Modeling the Hyperloop with COMSOL© :
On the Mechanical Design of the EPFLoop Capsule

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COMSOL Conference Lausanne 2018

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THE 2018 POD DESIGN

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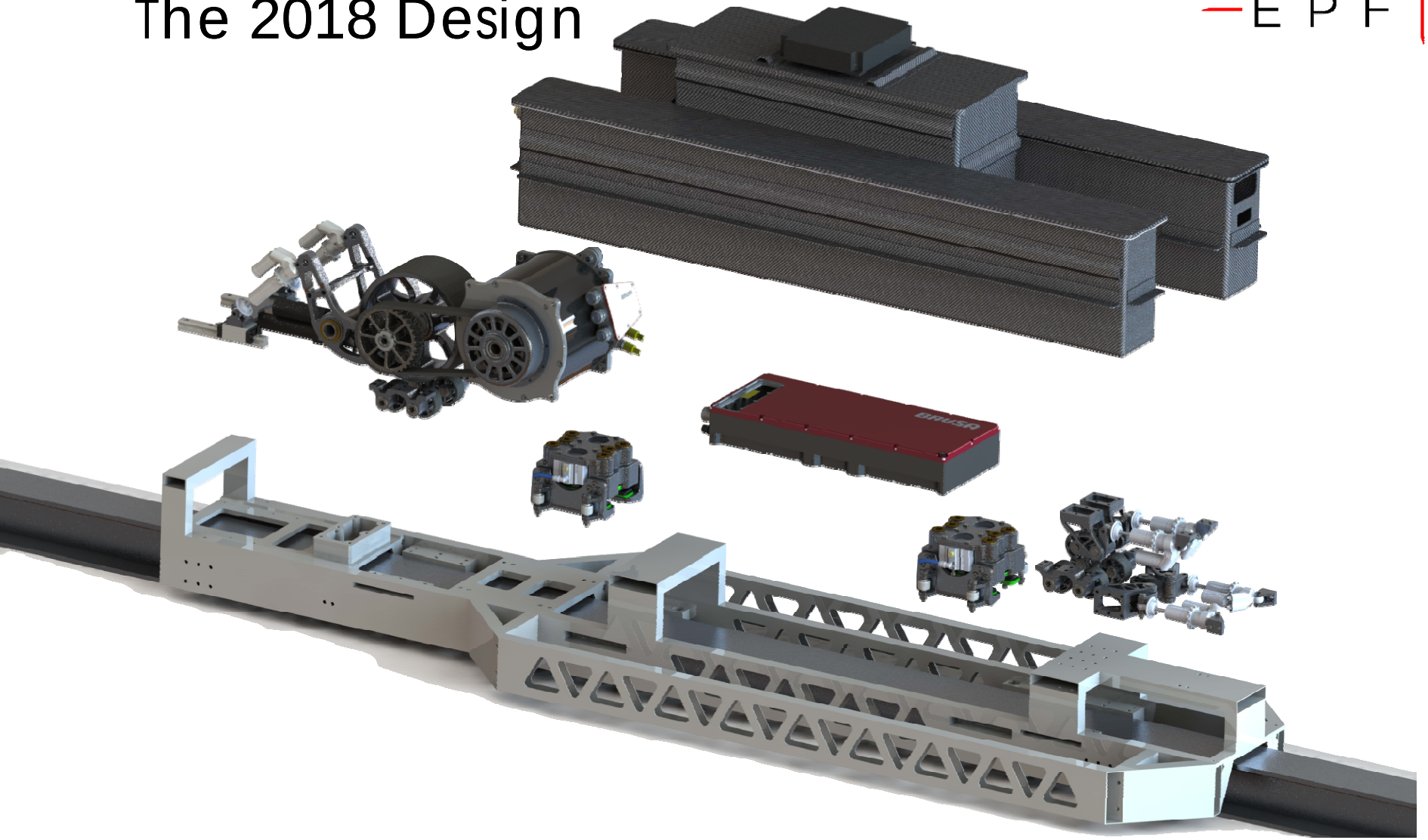
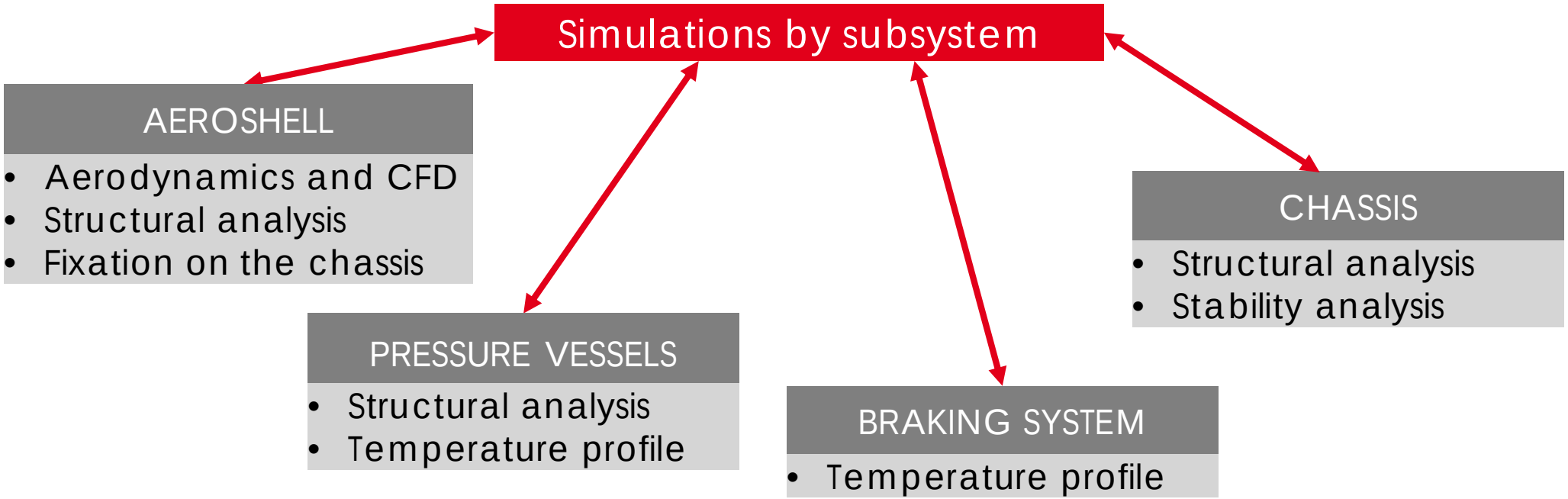
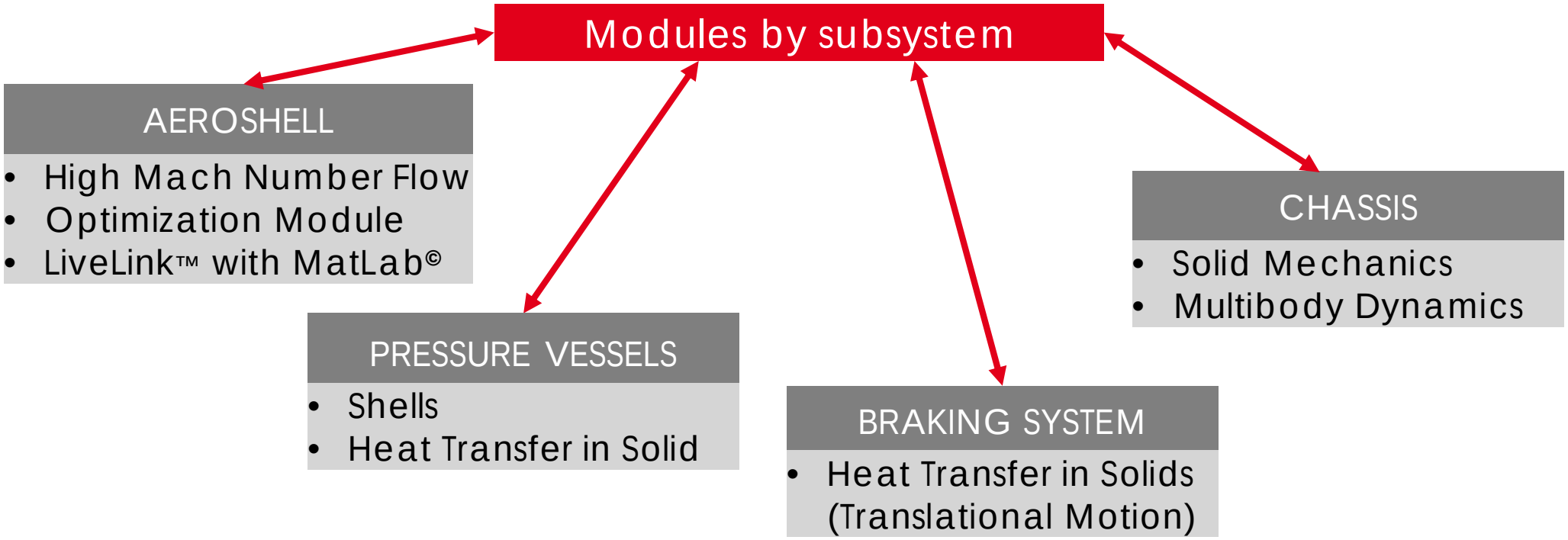
The 2018 Design



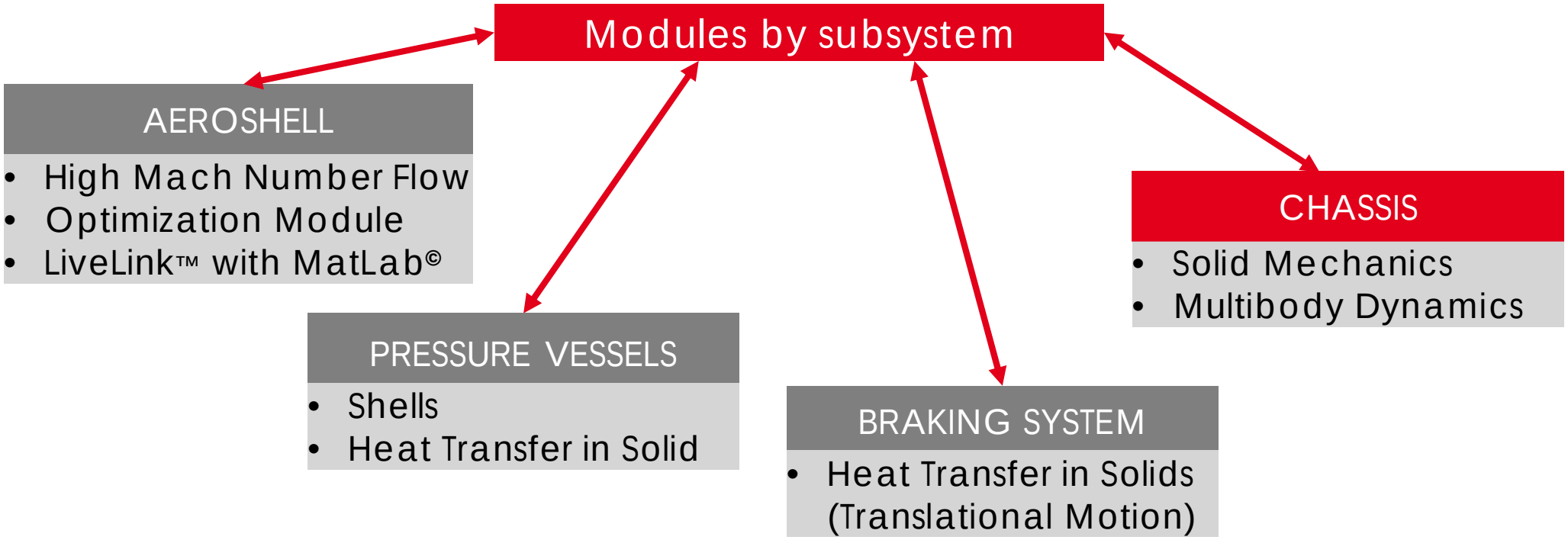
Subsystems Modeled with COMSOL



Subsystems Modeled with COMSOL



Subsystems Modeled with COMSOL

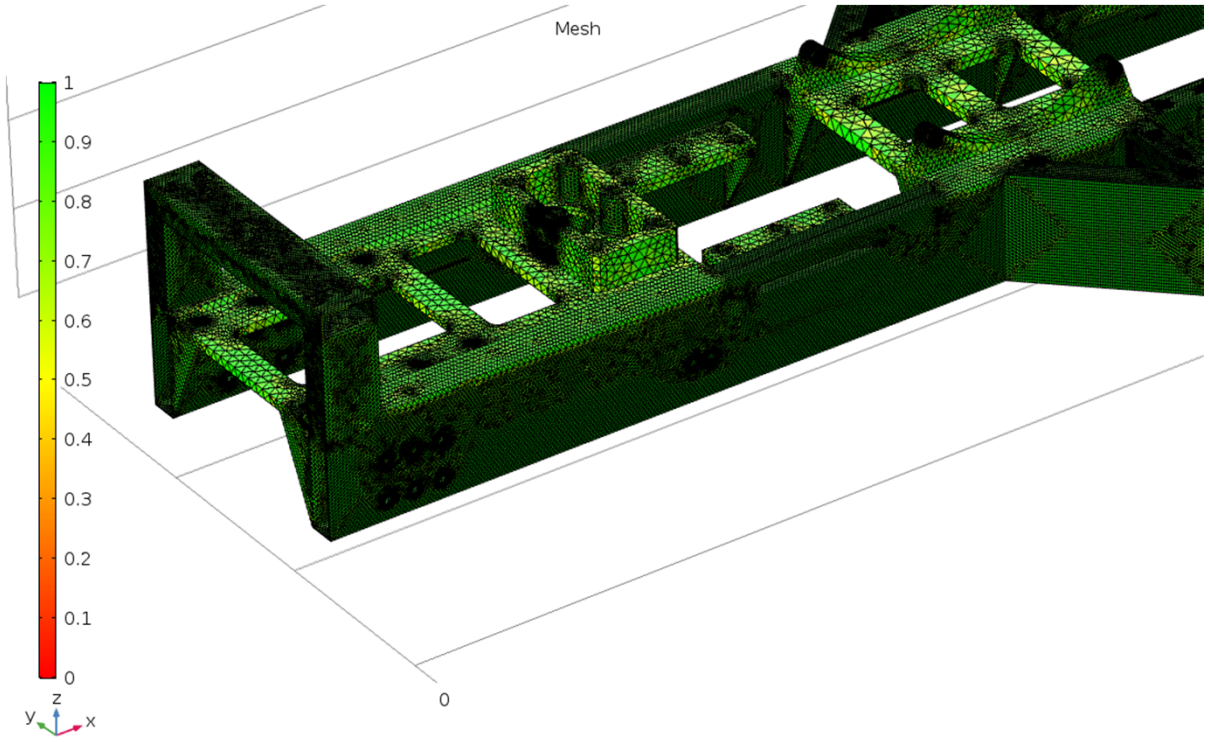


Simulations on the Chassis

Aim of the Simulations

- To evaluate the effect of the forces experienced during the run, a study of the **stresses** and the resulting **displacements** on the chassis has been done.

- In addition, due to the **high speed** and the possible occurrence of **vibrations**, the modelling of the **stability system** has been carried out with an eigenfrequency study.



Mesh on the chassis, mesh quality measured by skewness.

Simulations on the Chassis

Modules, Solvers and Strategies

Modules:

- Structural mechanics: The **Solid Mechanics** module has been used to simulate in stationary conditions the **safety factor** and the **Von Mises stresses**.

Strategies:

- The loads applied are **acceleration (1.5 g)**, **deceleration (3.0 g)** and weight of the components.

- After a study using nominal loads, a **load sweep** and a **linear buckling** study have been performed to determine the **maximum acceleration** at which the chassis will **withstand the stresses**.

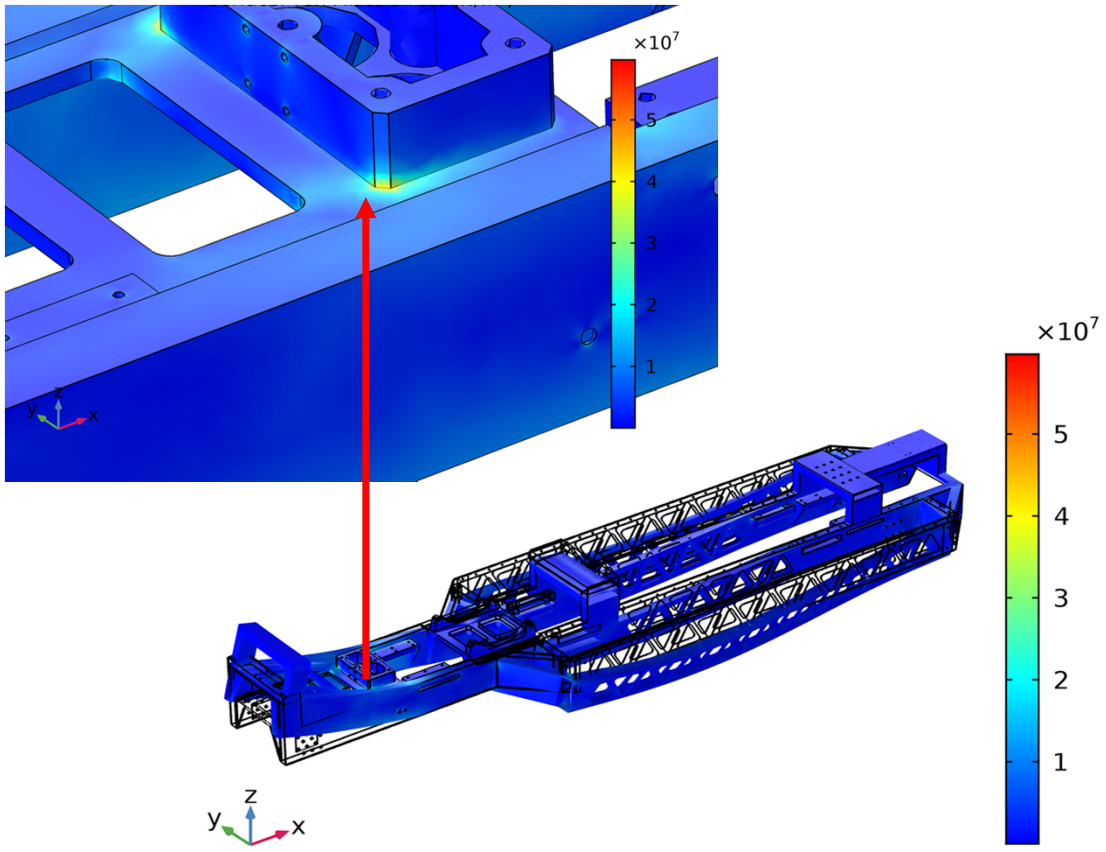
Type of Load	Fx [Acc]	Fx [Dec]	Fy [Gravity]
Motor	714 N	1428 N	500 N
VSI+Electronics+PV	336 N	672 N	235 N
Batteries	1204 N	2408 N	843 N
Stability System	154 N	308 N	107 N
Transmission	308 N	616 N	215 N
Cooling	70 N	140 N	49 N
Braking	224 N	448 N	156 N
Aeroshell	168 N	336 N	118 N

Simulations on the Chassis

Results

- In the structural analysis, the applied loads are the **nominal loads given by each subsystems**.

- The **aluminum chassis** (6060-T6) has an ultimate tensile strength of 275 MPa. Considering a safety factor of 2, the **allowed octahedral stress is 65 MPa**. The structural analysis showed that there are no stresses above this value on the structure.

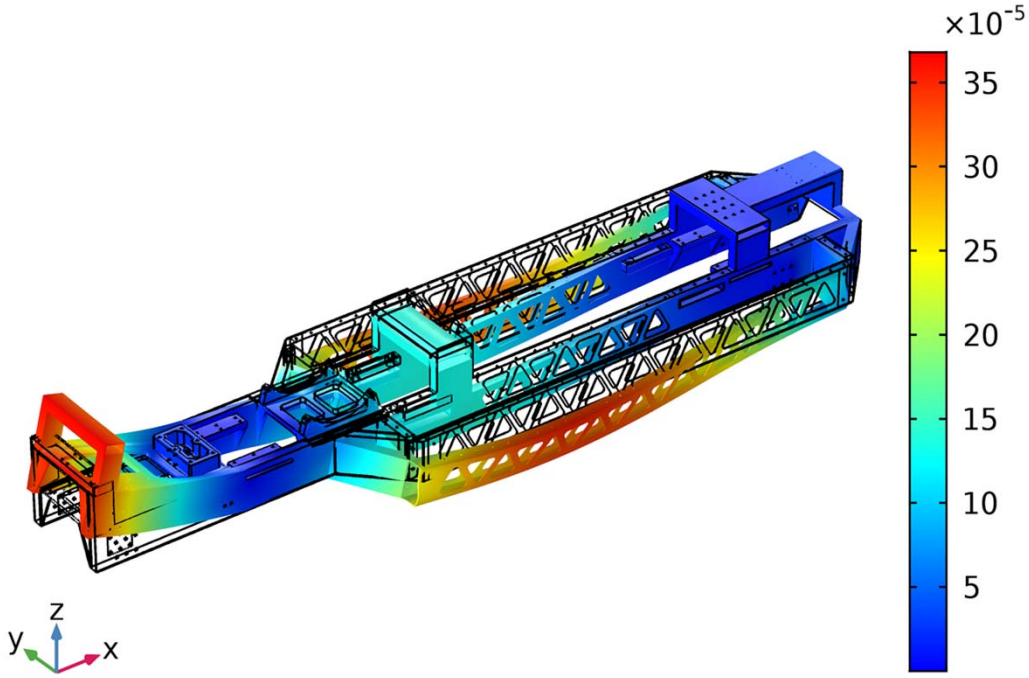


Von Mises stress [Pa].

Simulations on the Chassis

Results

- In the structural analysis, the applied loads are the **nominal loads given by each subsystems**.
- The **aluminum chassis** (6060-T6) has an ultimate tensile strength of 275 MPa. Considering a safety factor of 2, the **allowed octahedral stress is 65 MPa**. The structural analysis showed that there are no stresses above this value on the structure.
- The linear buckling study showed that the chassis can **withstand the nominal loads up to 15 times with a safety factor of 2**.



Total displacement [m].

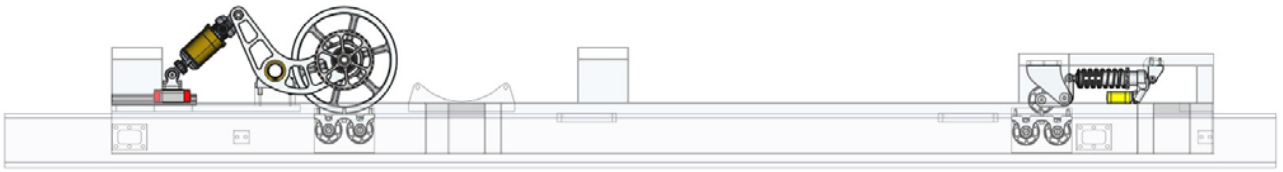
Simulations of the Stability System

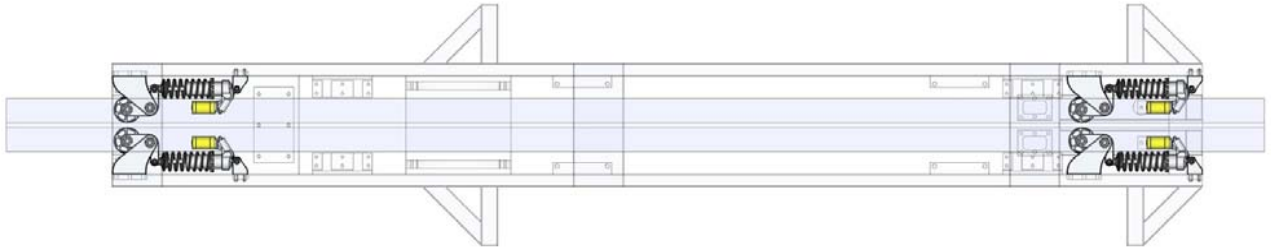
Aim of the Simulations

- The objective is to understand the behavior at **high speed** and **sustained vibration** of the pod.

- The stability system is composed by multiple subsystems:

  - **Vertical suspensions** (front and back), located over the rail
  - **Set of wheels**, located under the rail
  - **Lateral suspensions** (front and back) located between the chassis and the vertical part of the rail

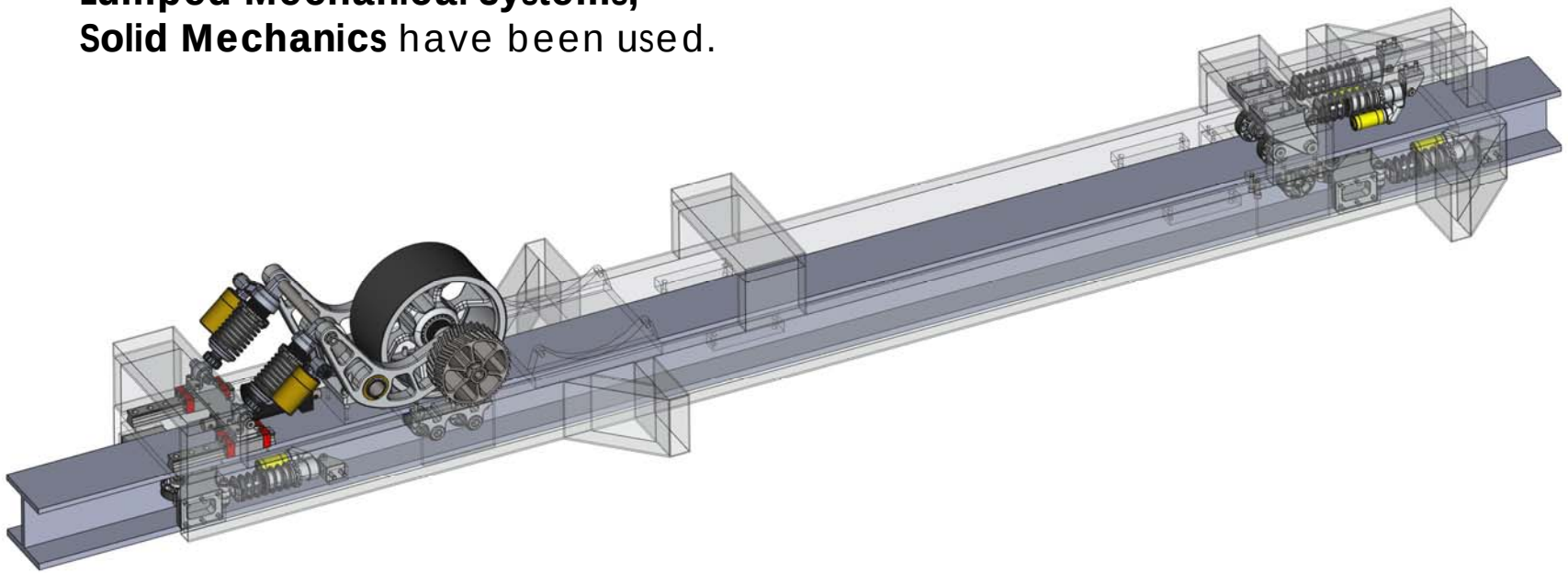




Simulations of the Stability System

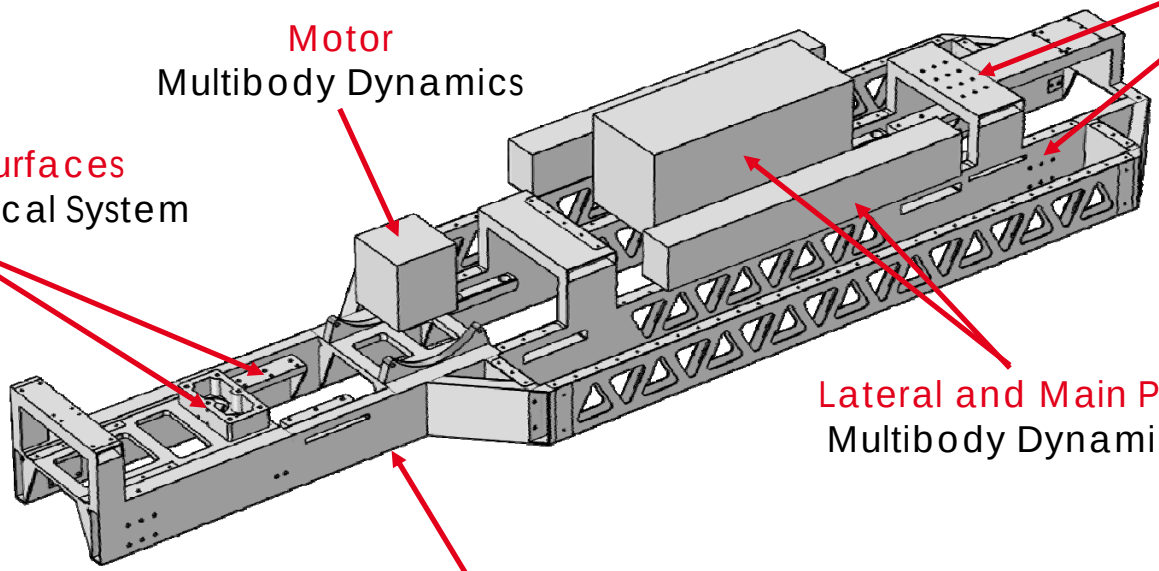
Modules, Solvers and Strategies

- Modules for the stability analysis:
  Multibody Dynamics,
  Lumped Mechanical Systems,
  Solid Mechanics have been used.



Simulations of the Stability System

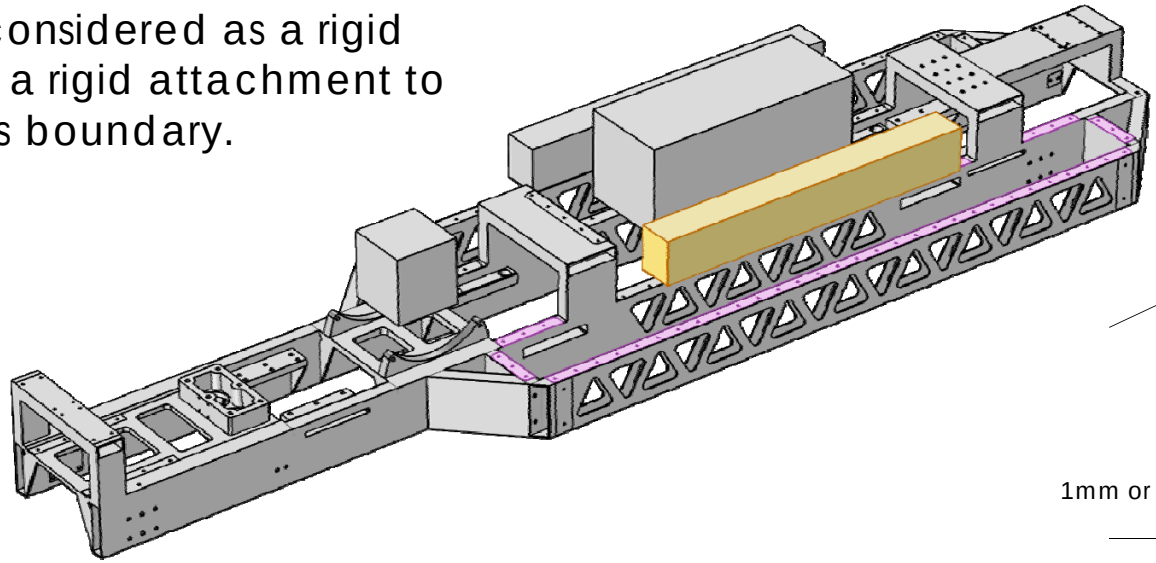
Geometry and Interfaces



Simulations of the Stability System

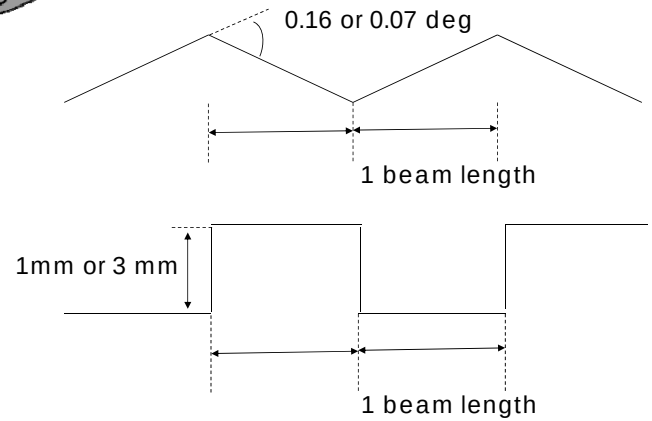
Geometry and Interfaces

- The PV is considered as a rigid body with a rigid attachment to the chassis boundary.



- The LMS will apply a force due to the imperfections of the rail.

Measured gaps per beam	
Vertical step	1 mm
Pitch	0.16 deg
Lateral step	3 mm
Yaw	0.07 deg

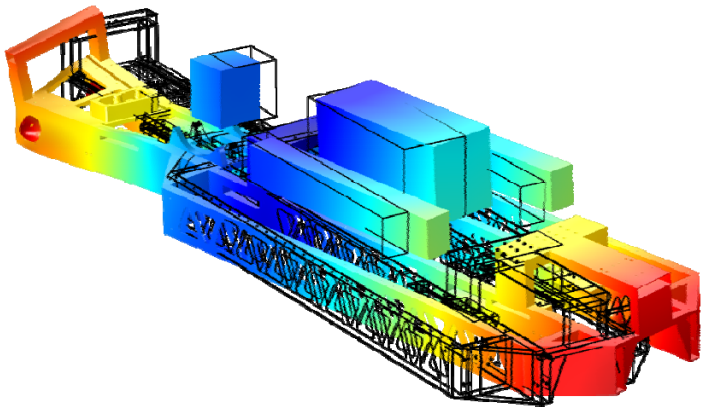


Possible displacement function.

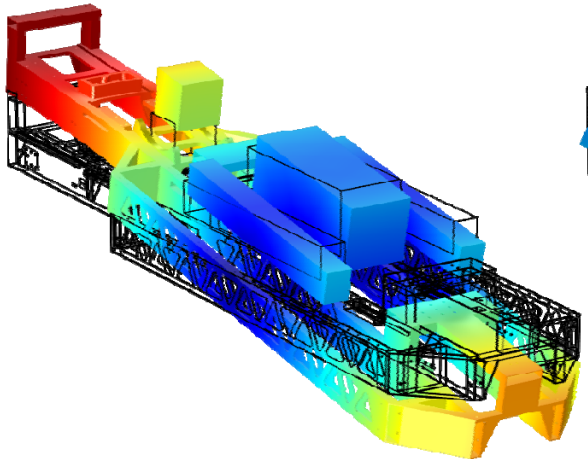
Simulations of the Stability System

Mode Analysis

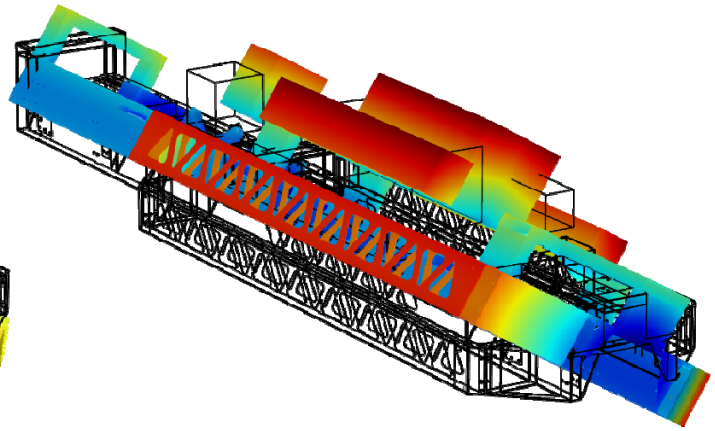
- COMSOL provides as first three modes those that are rigid motions (and their complementary ones).



Yaw mode



Pitch mode



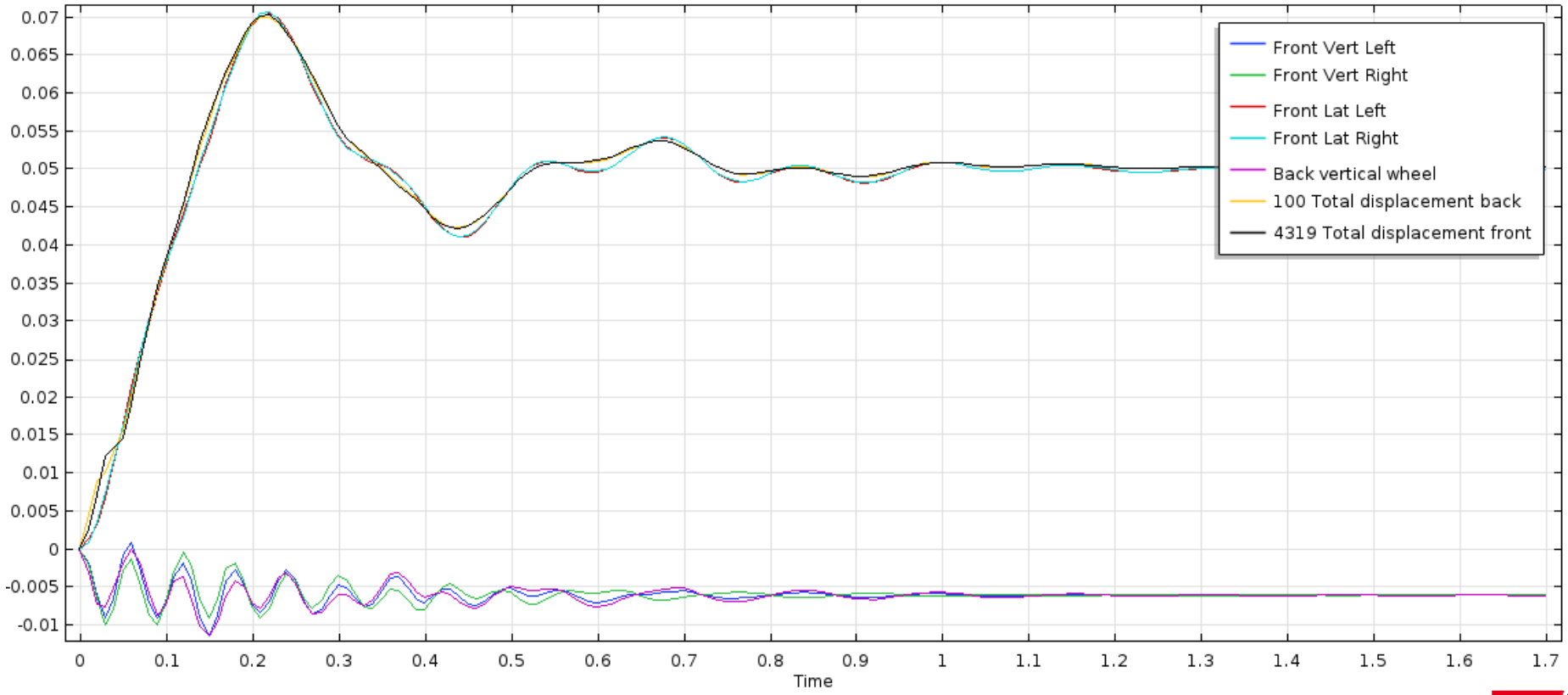
Roll mode

Surface: Total displacement (m).

- The first natural mode of vibration has been computed at 50 Hz, whereas the induced vibrations have max frequency of 35 Hz.

Simulations of the Stability System

Time Dependent Analysis



Total displacement: front and back (m).

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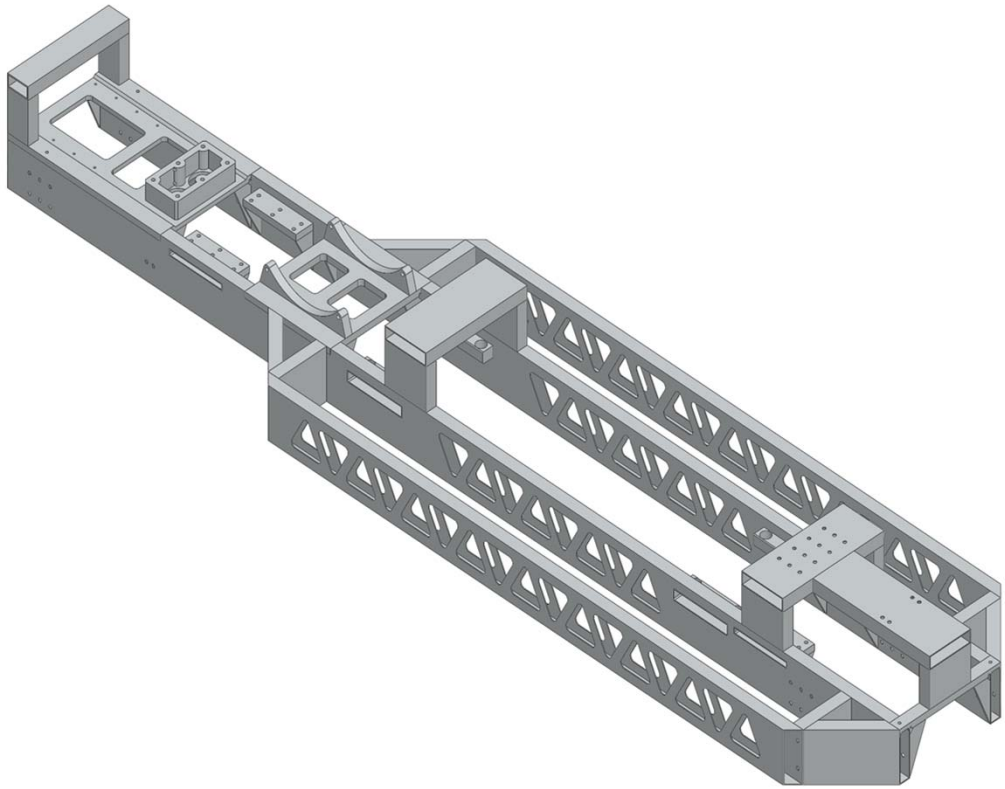
Manufacturing of the Chassis



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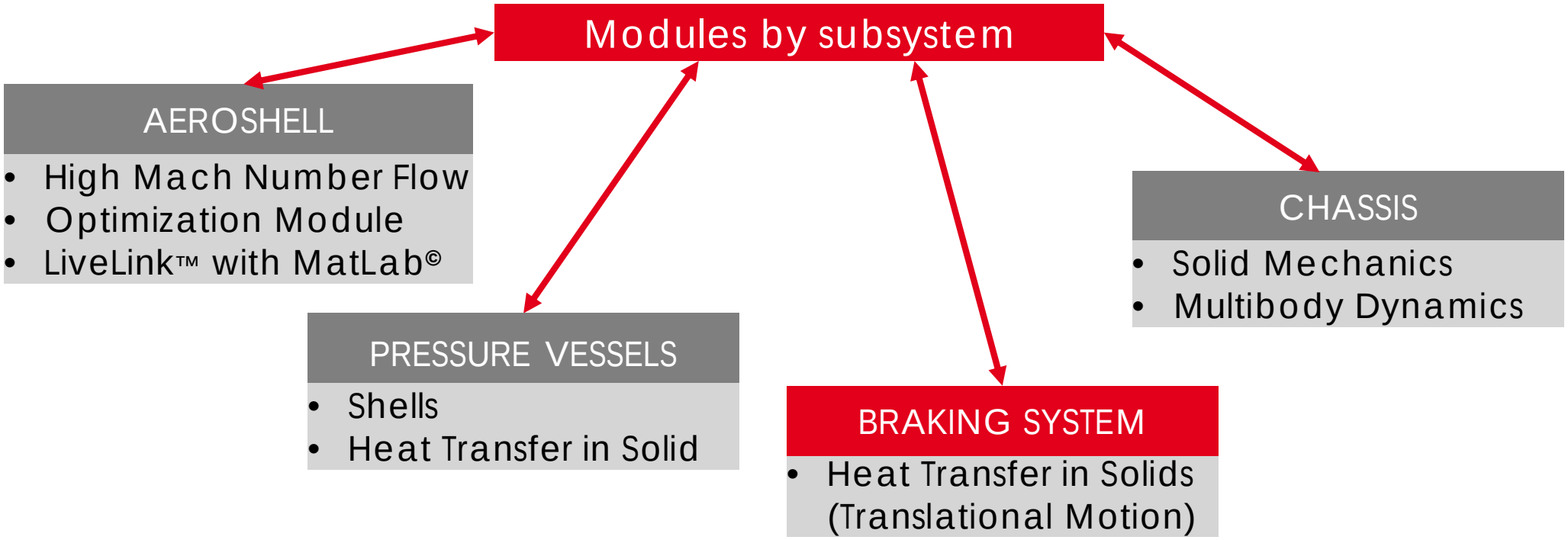
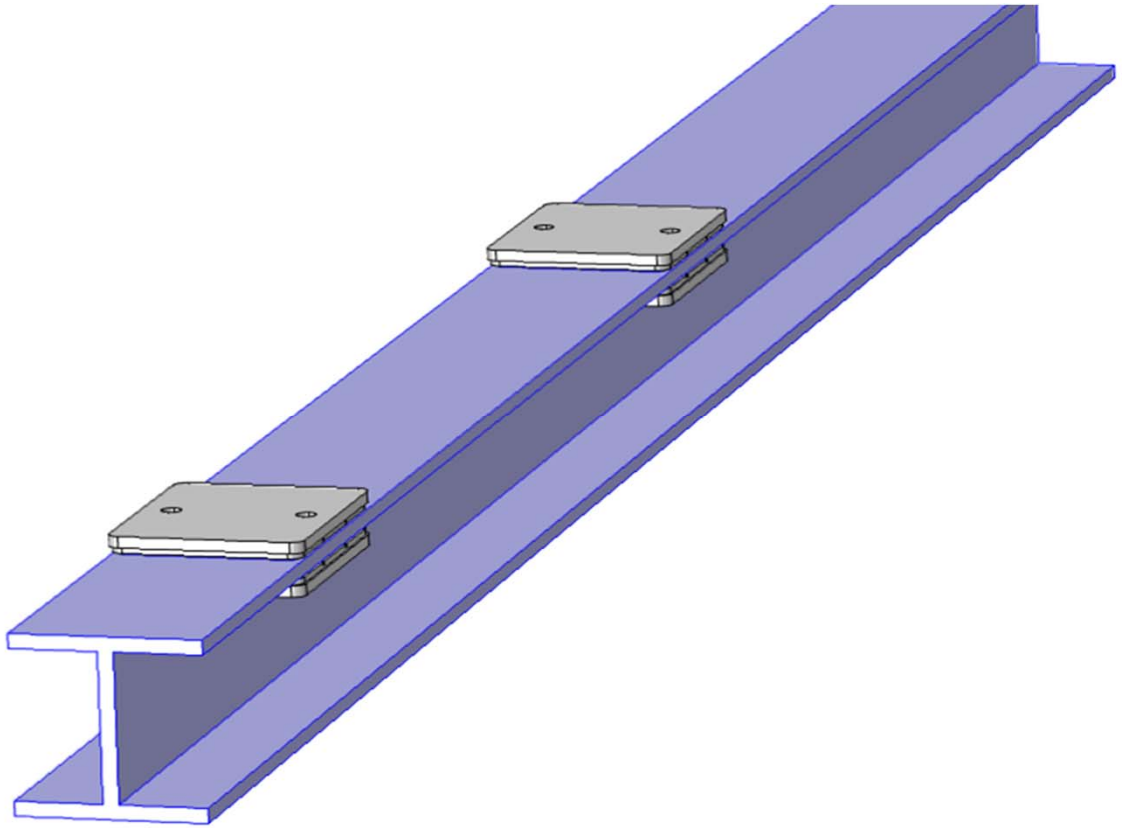
Subsystems Modeled with COMSOL



Simulations on the Braking System

Aim of the simulations

- In order to reach the **top speed** and then stop safely, it is required to have an **efficient braking system**.
- The amount of **kinetic energy** carried by the pod can create an excessive **increase of temperature** in the brakes.,
- Consequently, in order to **choose correctly the material** constituting the brakes and **avoid to reach problematic temperatures**, a set of simulations with heat transfer and frictional effects were performed.

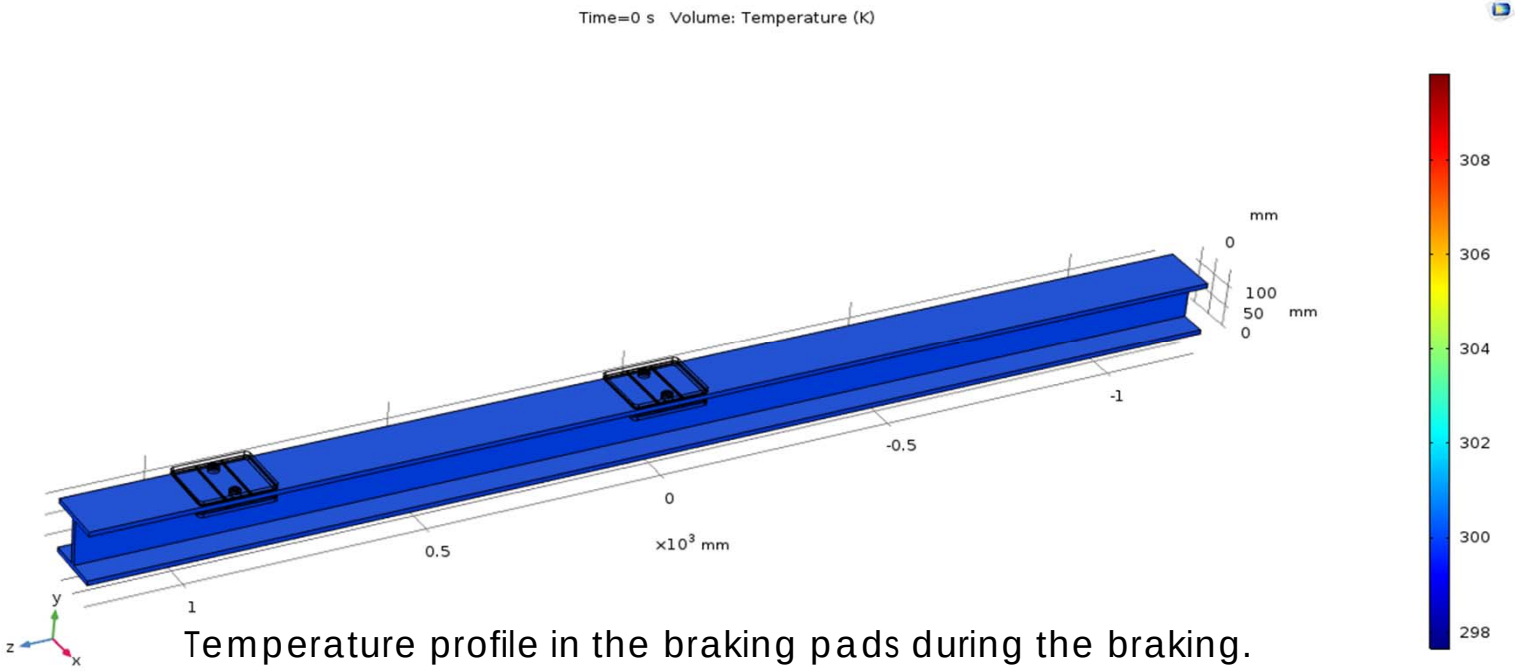


Simulations on the braking system

Modules, Solvers and Strategies

- **Module:** The **Heat Transfer in Solid** module has been used to simulate the temperature profile behavior of the brakes during the braking at the end of the run.

- **Strategies:** Using the **Translation Motion** and inserting the **deceleration profile** speed has been possible to **estimate the power** dissipated by friction on the rail and therefore the temperature rise in the pad volume.



Temperature profile in the braking pads during the braking.

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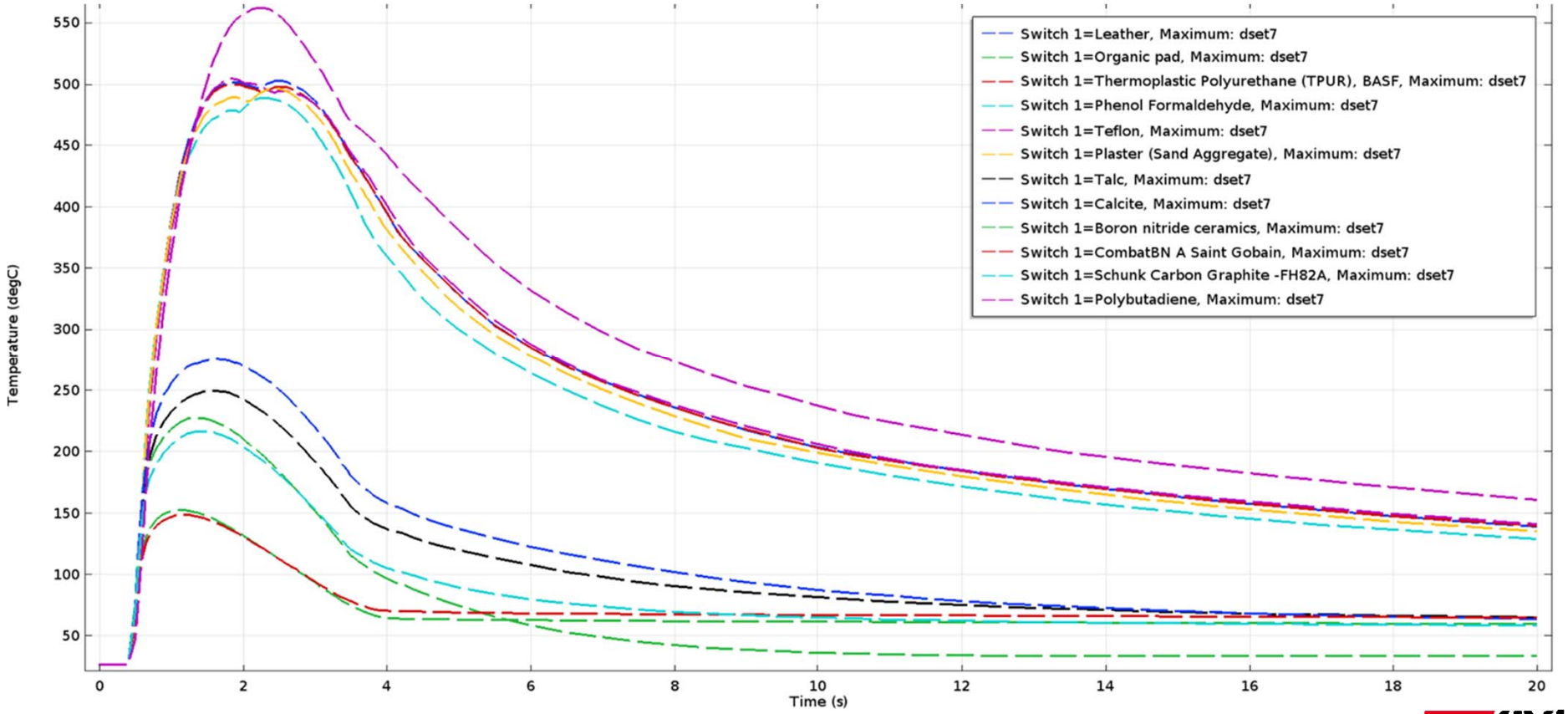
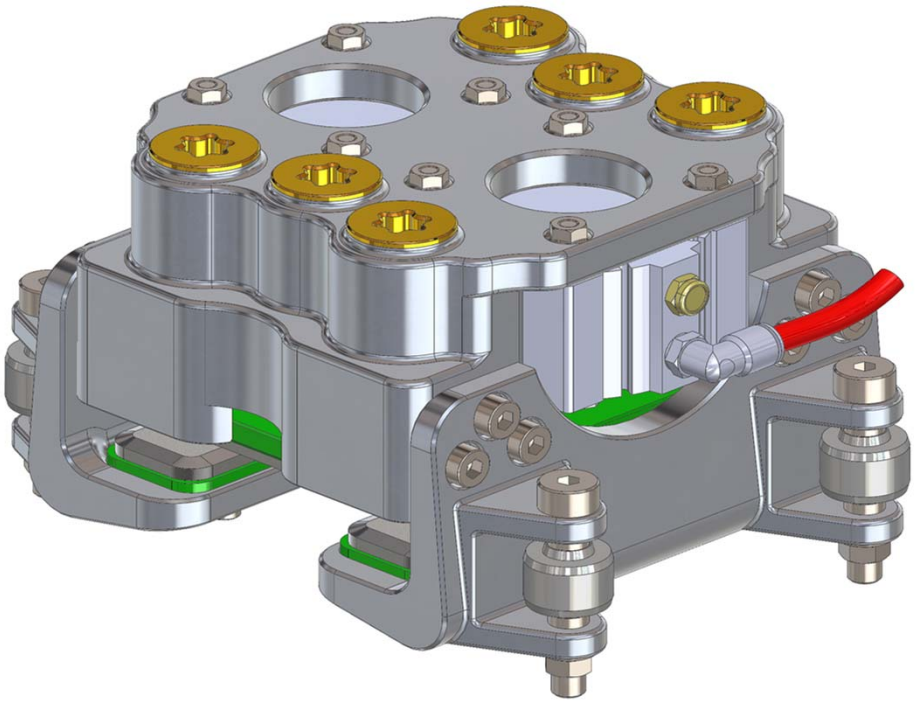
Simulations on the Braking System

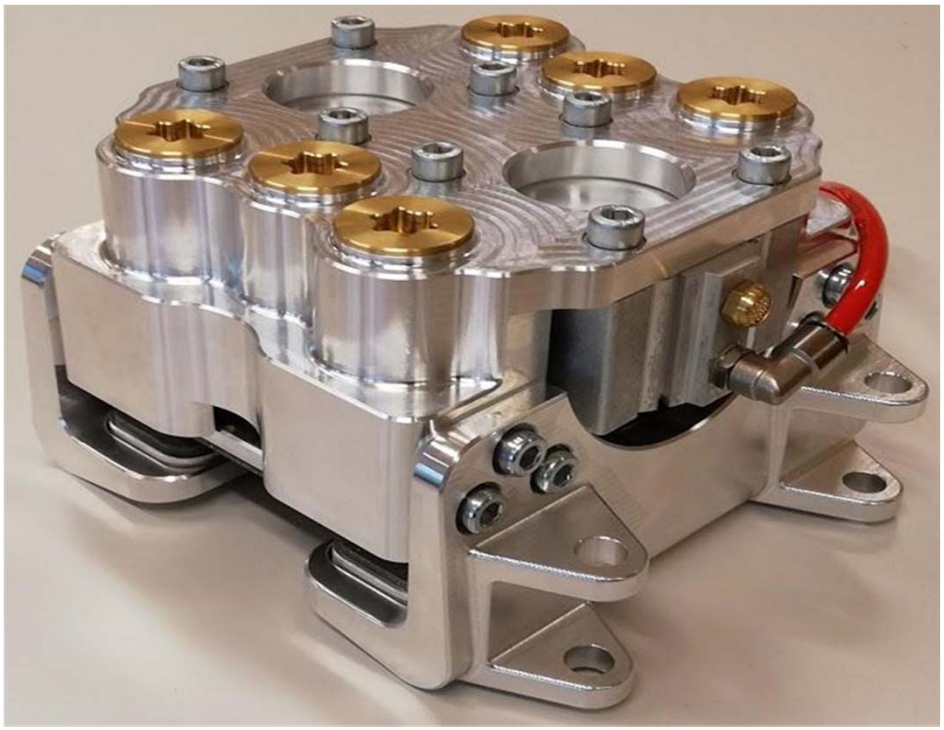
Results



Temperature profile in the braking pads during the braking : material sweep.

Manufacturing of the Brakes





Simulations on the Braking System

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Validation The brakes have been successfully validated and the run celebrated.

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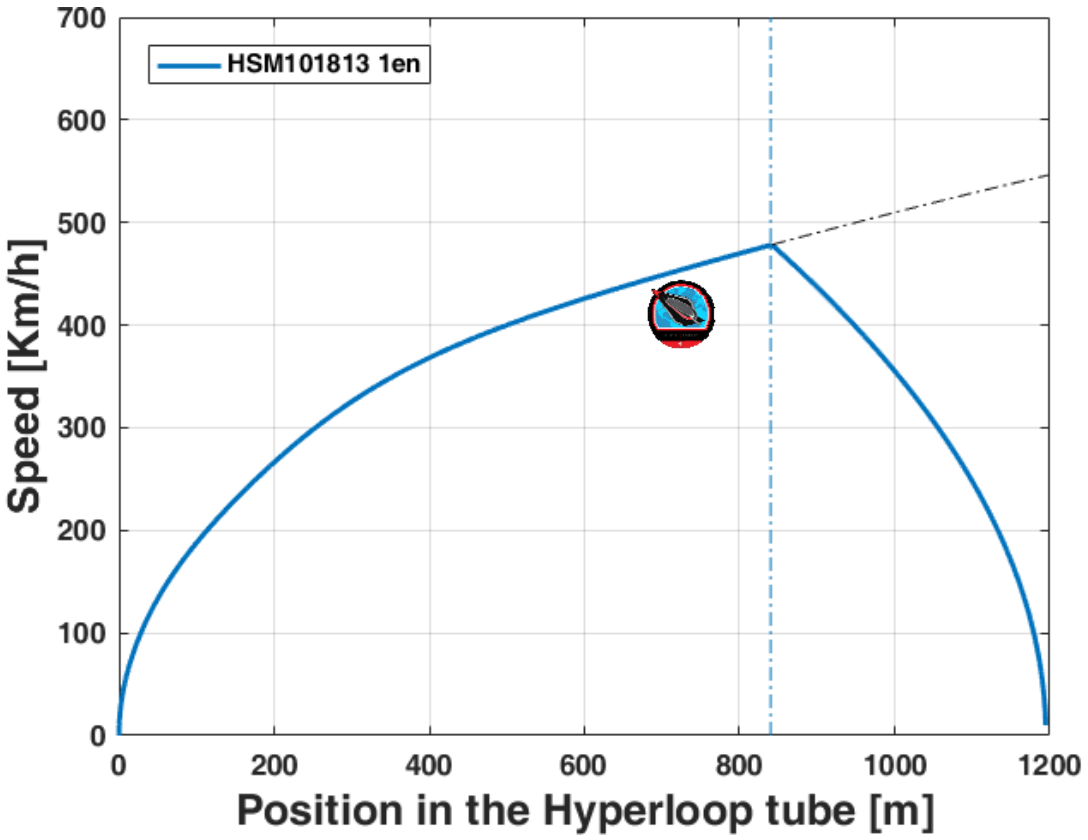
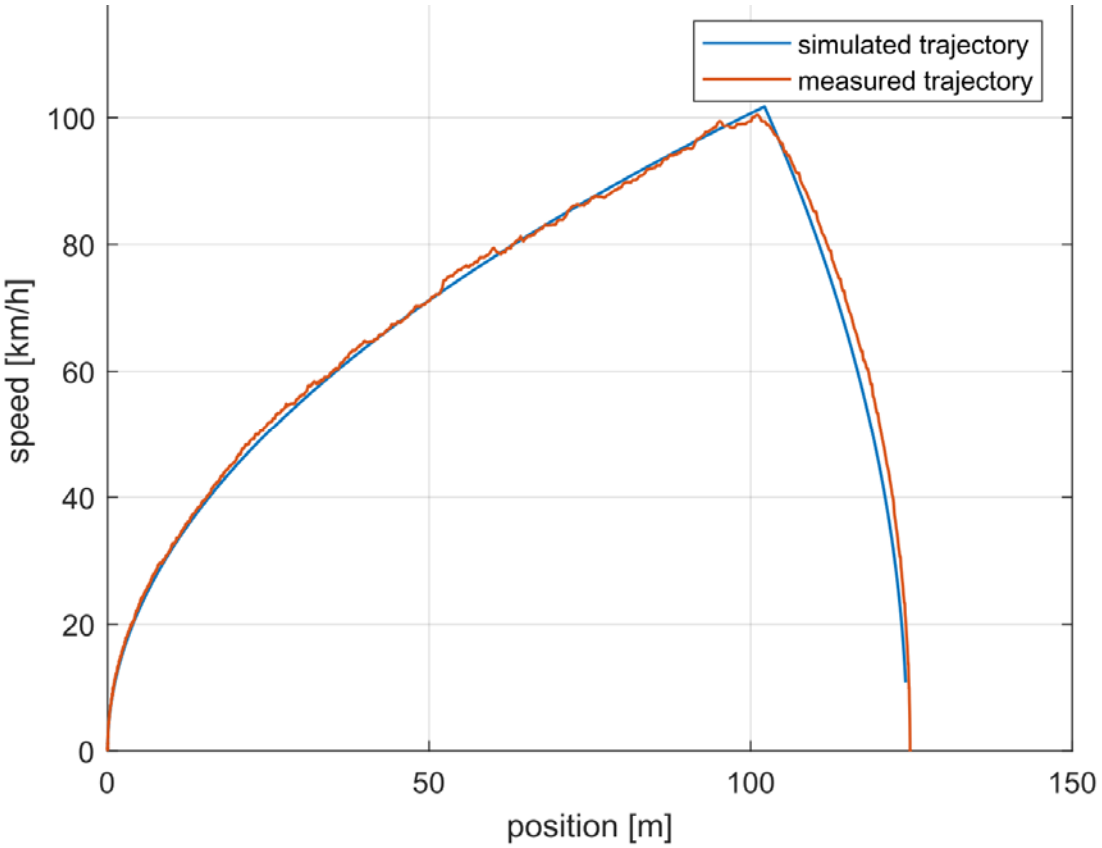
Pod Performances Prediction



Kinematics model for the EPFLoop pod.

Mass	295 kg
Max requested power	178 kW
Max torque	385 Nm
Total capacity	15 Ah
Estimated max speed	470 km/h

Pod Performances Validation



Kinematics model validation: 150 Nm, 305 kg.

- Comparison between the **kinematics model** developed by EPFLoop and measurements **during the run**

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The 2019 competition

EPFL OOP

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- SCALABLE PROTOTYPE
- NEW APPROACH INSPIRED BY SWISSMETRO
- OPTIMAL DESIGN
- STRICT COLLABORATION WITH PARTNERS SUCH AS COMSOL
- NEW INVOLVED STUDENTS

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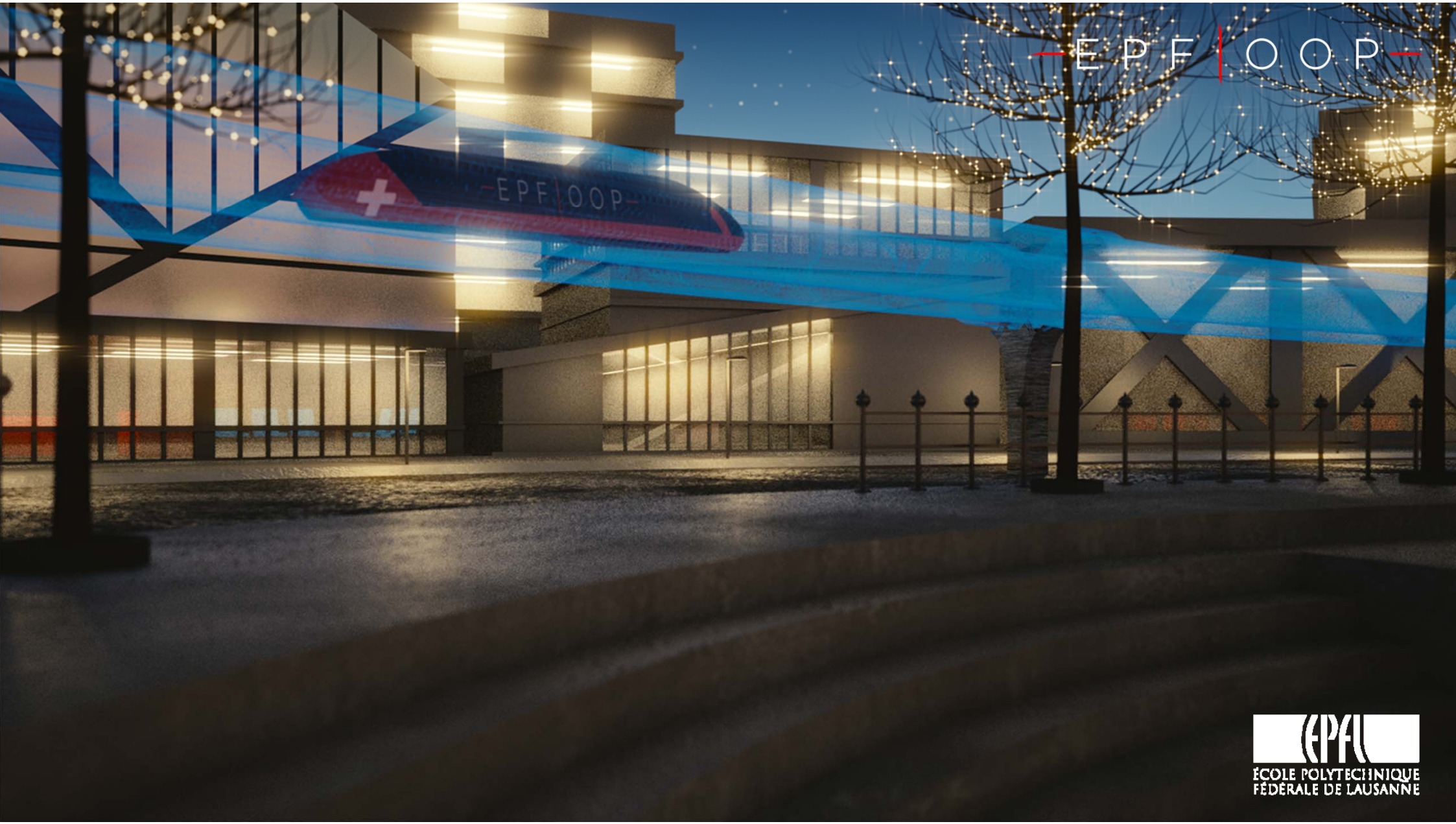
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