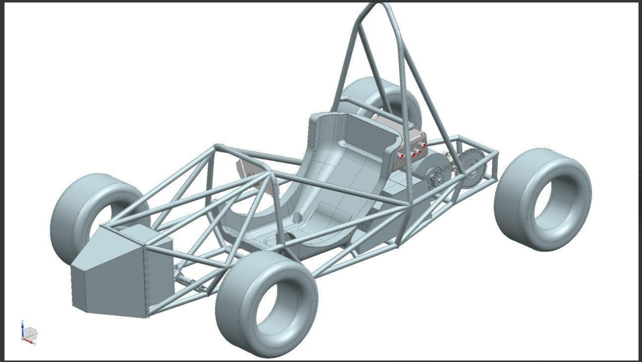
Racing

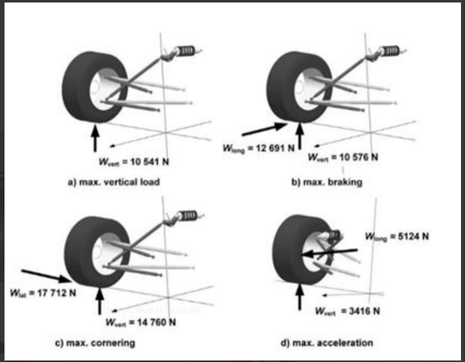
Introduction to PLM

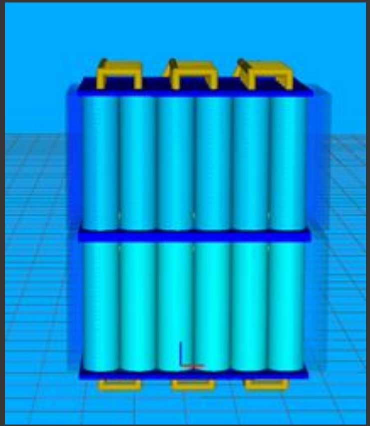


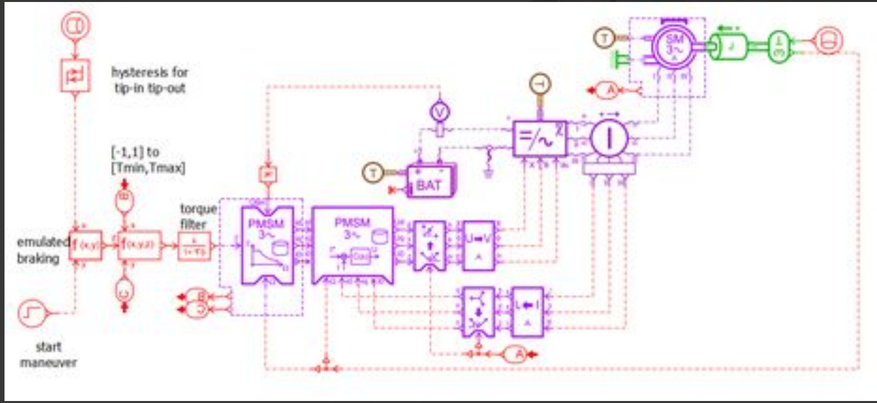


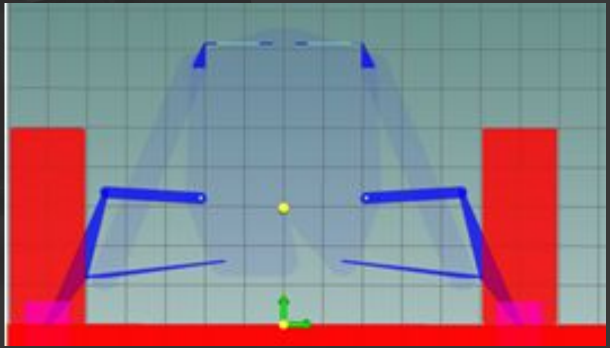
Advanced PLM







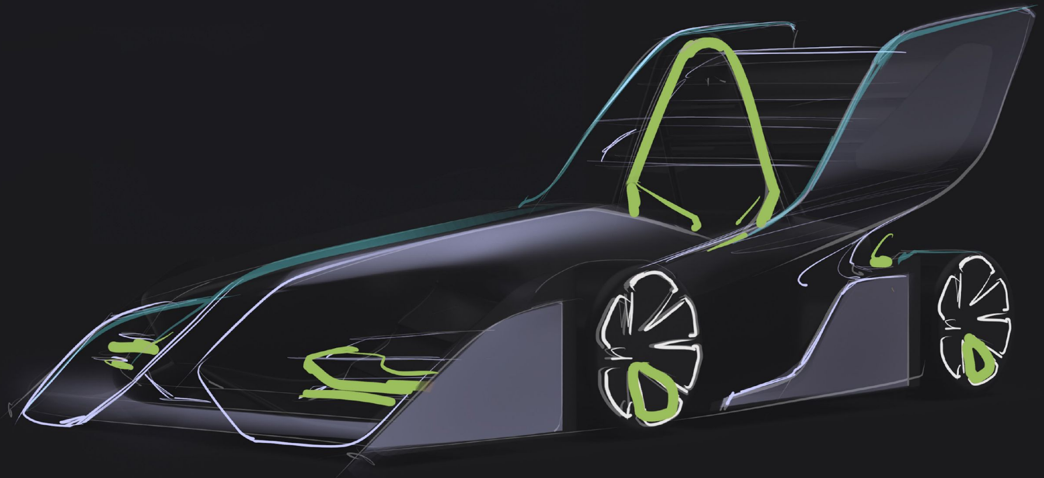




Highlights of today

- Possible designs
- Manufacturing plan
- Detailed design and preparation to manufacture:
  - Chassis
  - Powertrain supports
  - Electronics and energy storage
  - Car controls
  - Hub unit
- Verification system

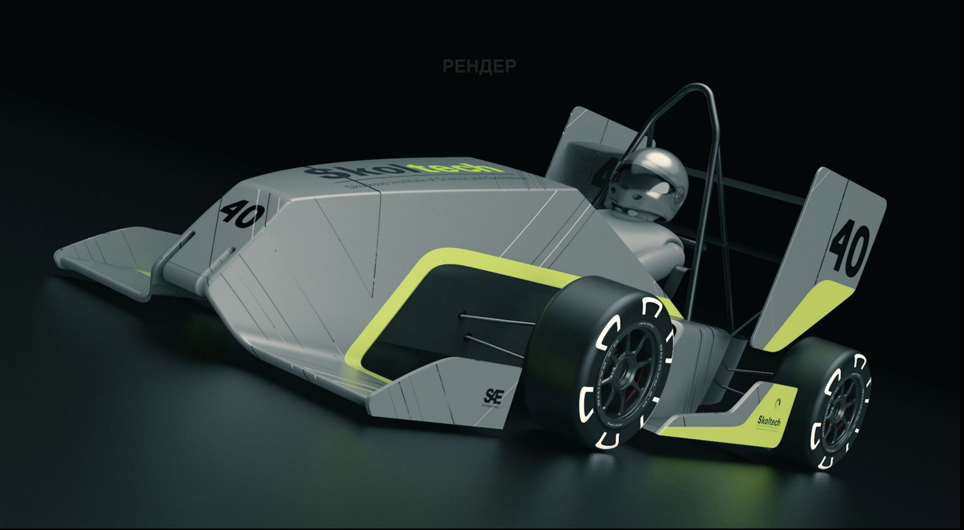
Initial design

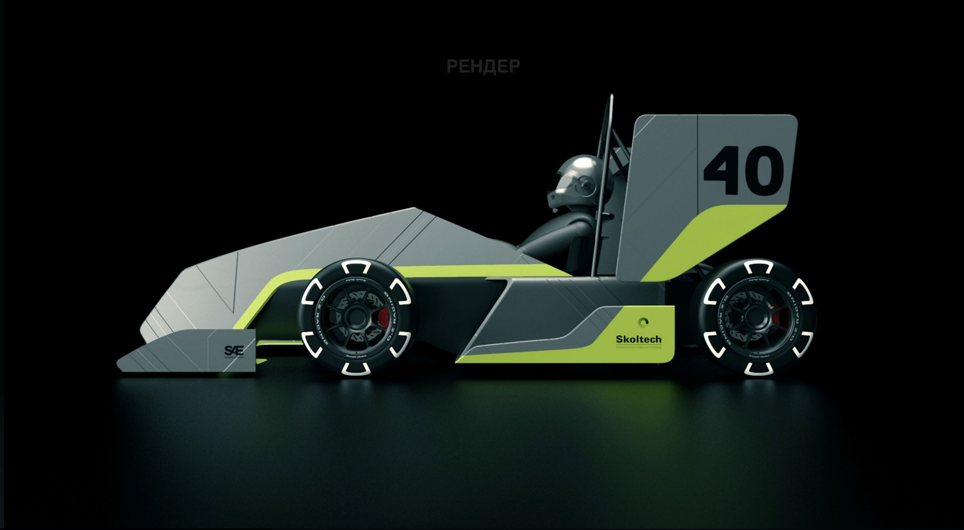


Collaborative design

Skoltech
Skolkovo Institute of Science and Technology

moscow polytech



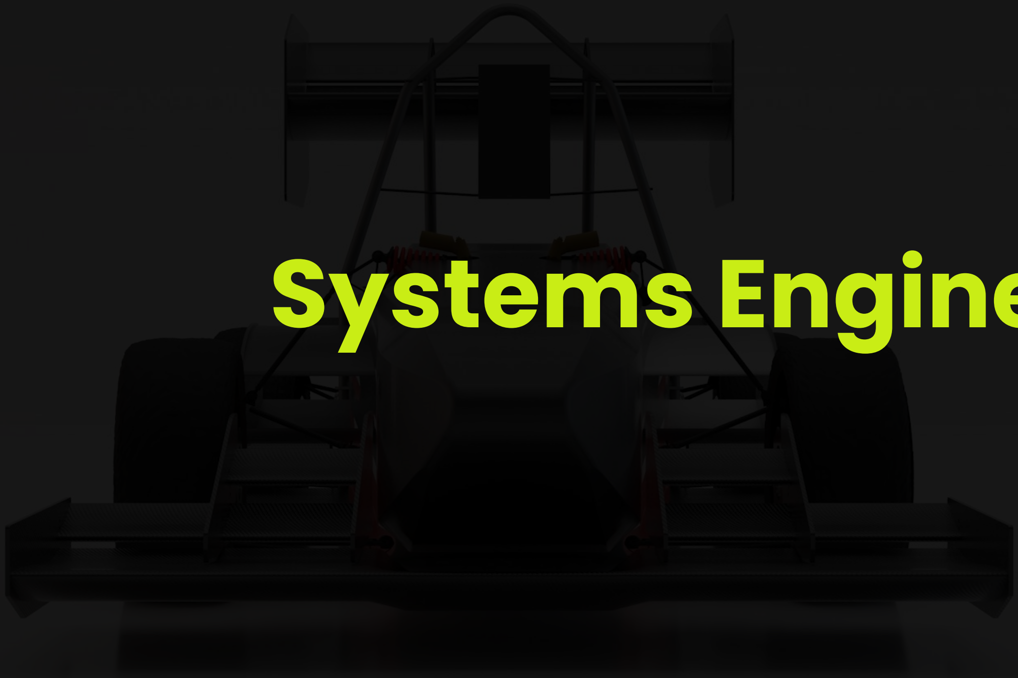


Timur Dautov

moscow polytech

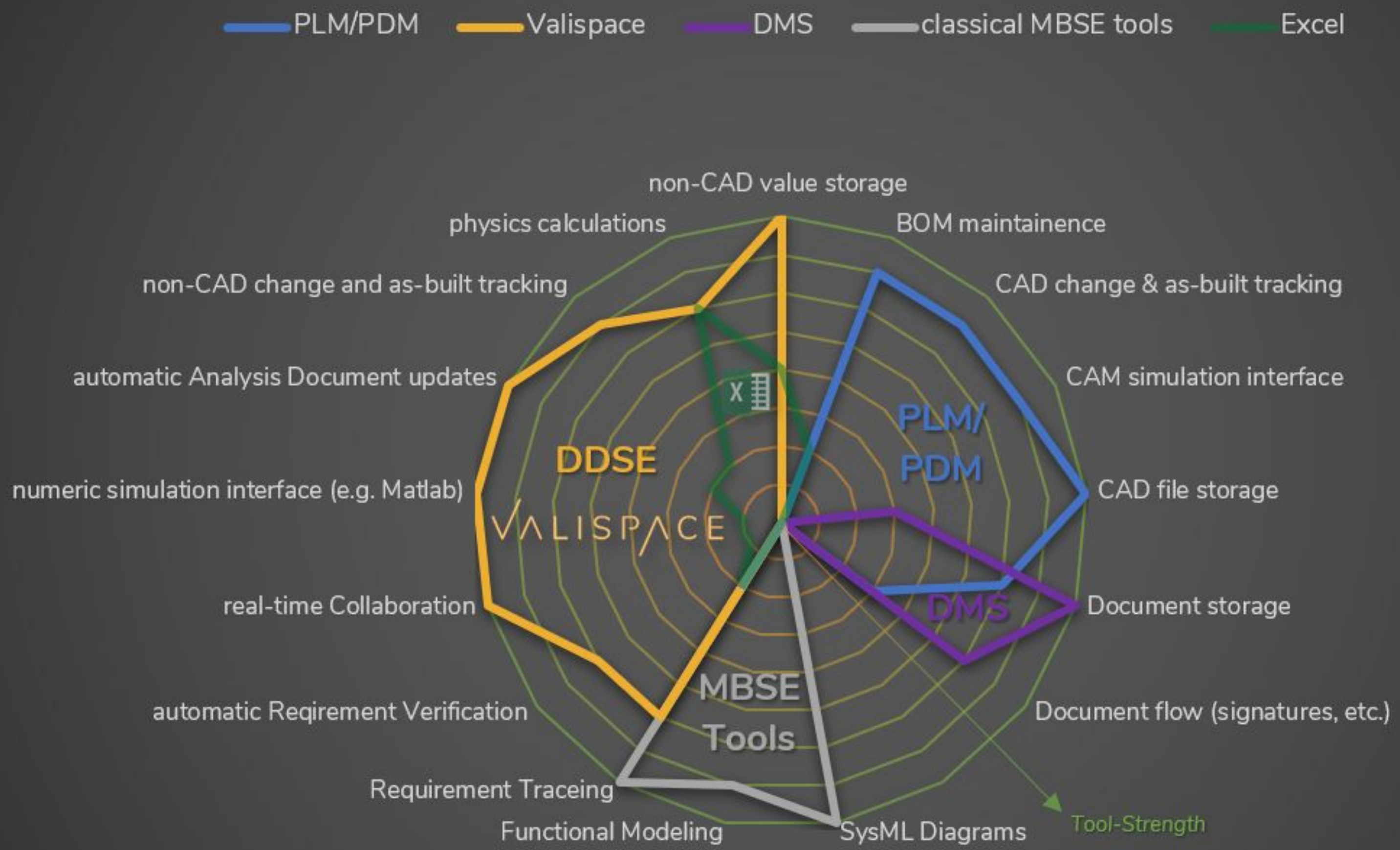
Arslanova L.

moscow
polytech



Systems Engineering

Tool Strengths and Complements



Products used:

TEAMCENTER

SIEMENS

SIEMENS NX

VALISPACE

SIMULIA Abaqus

Project

Excel

LOTUS

Google

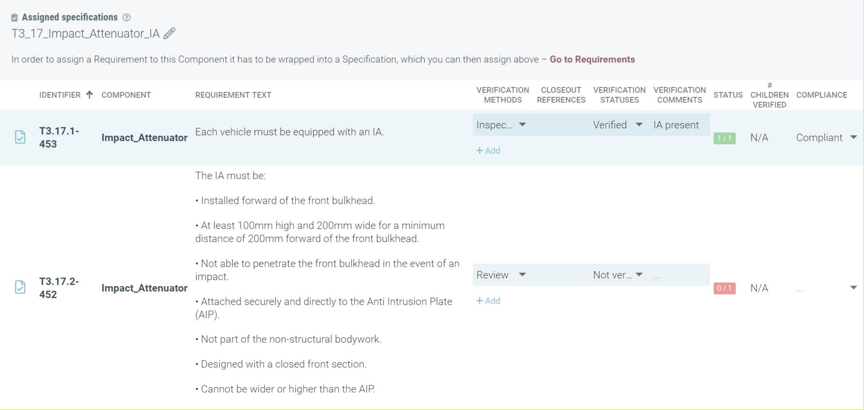
SOLIDWORKS

Versions control and verification

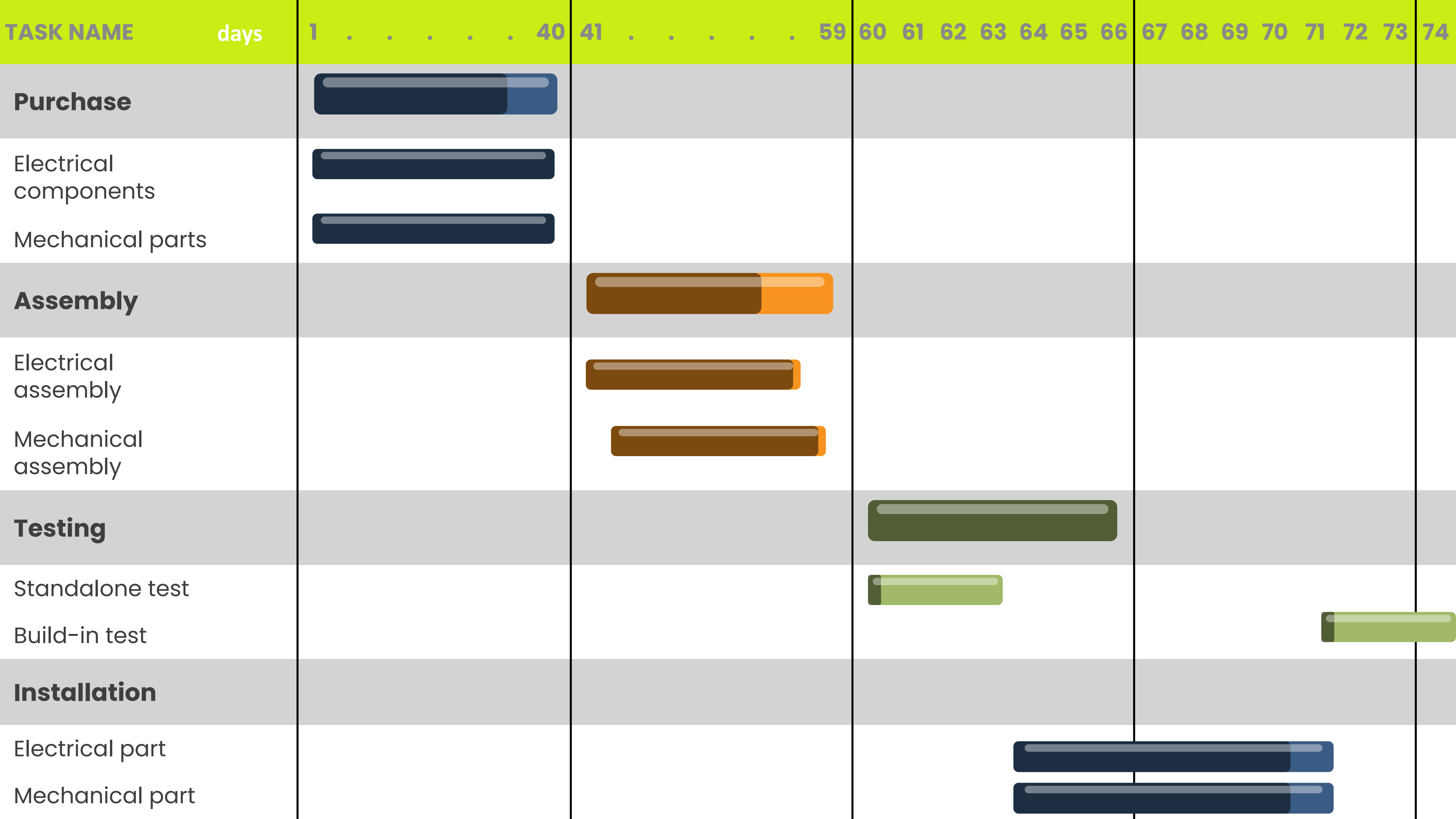
Modelling

PLM type organization

Verification



ValiSpace


TASK NAME
days
1 40
41 59
60 61 62 63 64 65 66
67 68 69 70 71 72 73
74
Purchase
Electrical components
Mechanical parts
Assembly
Electrical assembly
Mechanical assembly
Testing
Standalone test
Build-in test
Installation
Electrical part
Mechanical part

Manufacturing plan

- More than 120 tasks and sub-tasks
- 6 month - required time
- More than 2 200 man-hours required
- 350 man-hour for testing
- 30 people team

Budget estimates*

Car part	Costs, rubs
Chassis	279 026 ₽
Powertrain	2 148 576 ₽
Bodyframe	1 026 000 ₽
Brake system	278 625 ₽
Steering system	855 633 ₽
Suspension	1 498 396 ₽
	≈6 000 000 ₽

*only manufacturing included

Components

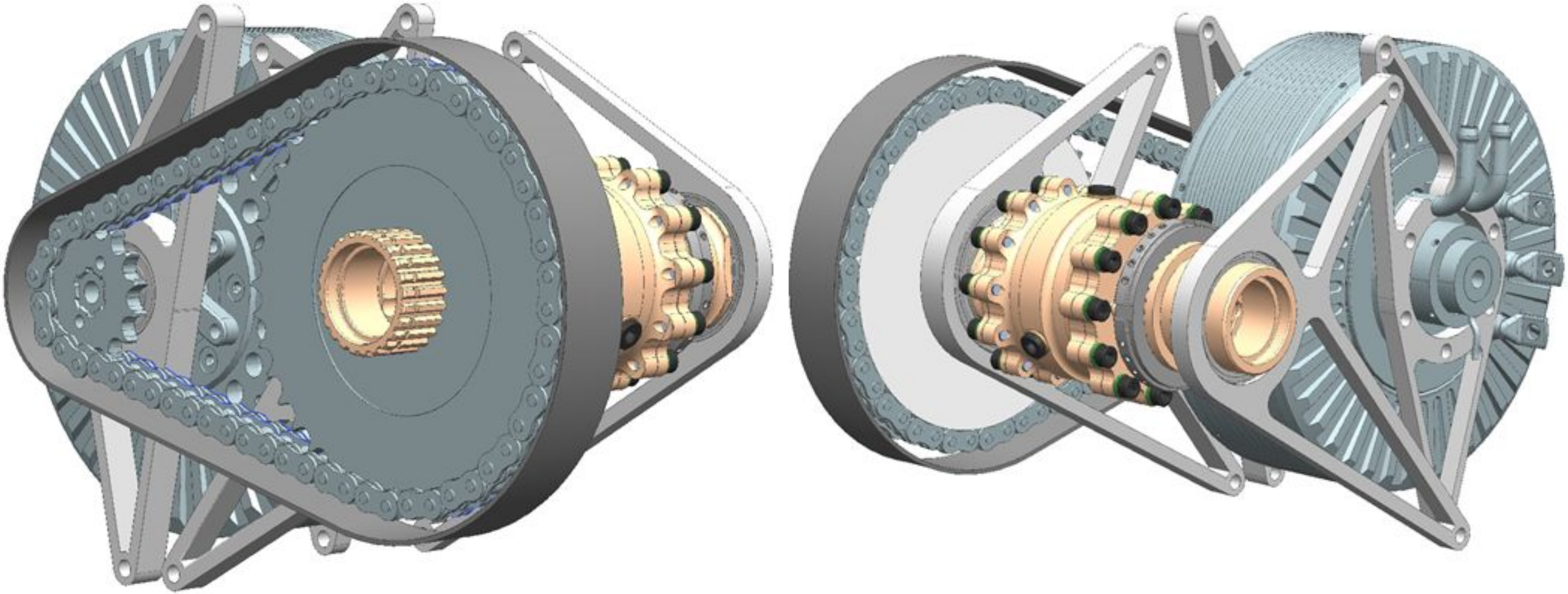
Overall look

Body Kit Parts

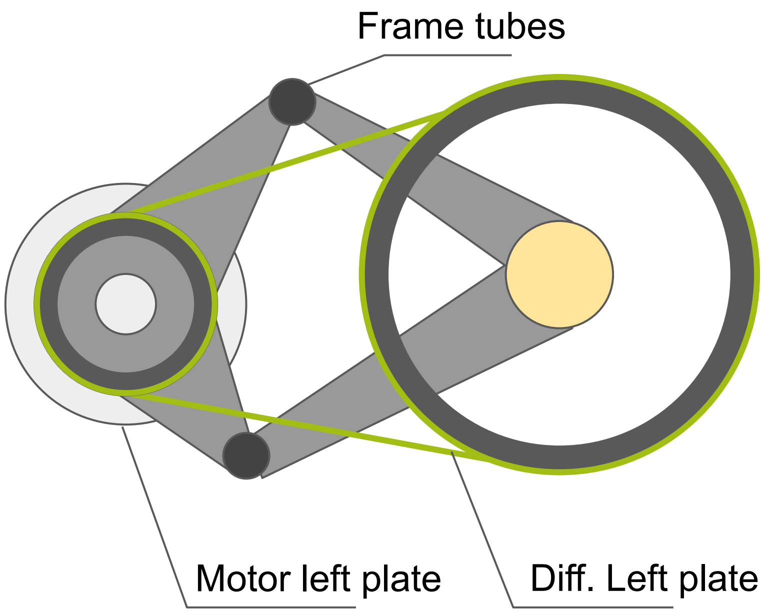
Overall look

Inner assembly

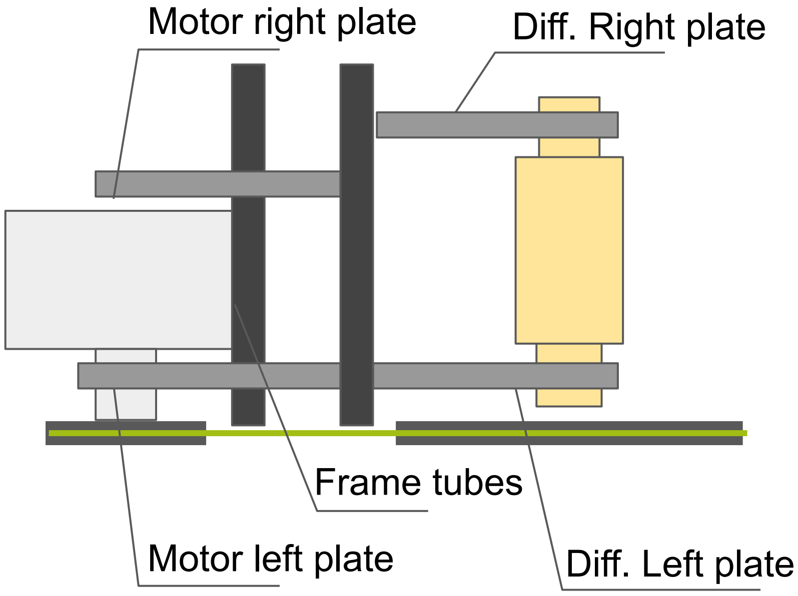
Powertrain



Transmission Scheme

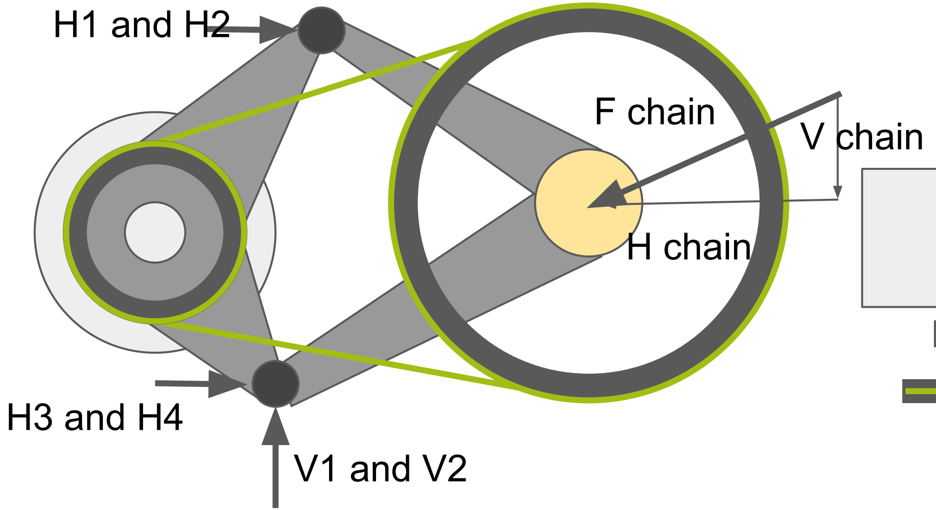


Side View

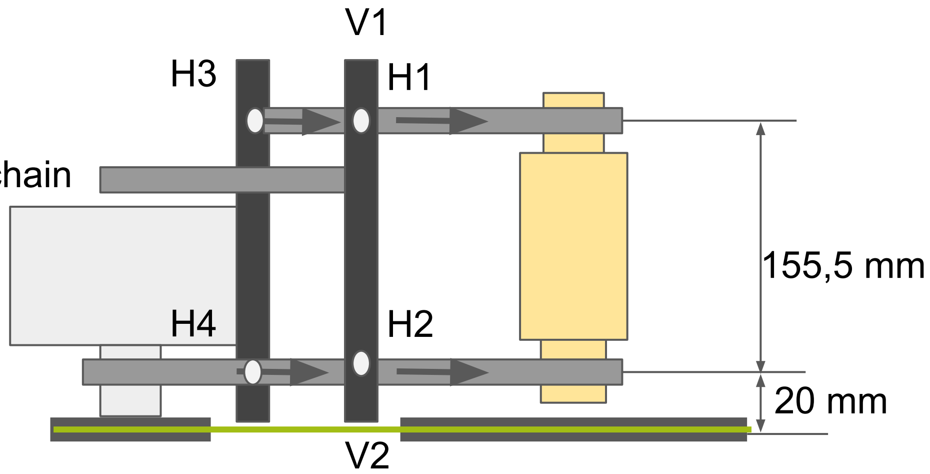


Top View

Transmission Scheme

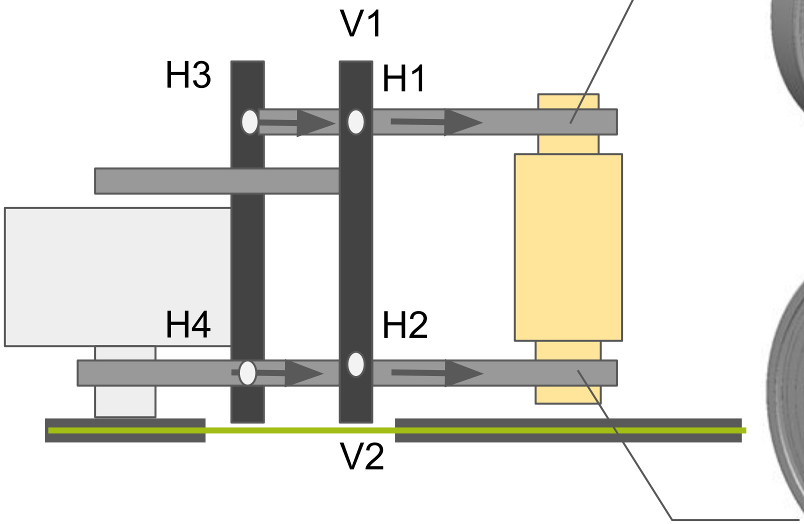


Side View



Top View

Bearings



61810-2RZ:

- Dimensions: 50x65x7 mm;
- Mass: 0,053 kg;
- Limiting speed: 10000 r/min;
- Basic dynamic load rating C: 6.76 kN;
- Basic static load rating C0: 6,8 kN.

Bearing 1 calculated load: 1,2 kN

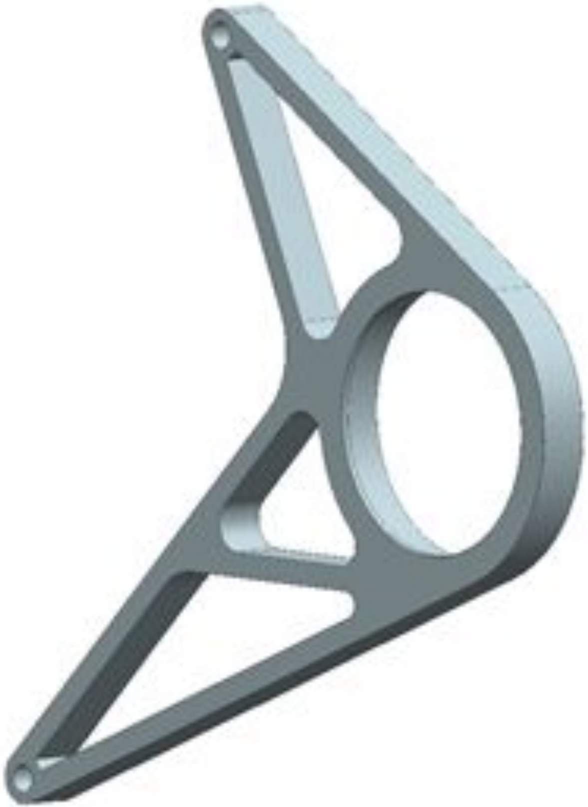
61911-2RZ:

- Dimensions: 55x80x13 mm;
- Mass: 0,19 kg;
- Limiting speed: 8500 r/min;
- Basic dynamic load rating C:16.5 kN;
- Basic static load rating C0: 14 kN.

Bearing 2 calculated load: 11 kN

Geometry

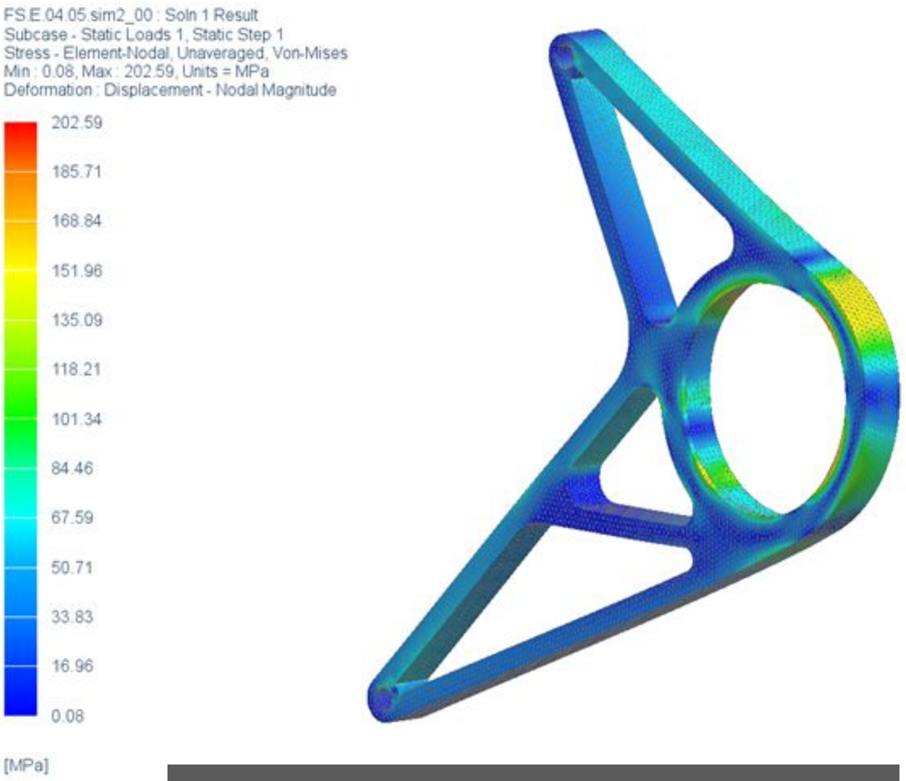
Selected material: D16T (duralumin) analog - 2024 T3511
Density: 2,78 g/cm3
Yield strength: 300 MPa
Young`s Modulus: 6900 kg/mm2



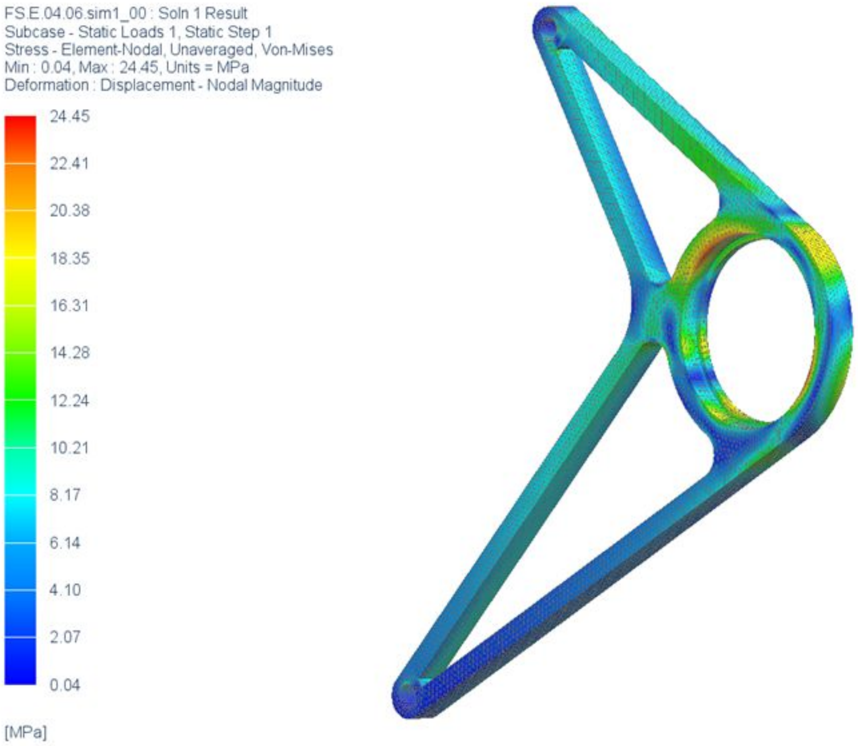
Mass: 0.3 kg

Mass: 0.177 kg

FEA analysis

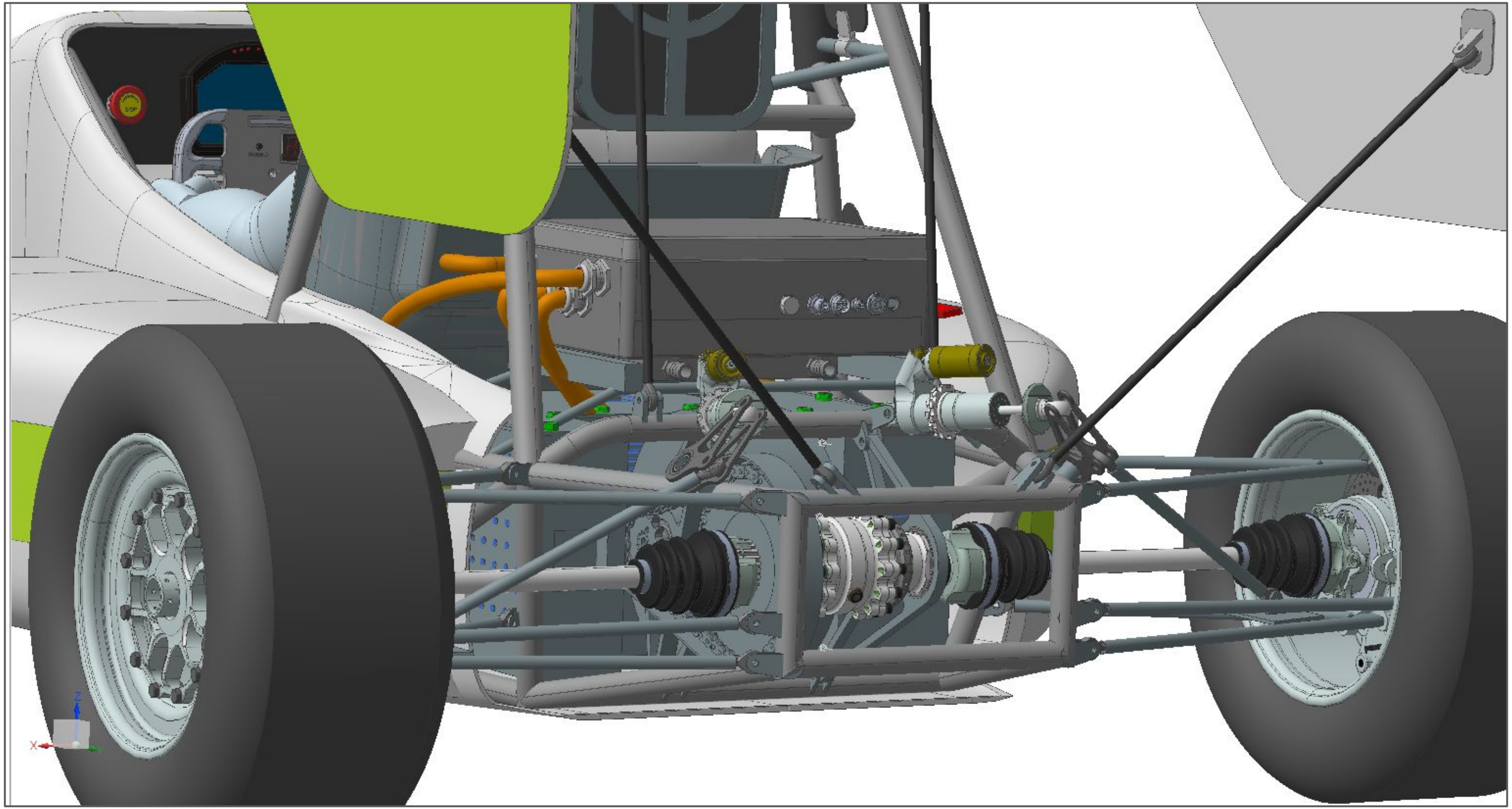


FoS: 1,6

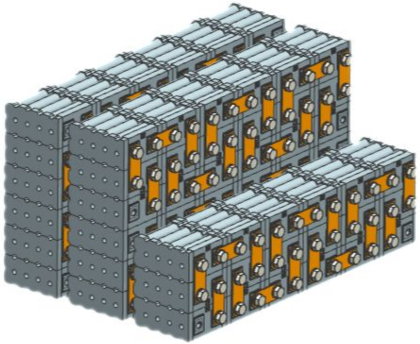


FoS: 15

Preallocation of elements

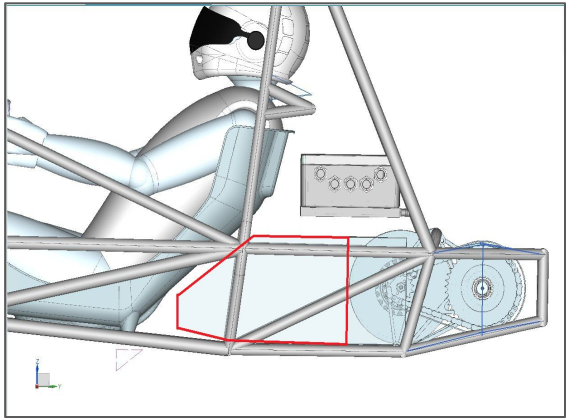


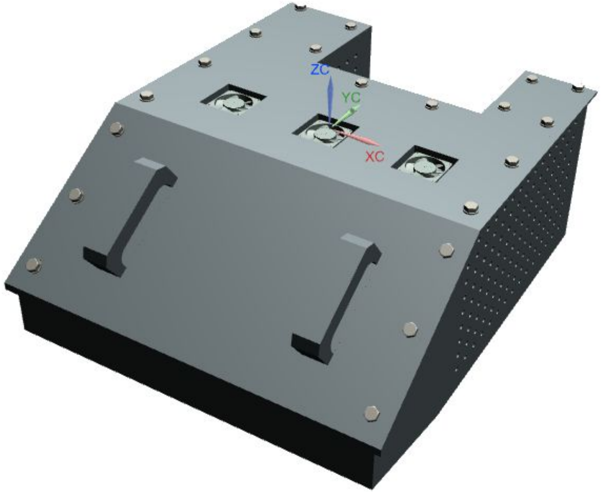
Battery layout and cooling components

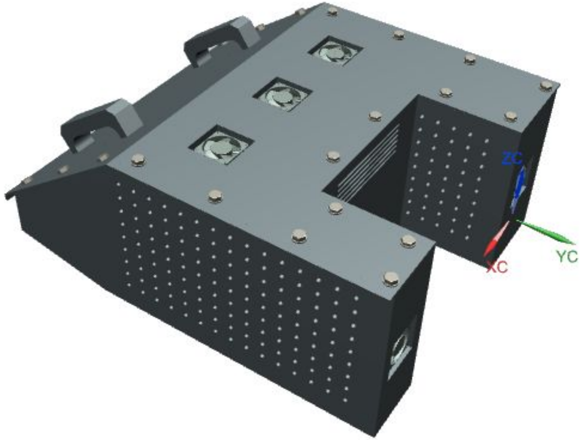


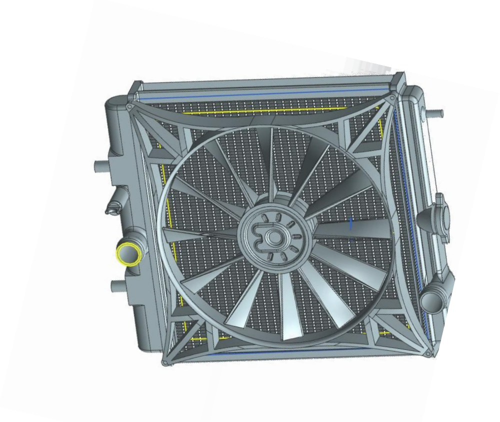
Size

Length : 290 mm
Height : 240 mm
Width : 425 mm









Battery CFD Analysis

Velocity of air inlet = 1.4, CFM

Power = 40, W

Heat transfer coefficient = 30, W/m K

Thermal conductivity = 0.66, W/m K

Specific heat = 740, J/kg K

Density = 2.3E-9, kg/ m3

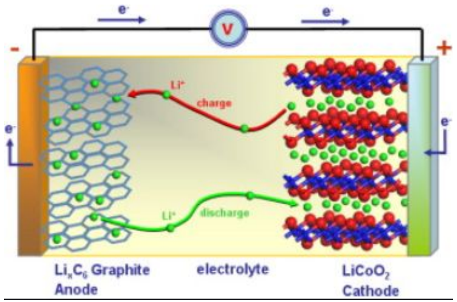
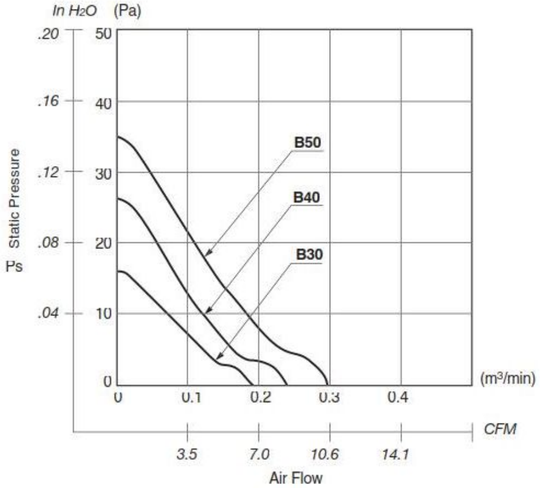


Table 4 Thermophysical properties of (a) $LiCoO_2$ and (b) $LiMn_2O_4$ cathode materials: available literature data and results from this study. Thickness of the material, when reported, is also included. In all the references, aluminium describes the current collector

Material/method	Specific heat ($J\ g^{-1}\ K^{-1}$)	Thermal diffusivity × 10^6 ($m^2\ s^{-1}$)	Density × 10^{-6} ($g\ m^{-3}$)	Thermal conductivity ($W\ m^{-1}\ K^{-1}$)	Thickness × 10^6 (m)	Ref.
(a)						
Cathode (wet)/manufacturer	1.1738	0.6021^a	2.6175	1.85	109.224	29
Cathode (wet)/estimated	0.849	0.541^a	2.81	1.29	—	30
Cathode (wet)/measured	1.2692	0.5346^a	2.3285	1.58	—	31
Cathode (probably dry)/measured	0.601	1.24	3.115	2.33	185	33
Composite (wet)/estimated	1.134	0.658^a	2.92	2.18	190	32
$LiCoO_2$ thin film/measured	0.73	—	—	5.4	0.5	38
$LiCoO_2$ in composite/estimated	0.7	0.846^a	2.5	1.48	92	37
Electrolyte ($LiPF_6$/EC + DMC + DEC)/—	*0.1339*	2.6	1.29	0.45	—	37
Aluminium/measured	0.897	97.2	2.7	237	—	19 and 25
Cathode (dry)/measured	0.77 ± 0.02	0.44 ± 0.02	2.34 ± 0.03	0.79 ± 0.06^a	110	This study
Composite (dry)/estimated	0.74 ± 0.02	0.39 ± 0.02	2.29 ± 0.02	0.66 ± 0.05^a	95	This study
(b)						
Cathode (probably dry) + Al/estimated	0.713	4.108^a	2.81	8.23	200	34 and 35
Composite (probably dry)/estimated	0.7	1.2^a	2.5	2.1	80	46 and 47
Composite (dry)/estimated	0.7	4.8^a	1.5	5	190	40–45
Composite (probably dry)/estimated	1.321	0.473^a	2.37	1.48	180	48
Composite (probably dry)/estimated	1.043	1.034^a	2.317	2.5	183	49
$LiMn_2O_4$ pellet/measured	—	94	—	—	—	39
Cathode (dry)/measured	0.83 ± 0.02	0.23 ± 0.01	1.73 ± 0.02	0.32 ± 0.02^a	160	This study
Composite (dry)/estimated	0.81 ± 0.02	0.22 ± 0.02	1.63 ± 0.02	0.29 ± 0.02^a	145	This study

"—": stands for "not specified".[a] Calculated using relation (3), with $\alpha(T) = \lambda(T)/(c_p(T)\cdot\rho(T))$, where $\lambda(T)$, $c_p(T)$ and $\rho(T)$ were taken from the respective reference data.



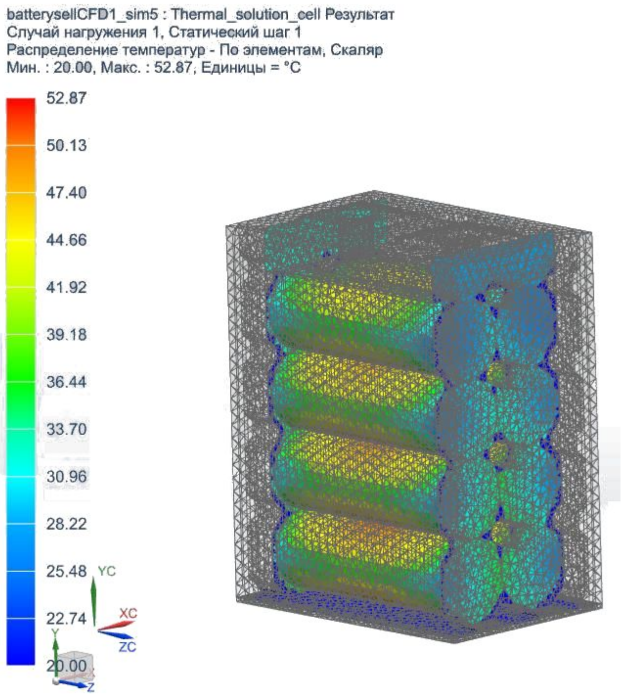
$$\Delta P = \rho \frac{\mu \cdot l * v^2}{2d} = 1{,}2 \frac{0{,}38 \cdot 0{,}45 * 1{,}42^2}{2 * 0{,}006} = 28{,}7\ Pa$$

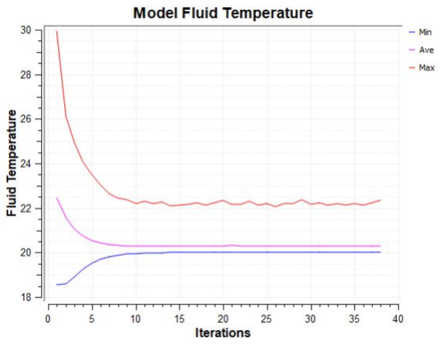
Initial data

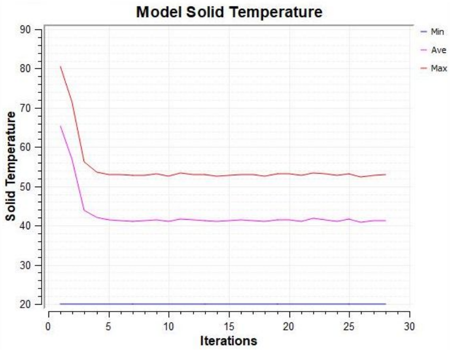
Battery material

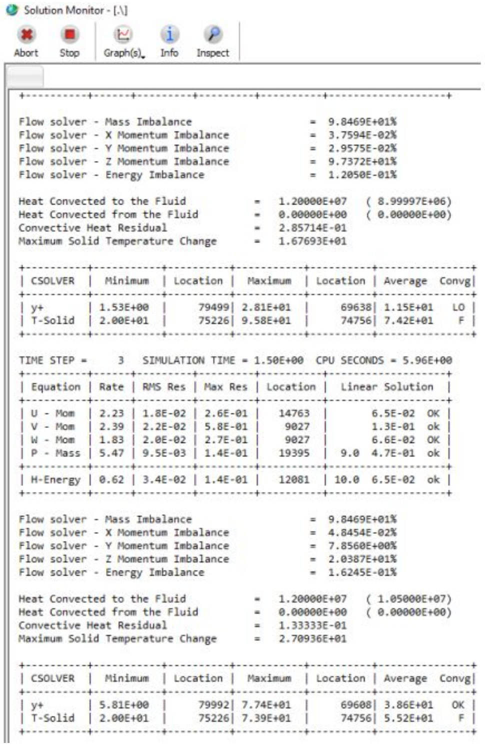
Pressure drops

Battery CFD Analysis

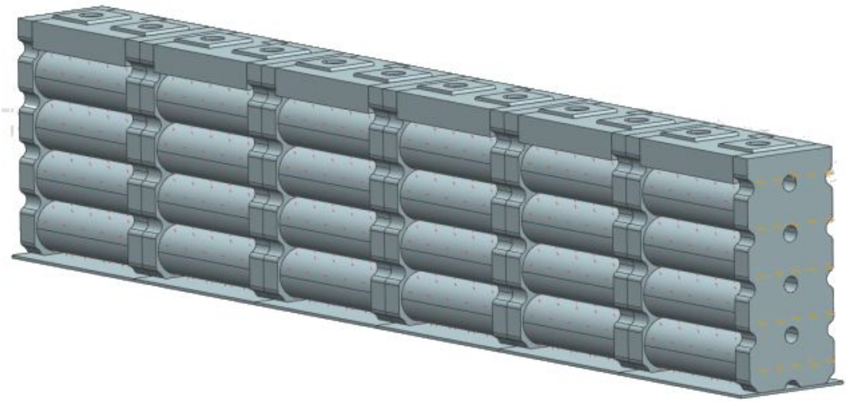




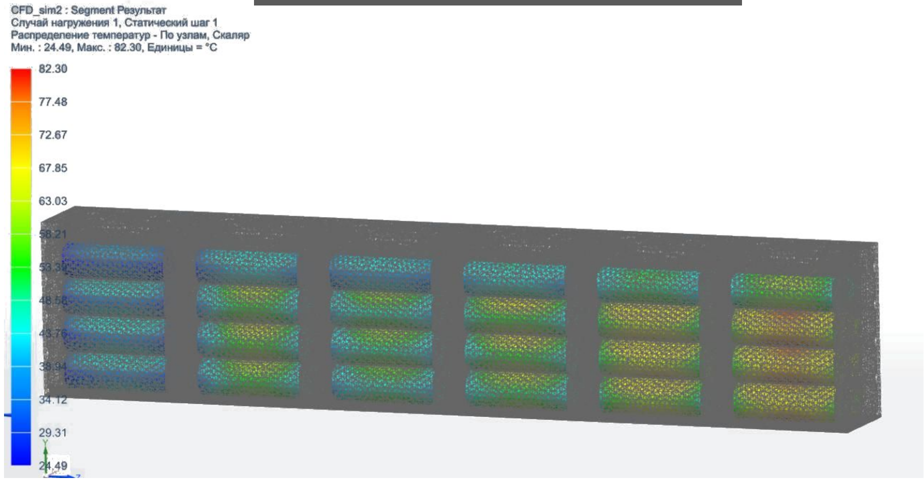




Battery CFD Analysis

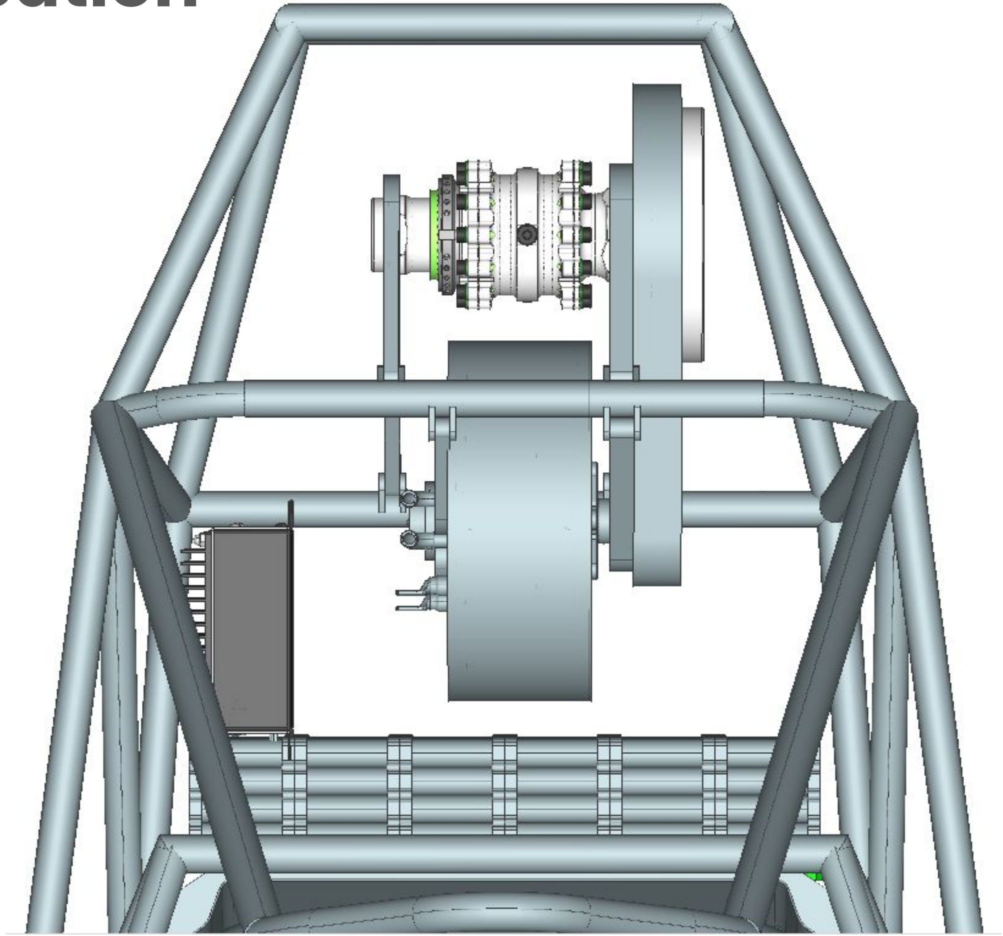


The most loaded area

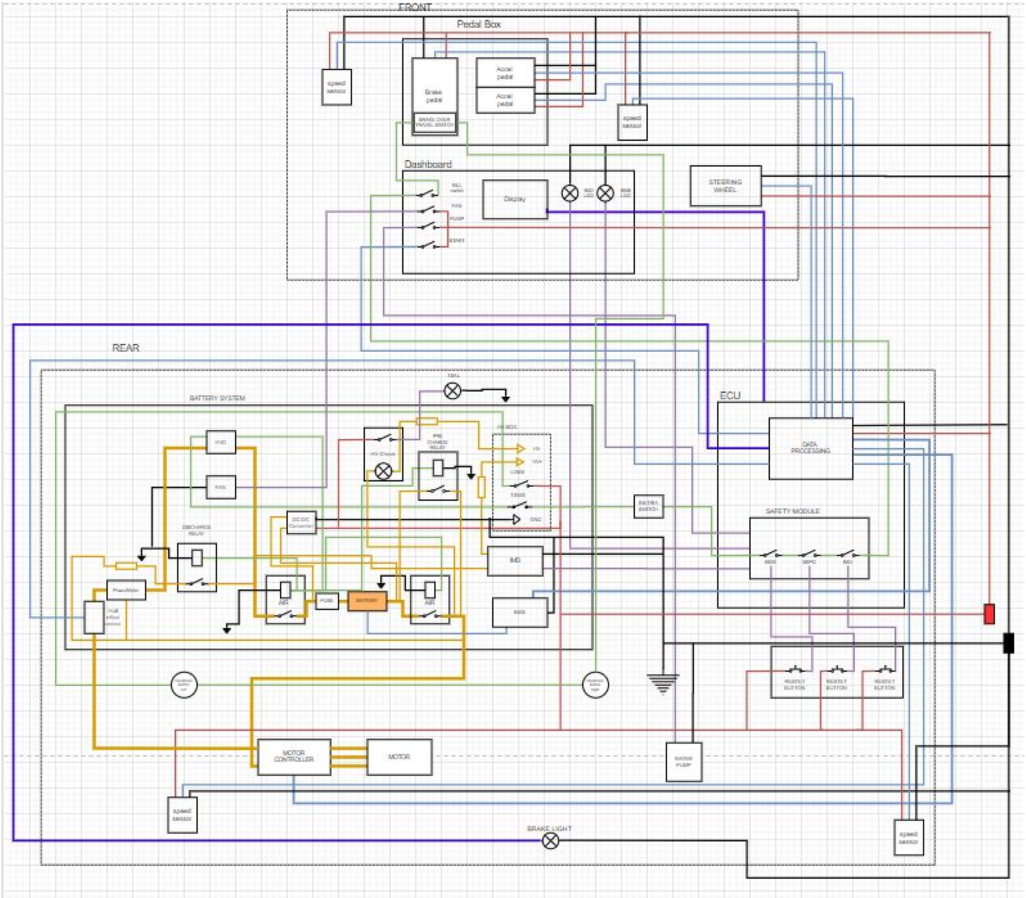


We have 4 battery cell in length

Battery location



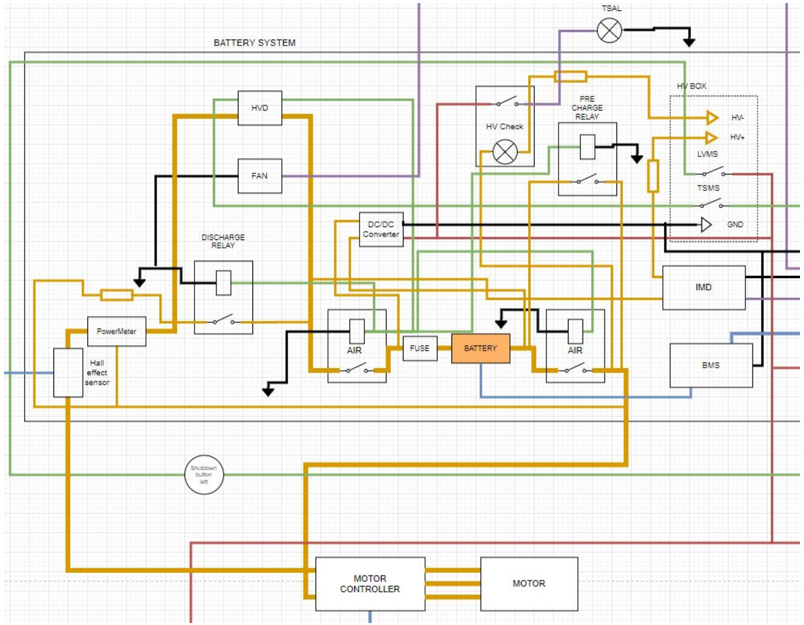
Wiring



Full car wiring:
-Low voltage circuits
-High voltage circuits
-safety circuits
-Logic inputs/outputs

All of the components are thought through and selected

Full powertrain



Emrax 228
109kW motor

Bamocar d3
motor
controller

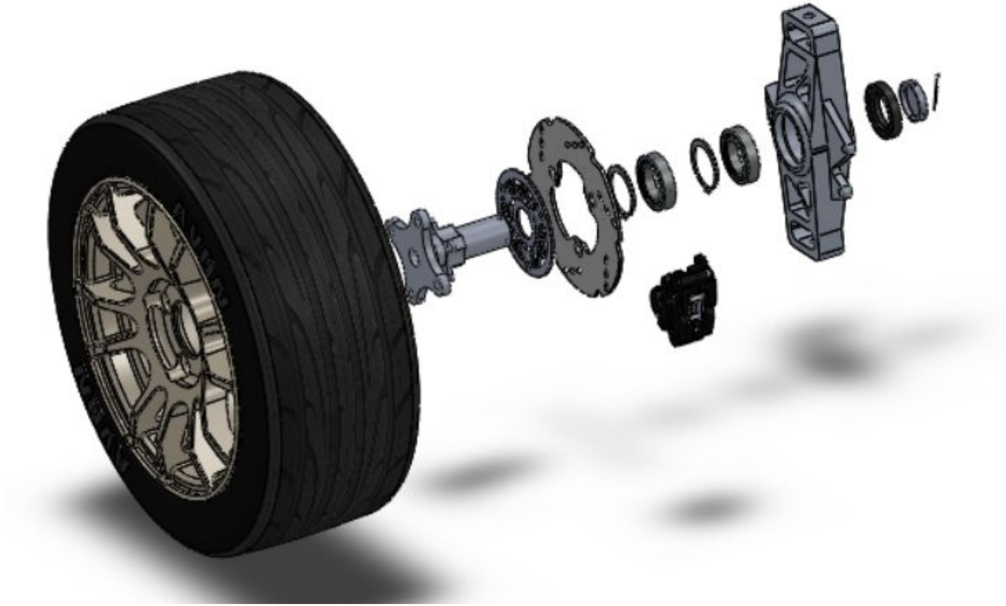
Orion BMS 2
Cell balancing
Cell monitoring

4 segments 24s7p
Total voltage 344V
Total capacity 6kWh
Mass w/o container 34kg

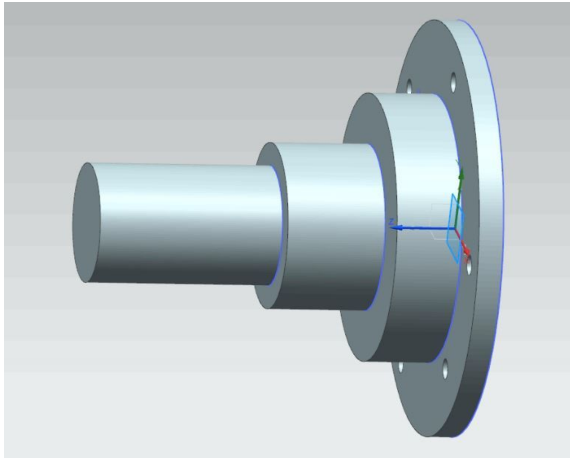
Mechanism of Up-Right part and Wheelhub system

This whole assembly is linking

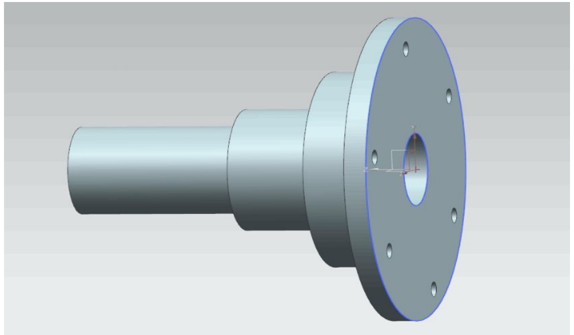
suspension system with front-wheel

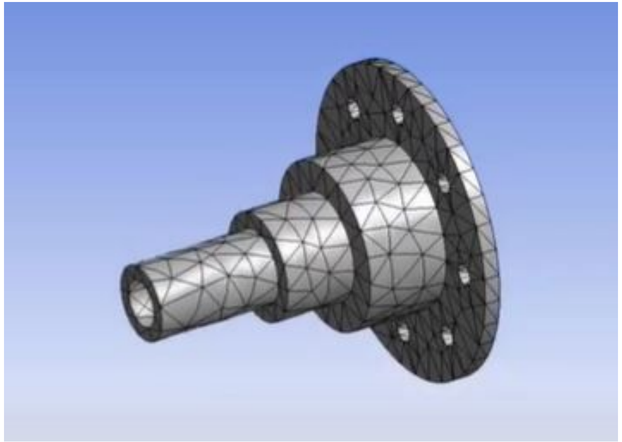


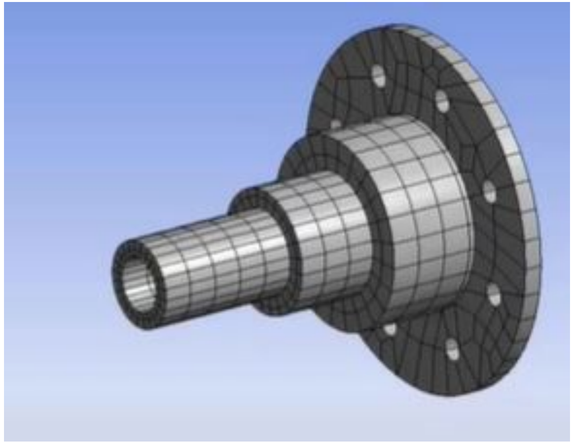
3-D model of wheel hub



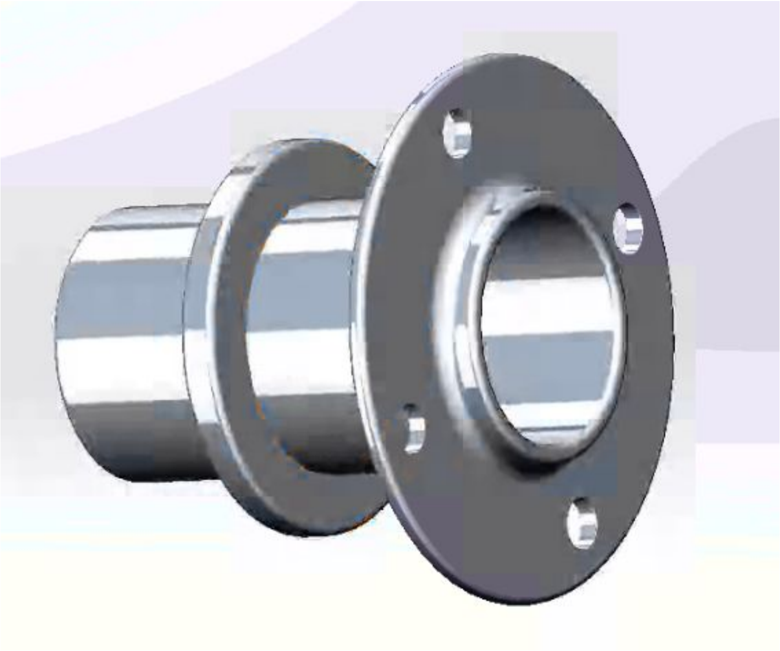
1. This model has been made in NX software.
2. For simulation, model is kept simple. Thread and external notches are not considered.

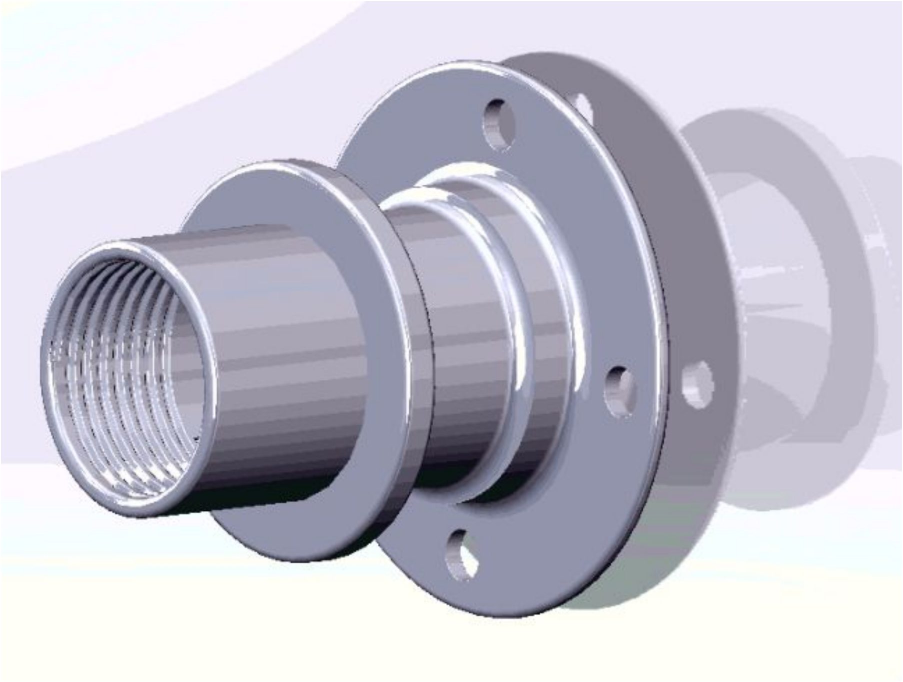






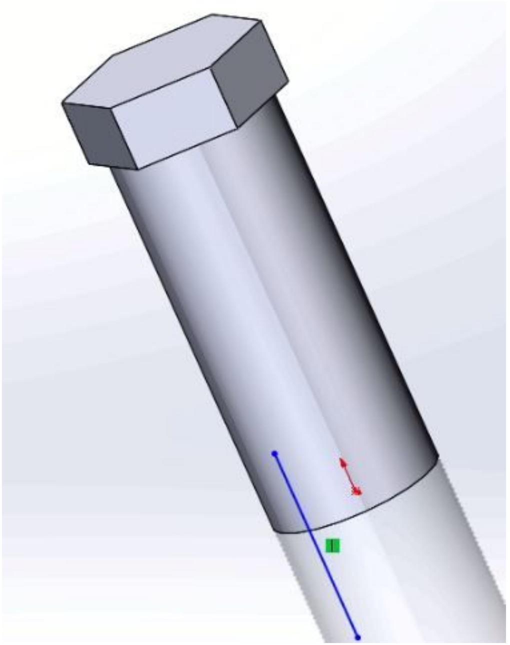
Final Model of wheelhub system

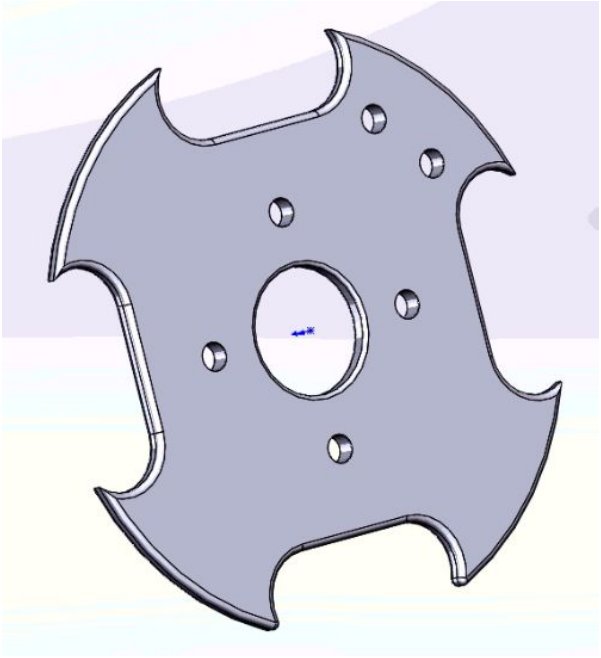




Disc-brake supporter

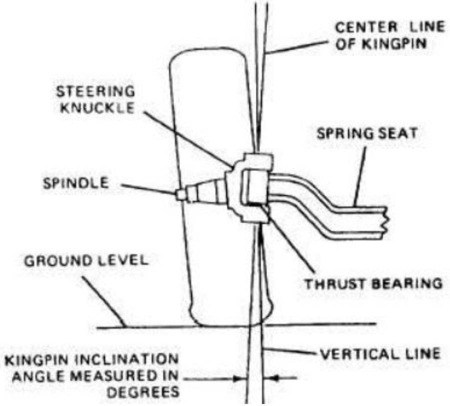
Breaking system will be attached to the plate.

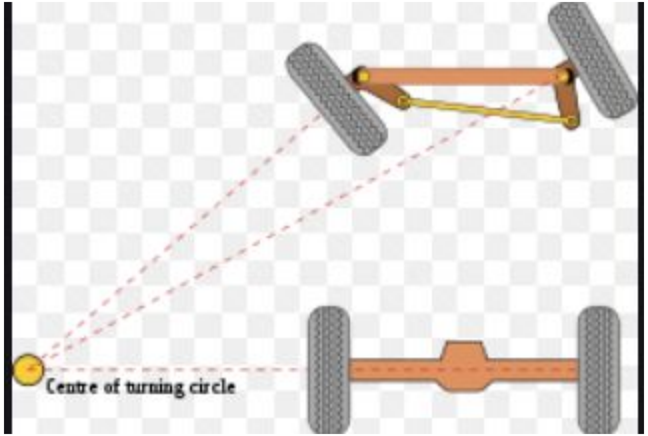




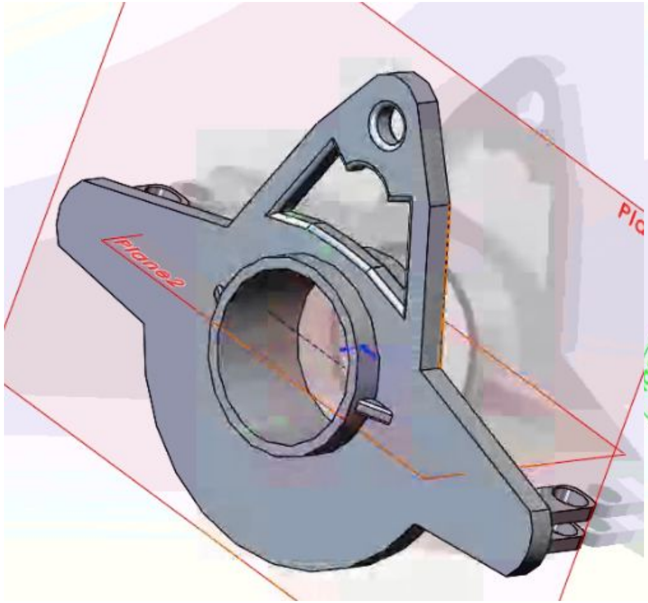
Calculations require to design Up-Right part

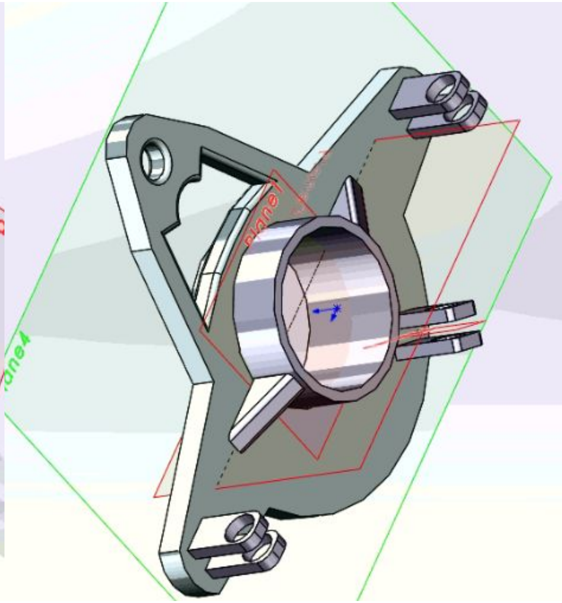
1. Distance between upper and lower mounting point of suspension system.
2. Kingpin angle.
3. Caster angle.

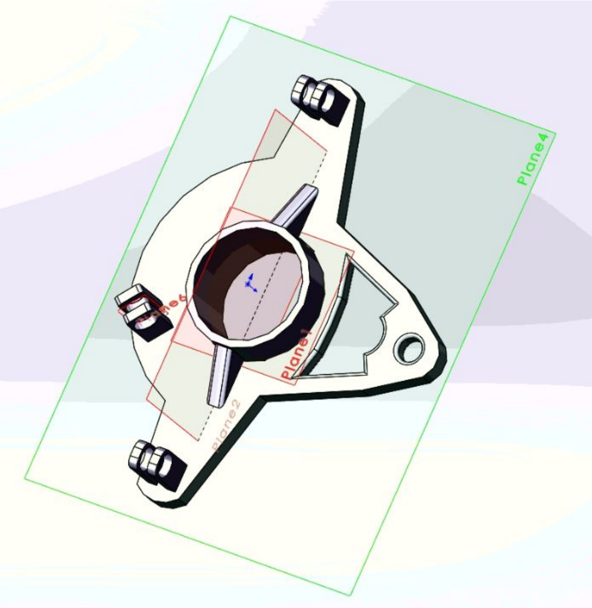




Up-Right part

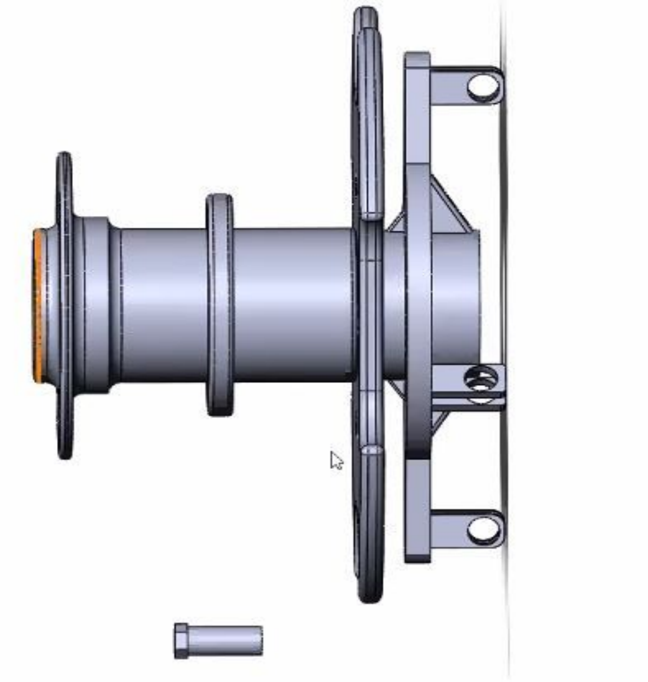


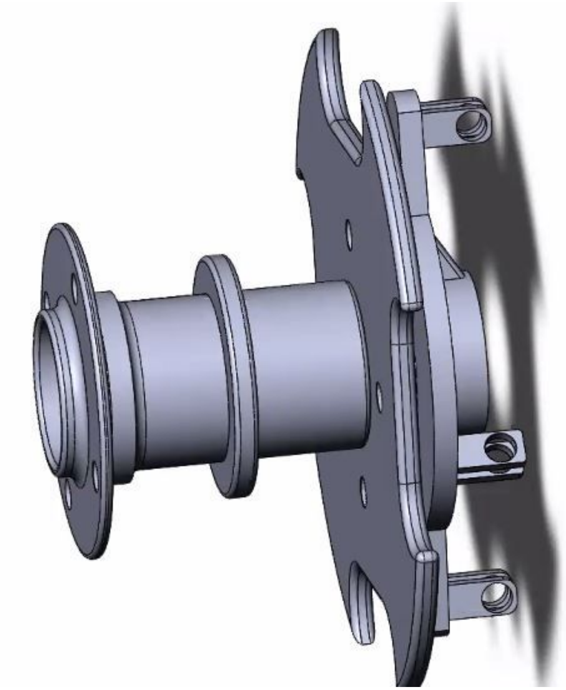




Assembly

This is how the assembly
look like.

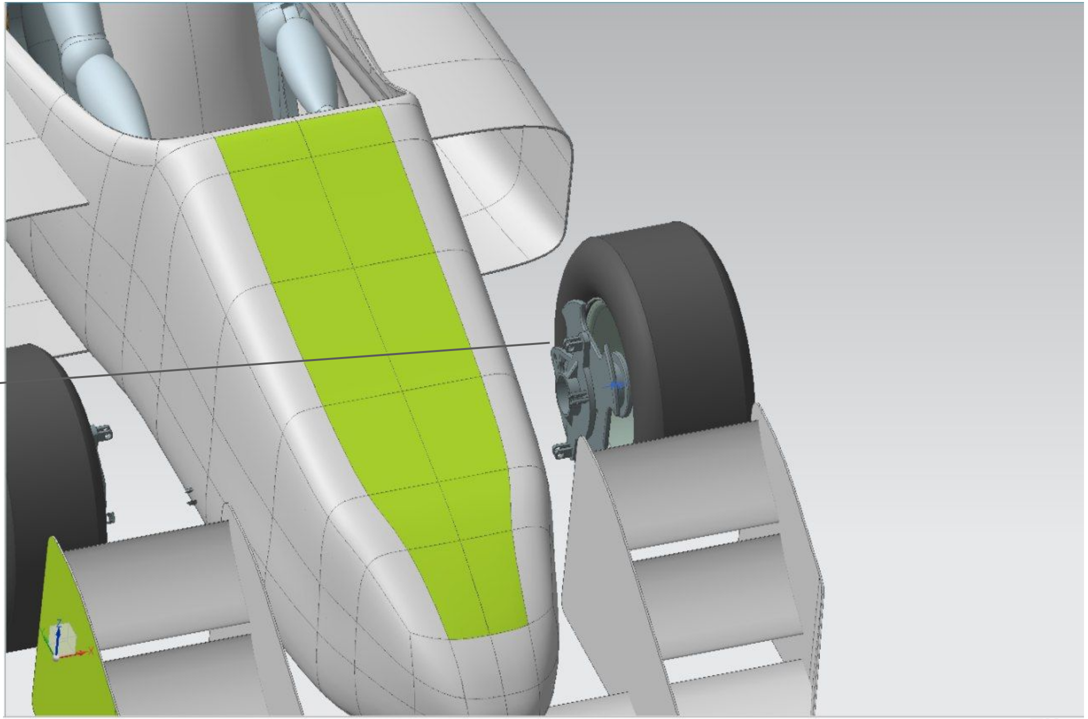




Inserting assembly in car

System has been successfully installed

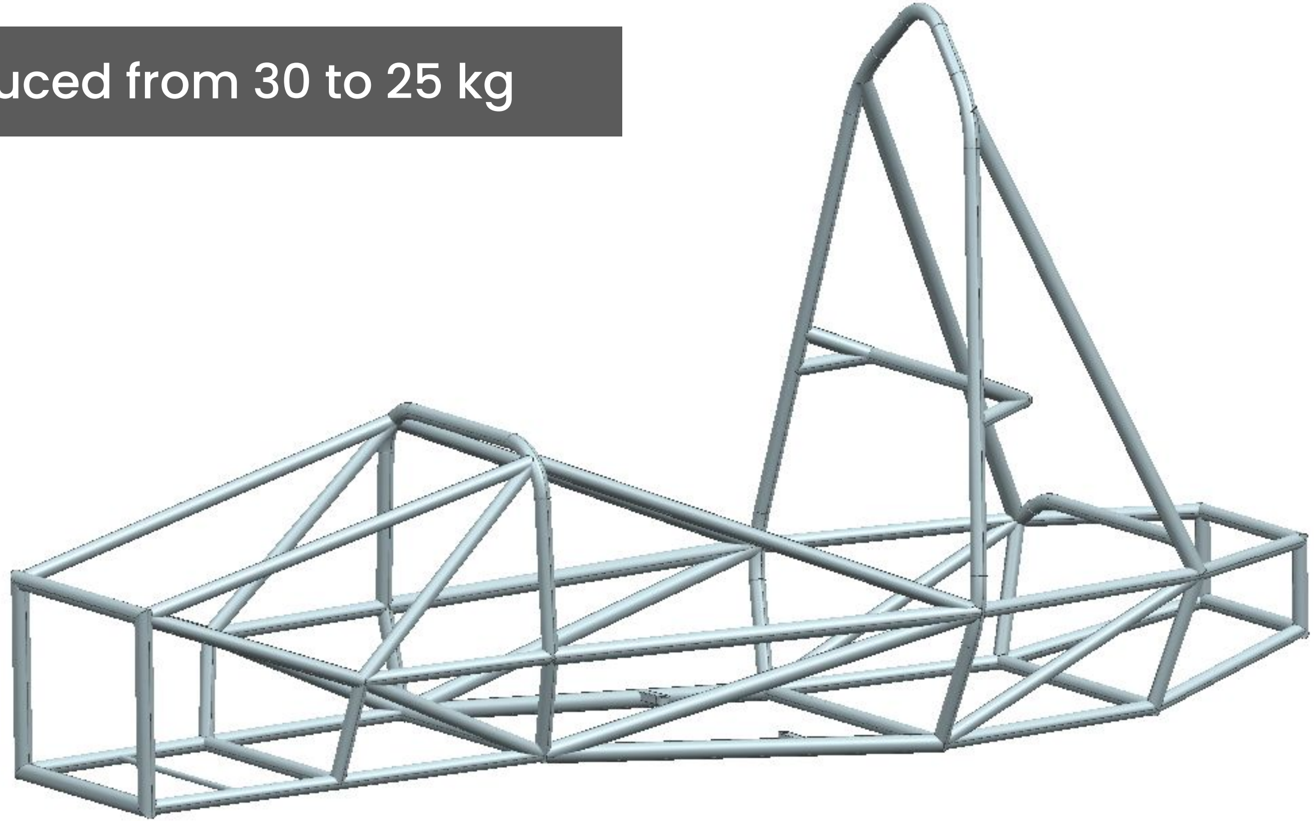
Wheelhub and upright assembly



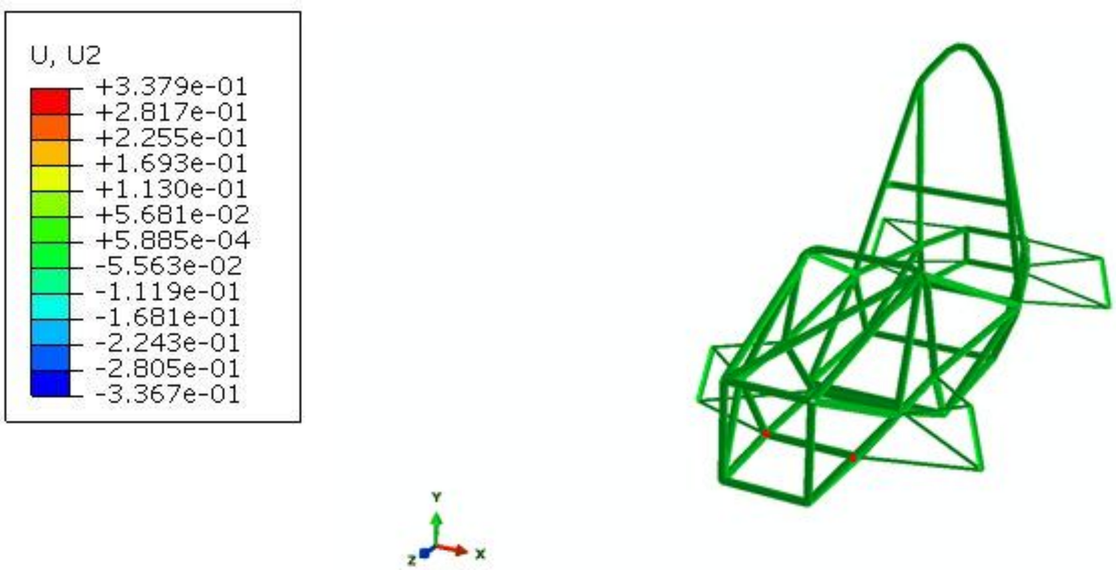
Strength analysis

Frame

Mass reduced from 30 to 25 kg

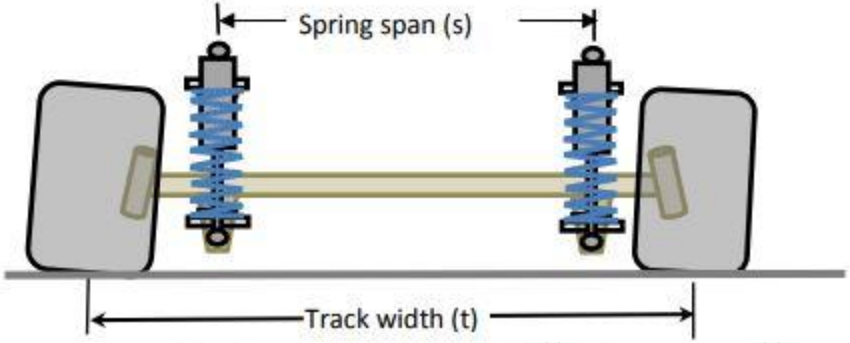


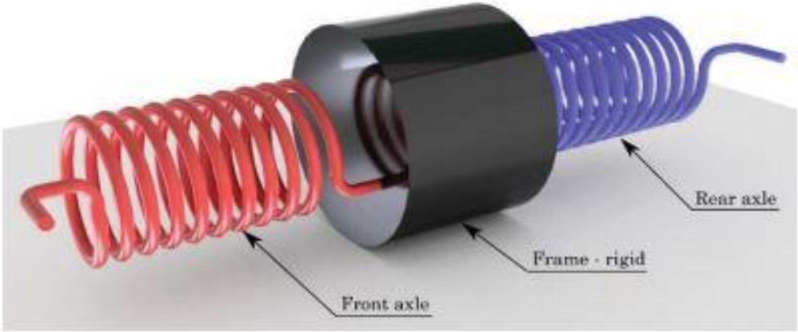
Torsional stiffness of the frame



Torsional stiffness	$C_T = \frac{T}{\theta}\left[\frac{Nm}{deg}\right] = 940\left[\frac{Nm}{deg}\right]$

Roll stiffness of suspension





Roll stiffness of each wheel axle

$$C_{axle} = \frac{TS^2 \boxed{K_{dumper}}}{1375} \left[\frac{Nm}{deg}\right]$$

Overall roll stiffness

$$C_{roll} = \frac{1}{\frac{1}{C_{rear}} + \frac{1}{C_{front}}}$$

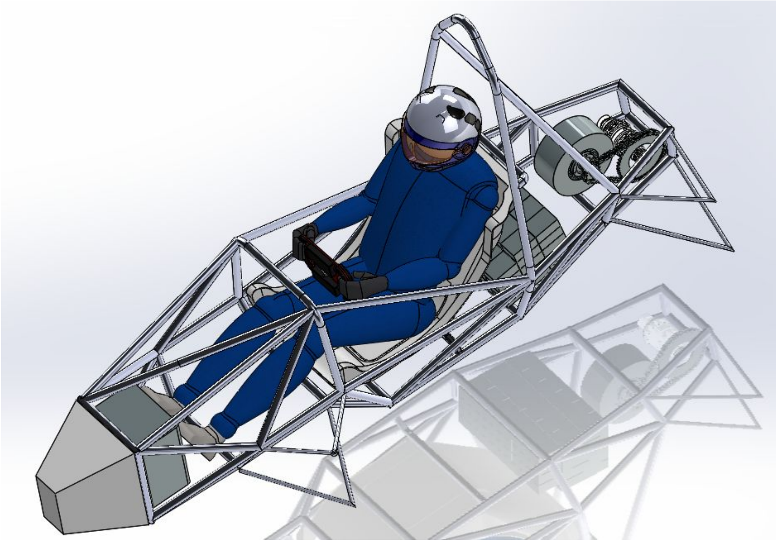
Analysis of results
Optimal selection of dumper

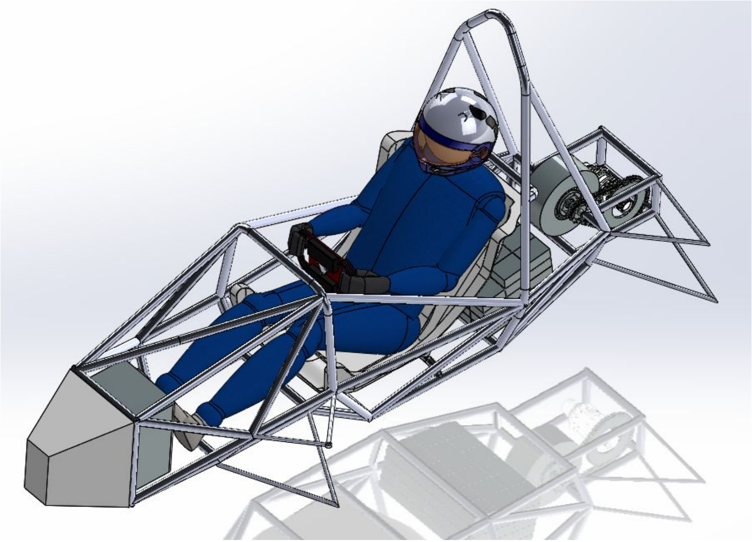
The required torsional/roll stiffness ratio	$\dfrac{C_T}{C_{roll}} \approx 4$

$$C_T = 940 \left[\frac{Nm}{deg}\right] \Rightarrow C_{roll} \approx 235 \left[\frac{Nm}{deg}\right]$$

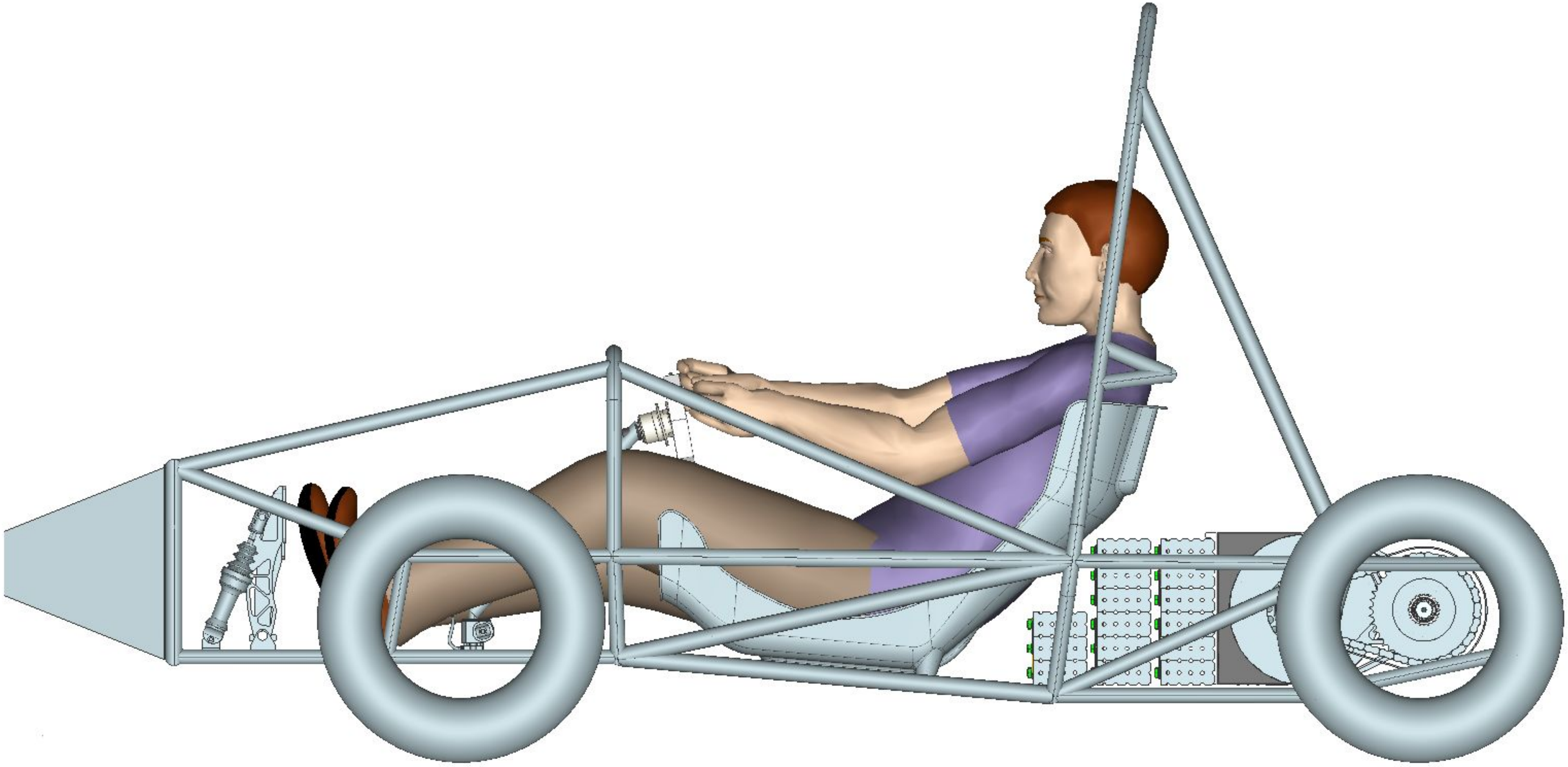
Optimal stiffness of dumpers	$K_{dumper} = 45 \left[\frac{N}{m}\right] = 400 \left[\frac{lb}{in}\right]$

Iterations 7 and 8

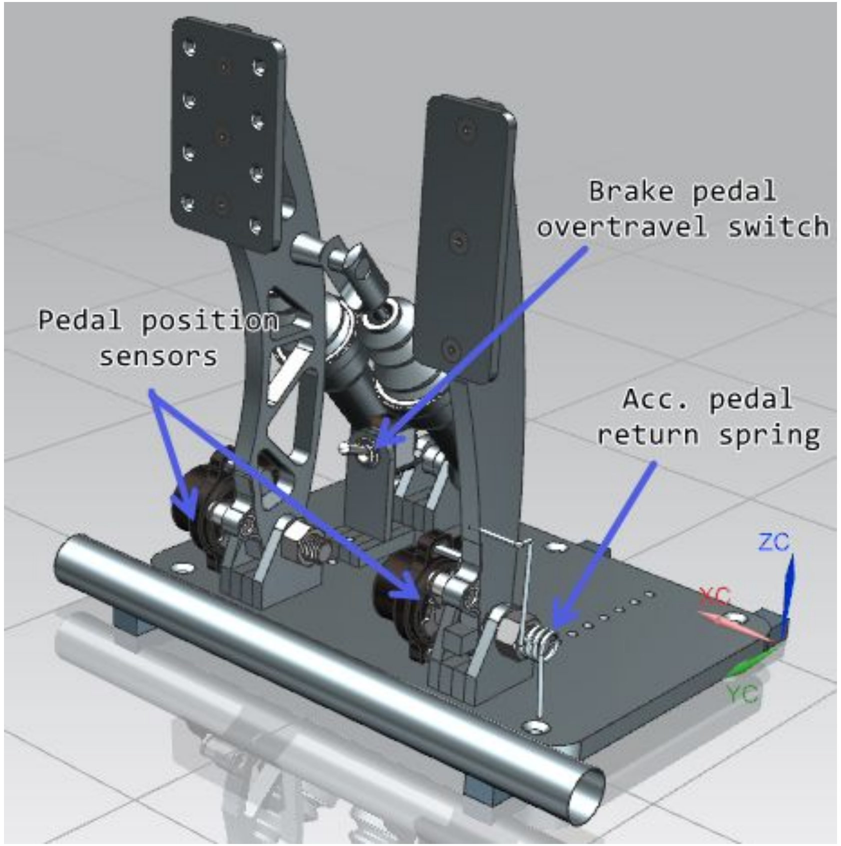




Pedal assembly & braking system

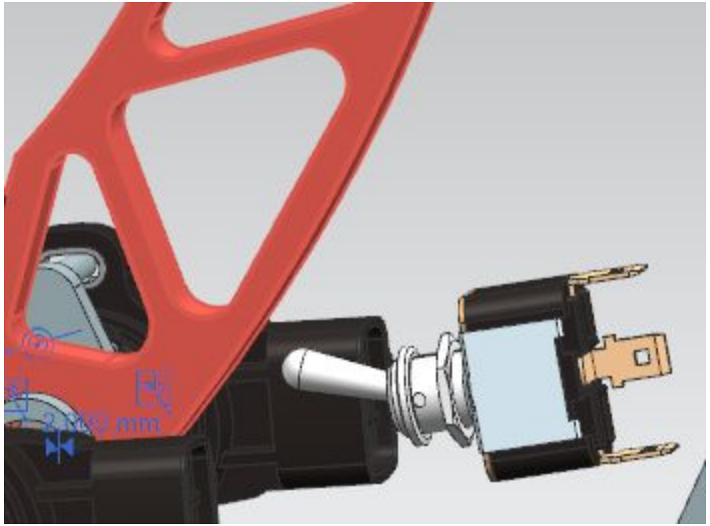


Pedal assembly & braking system

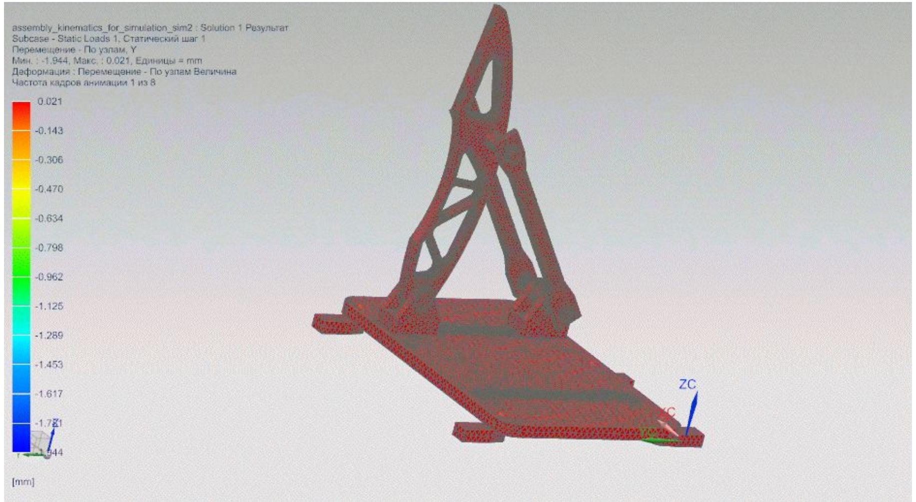


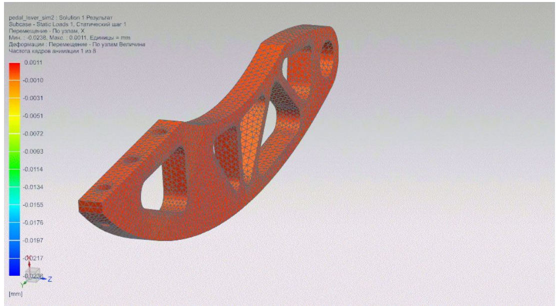
Material: D16T

Welded to the frame



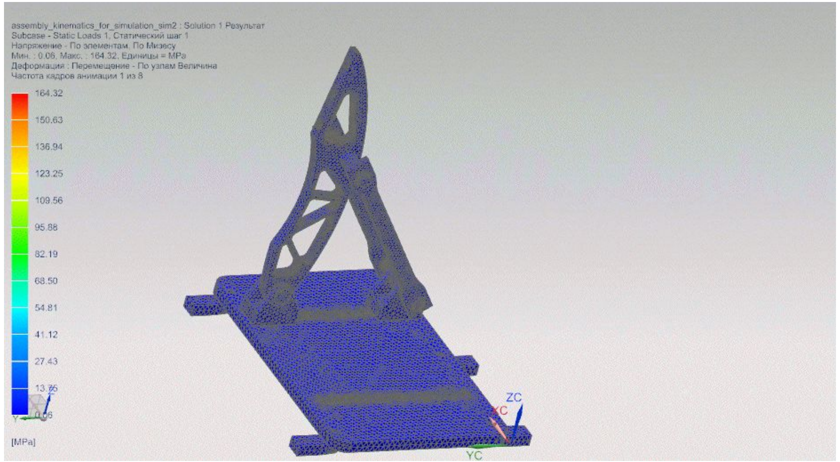
Pedal assembly & braking system





Simplified model for simulations

FoS = 4

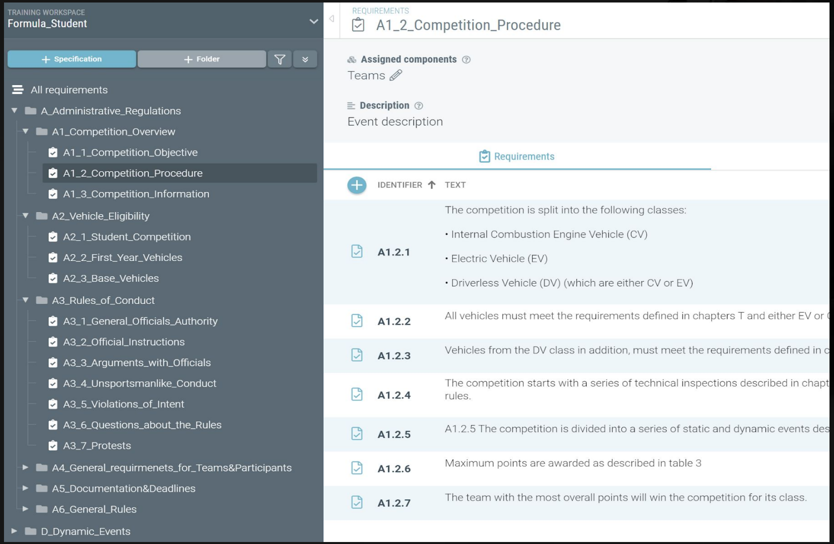


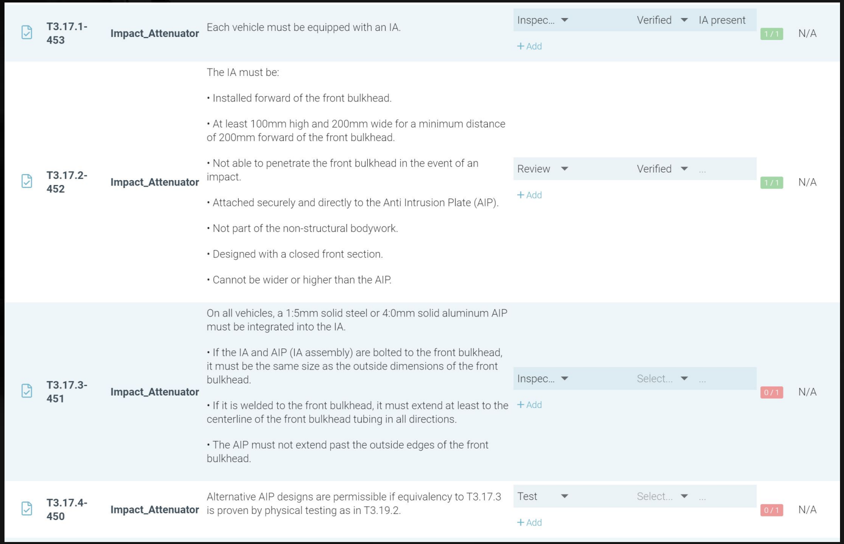
Verification

How do we make sure, our car is what it should be?

3D model verification

Assembly verification





Validation

That’s our first race!

Price

Car	Travelling	Marketing and PR
6.6 million	2 million	0.5 million

Goals reached

155 московский политех

Открытая международная студенческая научная конференция «СНК Московского Политеха – 2020»

СЕРТИФИКАТ
УЧАСТНИКА

открытой секции

«Актуальные проблемы транспортно-технологических средств»

Д.В. Артемов, А.Ю. Облупин, Р.И. Воробьев

студент(ка) группы Передовые производственные технологии

Сколковский Институт Науки и Технологий

Научный руководитель к.ф.-м.н., профессор, И.К. Ужинский

Ректор
В.В. Миклушевский

Москва
20–21 апреля 2020 г.

- There's a possibility to host the competition in Skoltech
- Car development paper presented on the conference
- Industrial Immersion collaboration with partners
- Registration for FS Switzerland confirmed!

Social

Latest news

@skoltech_racing

Communication

formula.skoltech.ru

Private

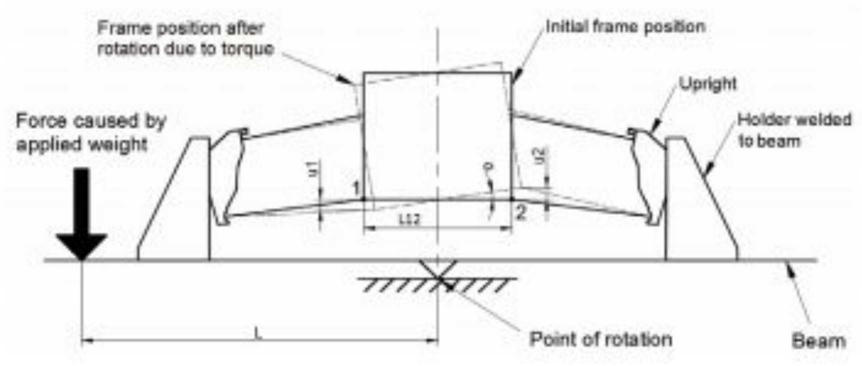
Purchases and contacts

racing@skoltech.ru

Coming

Thank You!
Keep Safe!

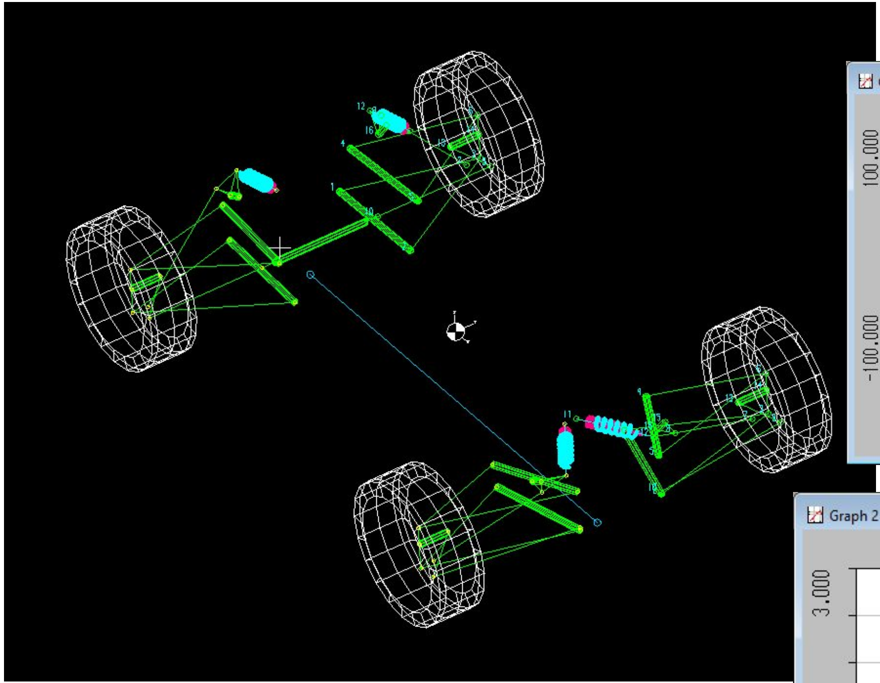
Torsional stiffness of the frame Additional

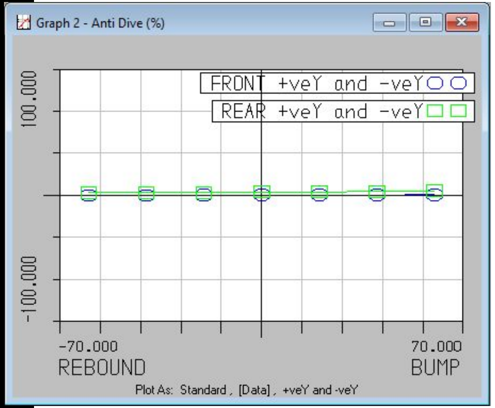


$$\theta = arctan\left(\frac{\mu_1 + \mu_2}{L_{12}}\right)[deg]$$

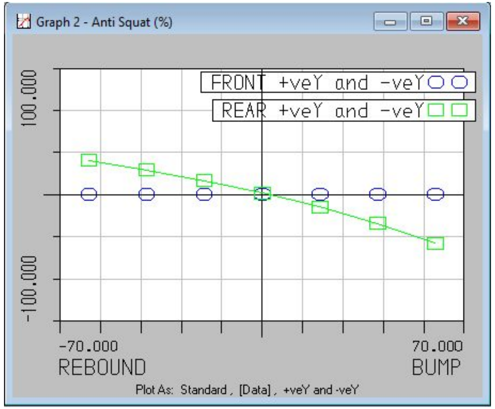
Torsional stiffness	$C_T = \frac{T}{\theta}\left[\frac{Nm}{deg}\right] = 940\left[\frac{Nm}{deg}\right]$

CFD analysis

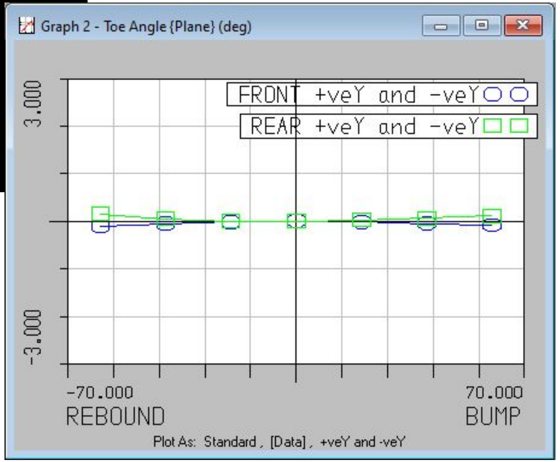




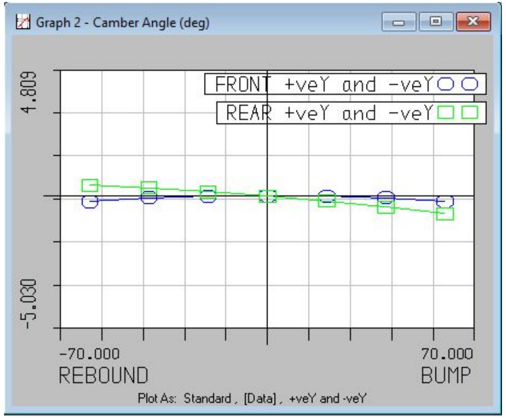
Graph 2 - Anti Dive (%)
FRONT +veY and -veY
REAR +veY and -veY
100.000
-100.000
-70.000
REBOUND
70.000
BUMP
Plot As: Standard, [Data], +veY and -veY



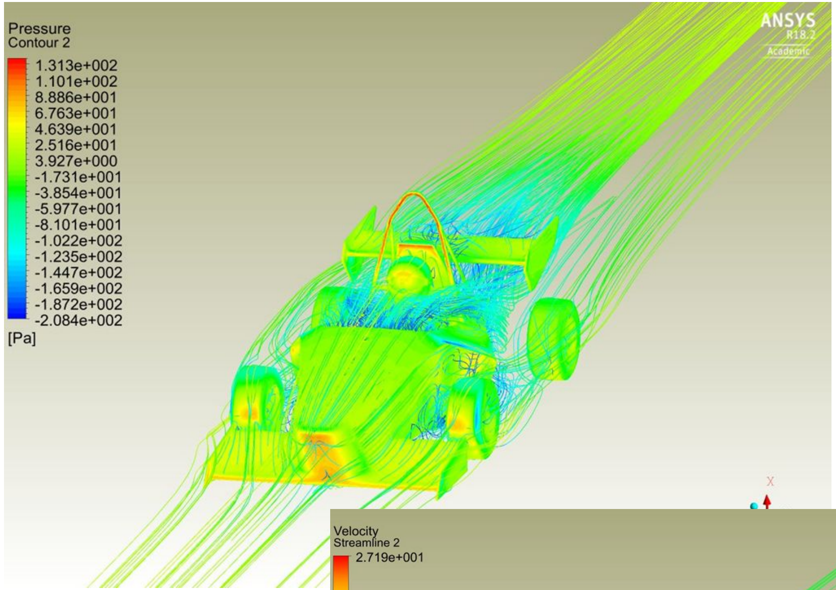
Graph 2 - Anti Squat (%)
FRONT +veY and -veY
REAR +veY and -veY
100.000
-100.000
-70.000
REBOUND
70.000
BUMP
Plot As: Standard, [Data], +veY and -veY

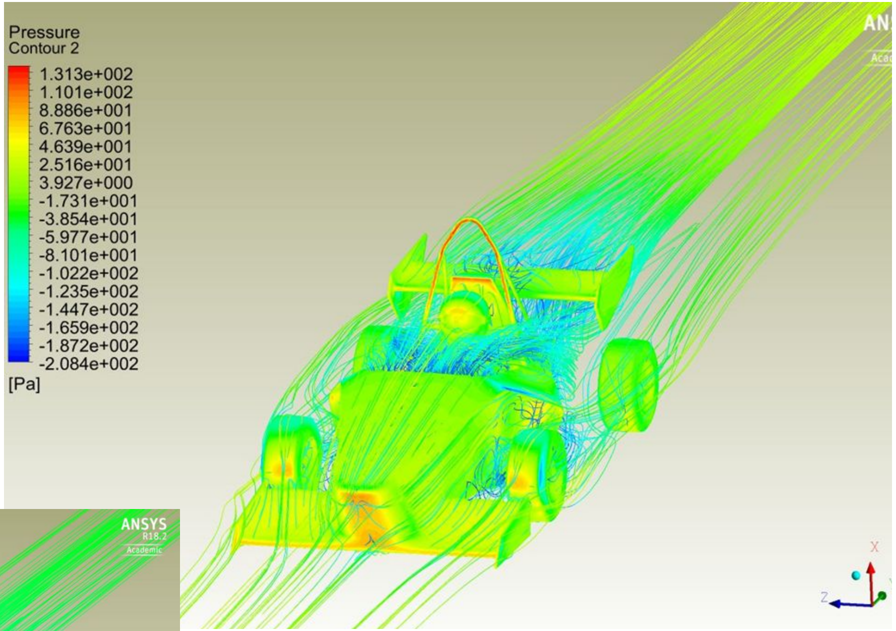


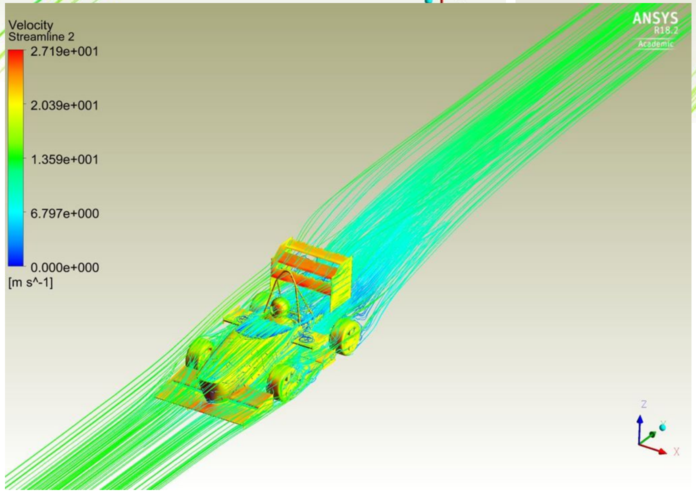
Graph 2 - Toe Angle {Plane} (deg)
FRONT +veY and -veY
REAR +veY and -veY
3.000
-3.000
-70.000
REBOUND
70.000
BUMP
Plot As: Standard, [Data], +veY and -veY



Graph 2 - Camber Angle (deg)
FRONT +veY and -veY
REAR +veY and -veY
4.809
-5.030
-70.000
REBOUND
70.000
BUMP
Plot As: Standard, [Data], +veY and -veY







CFD analysis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