# ANNUAL REPORT


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# 2026


Fakulteta za strojništvo
Univerza v Mariboru
FERI

# CONTENTS


***INTRODUCTION*** ***4***

***1. CHASSIS*** ***5***

1.1 MONOCOQUE 5

1.2 LAMINATION 6

1.3 CRUMPLE ZONE 7

1.4 COCKPIT 7

***2. POWERTRAIN*** ***8***

2.1 WHY FOUR-WHEEL DRIVE (4WD) 8

2.2 ELECTRIC MOTOR 8

2.3 PLANETARY GEARBOX 10

2.4 HIGH-VOLTAGE BATTERY 12

2.5 INVERTER 15

***3. ELECTRONICS*** ***18***

3.1 PRINTED CIRCUIT BOARDS AND CONTROL SYSTEMS 18

3.2 SOFTWARE 19

3.3 WIRING HARNESS 21

***4. SUSPENSION AND VEHICLE DYNAMICS*** ***22***

4.1 INTRODUCTION AND SEASON GOALS 22

4.2 DEVELOPMENT APPROACH AND GEOMETRY 23

4.2.1 TYRES AND DEFINING TARGET PARAMETERS 23

4.2.2 SUSPENSION GEOMETRY DEVELOPMENT 23

4.3 SUSPENSION DESIGN AND VEHICLE BALANCE 24

4.3.1 NEW FRONT SUSPENSION SYSTEM 24

4.3.2 VEHICLE BALANCE ANALYSIS 24

# CONTENTS


4.4 CONTROL SYSTEMS 25

4.4.1 CONTROL SYSTEM ARCHITECTURE 25

4.4.2 TORQUE VECTORING 26

4.4.3 SIMULATION AND VALIDATION 26

4.5 TESTING AND SEASON REVIEW 27

4.5.1 TESTING AND VALIDATION 27

4.5.2 SEASON REVIEW AND FUTURE DEVELOPMENT 27

***5. AERODYNAMICS*** ***28***

5.1 SIMULATION PROCEDURE 29

5.2 FRONT WING DEVELOPMENT 30

5.3 UNDERTRAY DEVELOPMENT 30

5.4 REAR WING DEVELOPMENT 31

5.5 AERODYNAMIC PACKAGE RESULTS 31

5.6 VALIDATION 32

5.7 CONCLUSION 32

***6. MARKETING*** ***33***

***7. COMPETITION REPORT*** ***36***

7.1 FORMULA STUDENT ALPE ADRIA 36

7.2 FORMULA STUDENT POLAND 38

7.3 ANALYSIS OF COMPETITION RESULTS 40

# INTRODUCTION

Last year, with Layla, we finished 4th at FS Alpe Adria, our best result to date, and took the trophy for 3rd place in the Efficiency event. The easy option would have been to refine a proven concept a little further. Instead, we decided to take the biggest technological step we have ever made and switch to four-wheel drive.

That is how Roxy was born. As always, we built almost everything ourselves, and this time that included the powertrain. Together with Fischer Elektromotoren, we designed our own 30 kW electric motors, engineered planetary gearboxes for them, and developed our own inverter along with a torque vectoring algorithm that distributes torque between the individual wheels. We raised the voltage of the high-voltage system from 400 to 600 V, redesigned the front suspension, moved to wider tyres, and built a new chassis and aerodynamic package. Despite all the new components, Roxy weighs 193 kilograms, which is a very good result given the scope of development and the number of new solutions integrated into the car.

The season was not without its difficulties. Since we were doing many things for the first time, we learned a lot along the way. The biggest challenges came from manufacturing the planetary gearboxes, air cooling, the inverter and its oscillations, and integrating torque vectoring into the car. Even so, we achieved good results at the competitions. At FS Alpe Adria we finished 15th out of 42 teams, and at FS Poland we placed 13th overall and sixth in Skidpad.

Even more than the placings, we are proud that, for the first time in the team's history, we finished every endurance race of the season. The Endurance event exposes every weakness of a car, and in past years it stopped us short of the finish more than once. This year, Roxy and its all-new powertrain made it to the finish in both races, the best proof that we have built a reliable and durable car.

Behind all of this stands a team that has grown considerably over the past two years. Today we are more than 70 students across six technical departments. The season was marked by long evenings in the workshop, 27 chassis iterations, more than 150 aerodynamic simulations, 20 new printed circuit boards and 420 battery cells that we connected ourselves. We presented the project at numerous fairs, conferences and automotive events, and a documentary film was even made about our team.

None of this would have been possible without the Faculty of Mechanical Engineering, the Faculty of Electrical Engineering and Computer Science, the University of Maribor, and more than 100 partners and donors. Above all, it would not have been possible without all the team members, who put an enormous amount of effort and energy into this season. Thank you all for your trust and support.

For us, Roxy is only the beginning. The knowledge we gained this season will form the foundation for future cars. On the following pages, we present in more detail how it all came together.

Enjoy the read.

Tim Vogrinc
Project Leader

# 1. CHASSIS

This season we continued to use a composite monocoque, which has proven to be the optimal solution for our car in previous years. The reasons for choosing a monocoque over a tubular spaceframe with bodywork remain unchanged: compared to a tubular frame, it offers higher stiffness per unit mass, gives us more freedom in positioning the suspension mounting points, and allows aerodynamic components to be integrated directly into the monocoque. Most of this year's development focused on adapting the monocoque to the new powertrain and suspension concept.

Our goals for the season were to modify and adapt the monocoque to the new car concept, package all internal components optimally, and keep the mass as low as possible.

## 1.1 MONOCOQUE

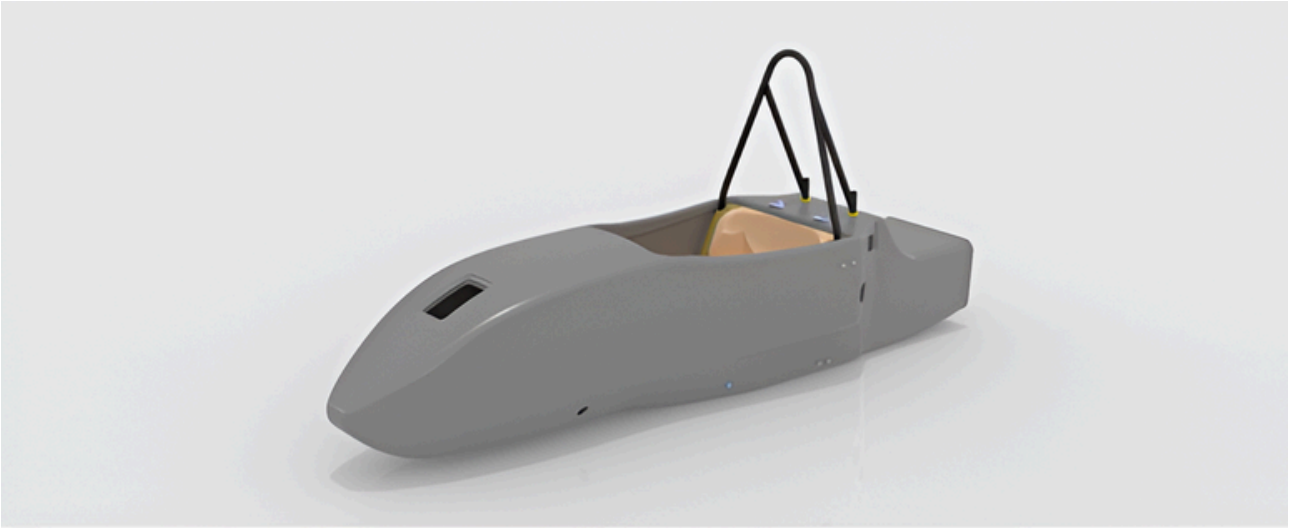


Figure 1.1: 3D model of the monocoque.

Compared to last year, the shape of the monocoque has changed completely to accommodate the changes to the powertrain and suspension. Further adjustments were made in line with the requirements of the aerodynamics department. During the design phase, we followed "design for manufacturing" principles to simplify production. We also reshaped the rear of the car for the new battery shape and adapted the cockpit so that the roll hoop could be moved to the inside of the monocoque, saving some weight here as well.

We also changed the tube used in the front hoop from a round to a square profile, which eliminated the additional fillers around the hoop and reduced the risk of manufacturing errors. The front hoop is laminated into the monocoque between its outer and inner skins, while the main hoop is bolted to the monocoque after manufacturing.

# 1.2 LAMINATION

This year's layup was based on a detailed analysis of different carbon fibre orientations. We used a combination of plies oriented at 0°/90° and ±45°, which ensures an optimal distribution of load-bearing properties with respect to the load directions. The base material was carbon fibre with an areal weight of 430 g/m$^2$. For the cores, we combined different materials: aluminium honeycomb, aramid honeycomb and Rohacell foam. Experimental validation showed deviations of less than 5 % compared to numerical simulations. We also changed how some of the fillers are made, which saved time during manufacturing. After lamination, we 3D scanned the monocoque; the largest deviations from the 3D model were approximately 2 mm.

| **0°/90° and ±45°** | **430 g/m$^2$** | **< 5 %** | **≈ 2 mm** |
|---|---|---|---|
| CARBON FIBRE ORIENTATIONS | CARBON FIBRE | VALIDATION DEVIATION | MAX. 3D SCAN DEVIATION |

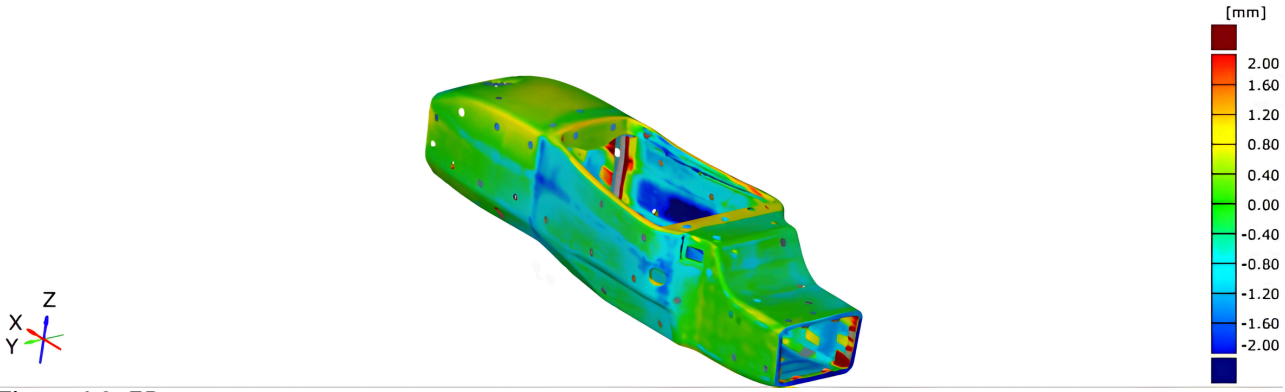



Figure 1.2: 3D scan.



Figure 1.3: Finished chassis.

# 1.3 CRUMPLE ZONE

The impact attenuator is one of the key safety elements of our car. Mounted at the front of the car, it protects the driver in a frontal collision by absorbing at least 7350 J of energy, and it also prevents foreign objects from intruding into the cockpit.

This season we started developing our own impact attenuator assembly. This year's car still uses a design that combines an aluminium anti-intrusion plate with aluminium honeycomb; the current assembly weighs 1.44 kg. During development, however, we realised that simply replacing the aluminium anti-intrusion plate with a composite one would save approximately 1 kg across the whole assembly while still meeting all the requirements of the rules. The project is still in the testing phase, and we hope to implement it in future seasons.

**≥ 7350 J**
ABSORBED ENERGY

**1.44 kg**
ASSEMBLY MASS

**≈ 1 kg**
POTENTIAL MASS SAVING



Figure 1.4: Impact attenuator.

# 1.4 COCKPIT

At the drivers' request, we kept the same seat and steering wheel position as on the previous car. The shape of the seat was based on a 3D scan of a moulded impression of the driver and partially adapted to the new shape of the monocoque. We optimised the seat laminate, which helped reduce its mass. We also built a new steering wheel to support the car's new concept for displaying information to the driver.

# 2. POWERTRAIN

For the 2026 season, we decided to completely redesign the powertrain. After three seasons of rear-wheel drive, we developed four-wheel drive (4WD) for the first time, with each wheel driven by its own electric motor with an integrated two-stage planetary reduction gearbox. We also developed our own inverters for the motors and moved from a 400 V battery to a 600 V system. The redesign enabled better power transfer from the battery through the electric motors and gearbox to the wheels and the road. To keep the car relatively light despite all this, we opted for air cooling of both the electric motors and the inverters.

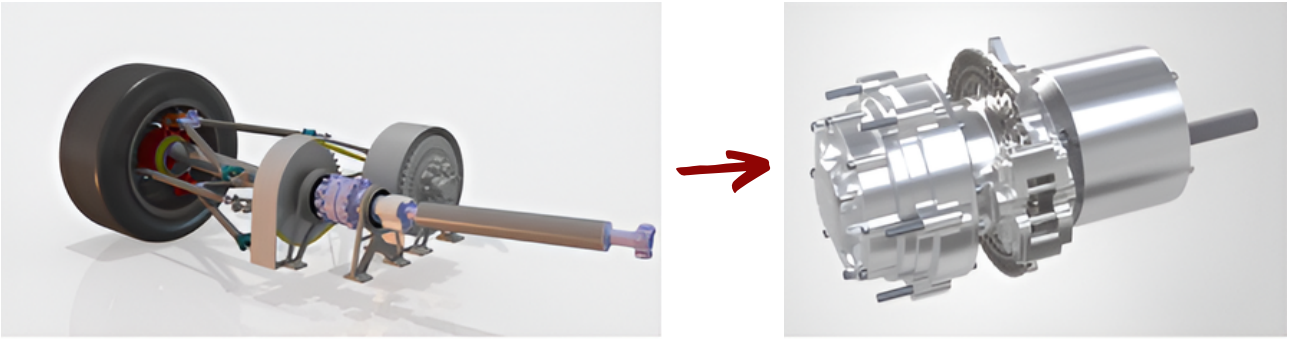


Figure 2.1: Powertrain redesign.

## 2.1 WHY FOUR-WHEEL DRIVE (4WD)

Switching to four-wheel drive allowed us to make better use of the available power (80 kW). With two-wheel drive, the amount of power that can be transferred to the road is limited mainly by the grip of the two rear wheels. By distributing torque to all four wheels, we reduce the chance of any single wheel slipping, which is especially important under acceleration.

Four-wheel drive also makes torque vectoring possible, allowing us to control the torque at each wheel independently every few milliseconds. This further improves the car's cornering behaviour and the use of the available grip.

## 2.2 ELECTRIC MOTOR

The powertrain uses four 30 kW PMSM electric motors, developed in cooperation with Fischer Elektromotoren from Germany. Fischer supplied the stators and rotors, while we designed and manufactured the mechanical parts of the motors ourselves, including the drive shafts, housings and cooling system.



Figure 2.2: Visit to Fischer Elektromotoren.

The electric motors are designed so that they can be reused in the next season if needed, giving us more flexibility in the further development of the powertrain.

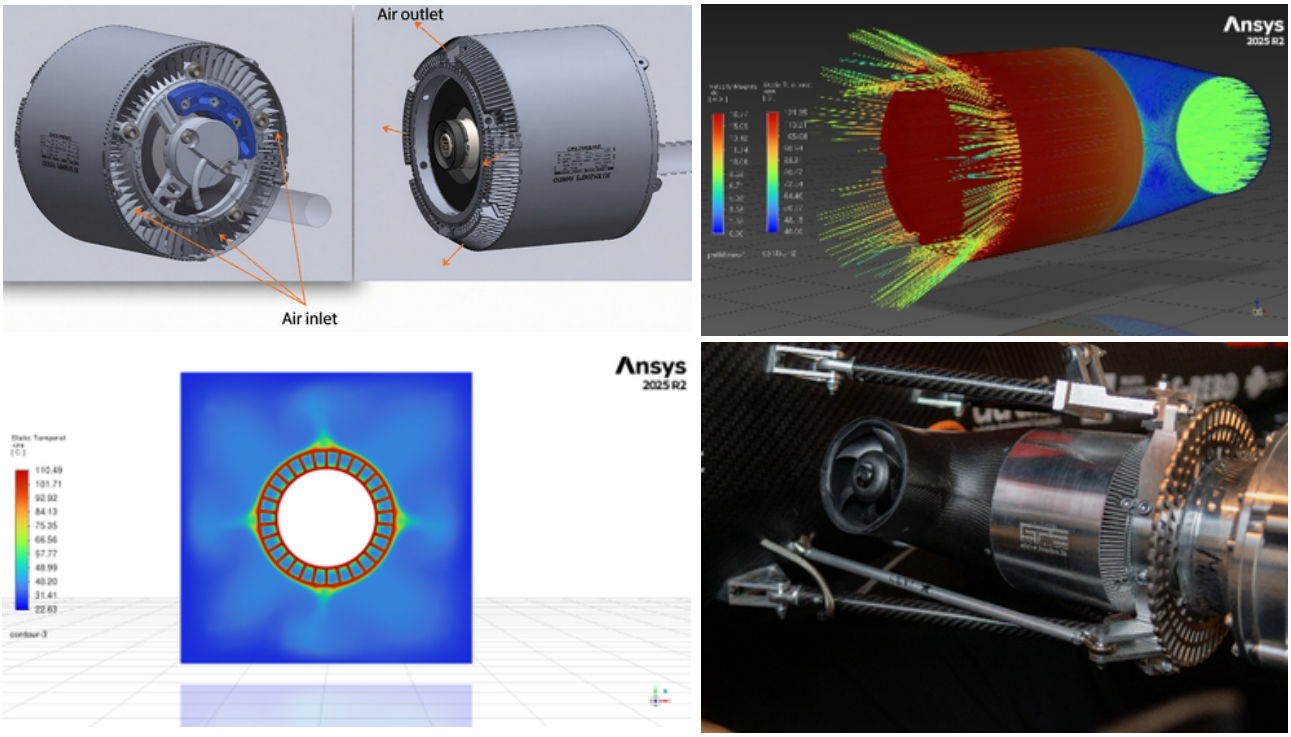



Figure 2.3: Air cooling of the electric motors.

We chose air-cooled motors because this design reduces the mass of the entire cooling system. Cooling performance was verified with simulations in Ansys, assuming 2 kW of power loss in the motor. The results showed that with air cooling, the motor temperature does not exceed the permissible 130 °C. Because of the limited space around the rim, we paid close attention to the shape of the cooling fins and the choice of a suitable fan, which resulted in a more compact cooling system with sufficient heat dissipation.

The motor housings were 3D printed in aluminium and then machined, while the drive shafts were made from titanium. The internal spline of the shafts was produced by sinker EDM.

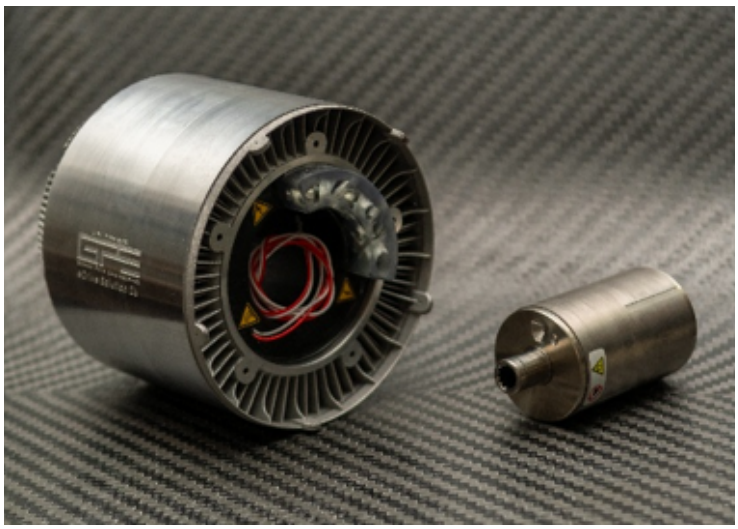


Figure 2.4: Finished electric motor and drive shaft.

**4 × 30 kW**

PMSM ELECTRIC MOTORS

**FISCHER ELEKTROMOTOREN**

STATORS AND ROTORS

**3D PRINTING**

ALUMINIUM HOUSINGS

# 2.3 PLANETARY GEARBOX

The electric motors reach speeds of up to 18,000 rpm, so a reduction gearbox was needed to transmit power to the wheels. We chose a two-stage 2AI-type planetary gearbox, which reduces speed and increases torque in a very compact package. We built a dedicated gearbox for each of the four drive units.

The gear ratio was determined through OptimumLap simulations of the acceleration event and an average AutoX track. The optimal ratio for our car was between 11 and 12; we chose 11 because it allowed better integration of the gearing into our drive unit.

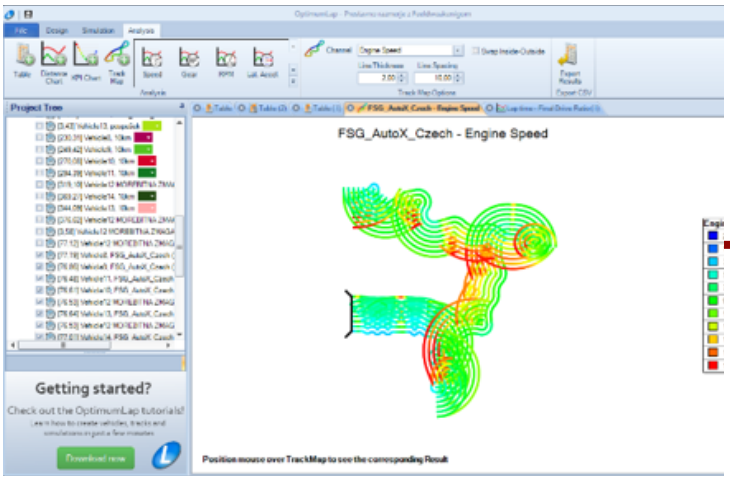


Figure 2.5: Simulations in OptimumLap.

The gearing, shafts and bearings were sized in KISSsoft. For the gears, which took the most development time, we defined the appropriate geometry of the gear pairs and checked the tooth root and flank load capacity. We also carried out contact analyses and backlash analyses.

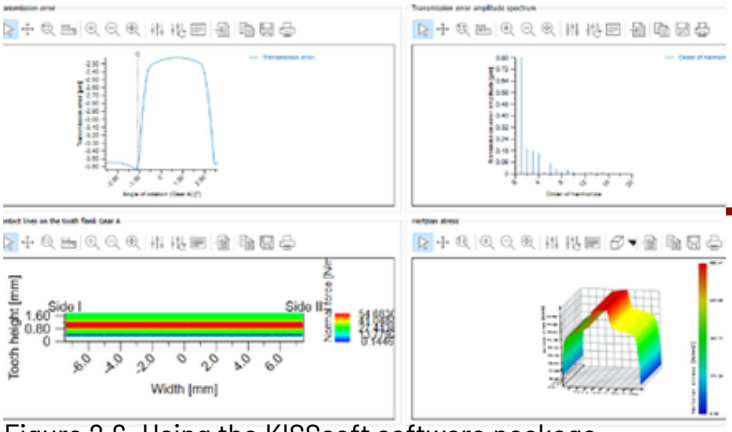
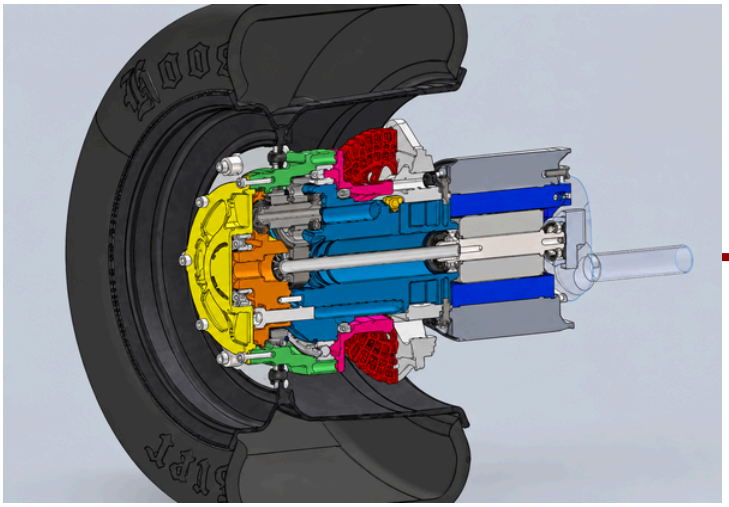


Figure 2.6: Using the KISSsoft software package.

The gears were then manufactured by wire EDM, which made it possible to produce the required geometry. The final models and gearbox integration were done in SolidWorks. During integration, we paid particular attention to fitting the brake calipers into the limited space inside the rim.

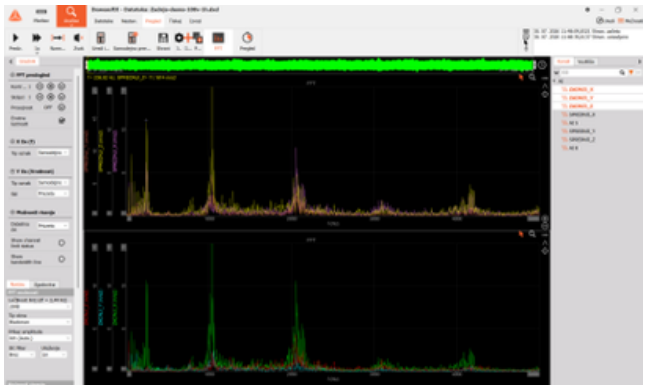

Figure 2.7: Final model.

For gearbox lubrication, we worked with ABC Maziva to select an oil suited to the demanding operating conditions in our gearbox.



Figure 2.8: Manufactured planetary gearbox parts.

After manufacturing, we assembled the gearboxes and ran them in at various speeds and loads. During the run-in, we also monitored gearbox vibrations (NVH) using accelerometers and a Dewesoft data acquisition system.

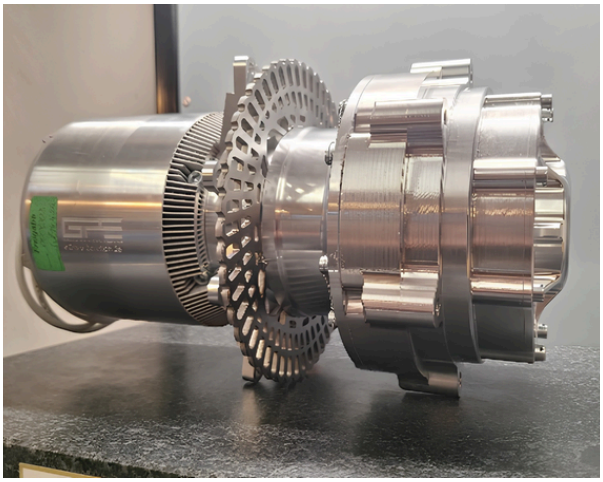


Figure 2.9: Testing and vibration analysis of the planetary gearbox.

We completed the development of the drive unit with four manufactured and tested planetary gearboxes, delivering a total power of 80 kW (as limited by the rules), 174.5 Nm of torque per wheel (698 Nm in total) and a top speed of 130 km/h.

**80 kW**
TOTAL POWER

**698 Nm**
TOTAL TORQUE

**130 km/h**
TOP SPEED



Figure 2.10: Assembled planetary gearbox and final drive unit.

# 2.4 HIGH-VOLTAGE BATTERY

This season we decided to completely redesign our high-voltage battery, from its shape and choice of cells to its control electronics.

## CELL SELECTION AND SEGMENT DESIGN

We once again chose cylindrical lithium-ion cells, this time the Reliance INR21700 RS50. We selected them for their combination of higher energy density and better thermal properties compared to cells from other suppliers.

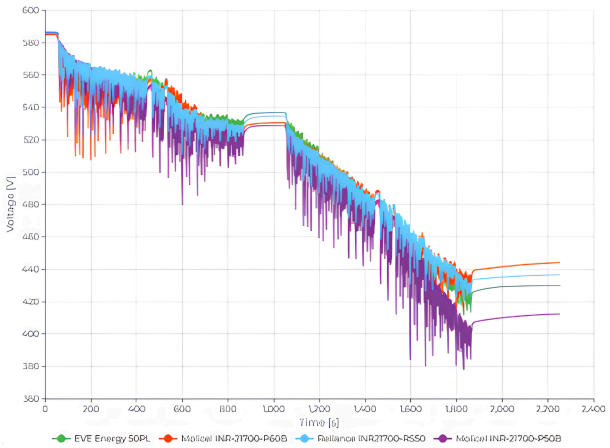


Figure 2.11: Simulated accumulator voltage for different candidate cells.

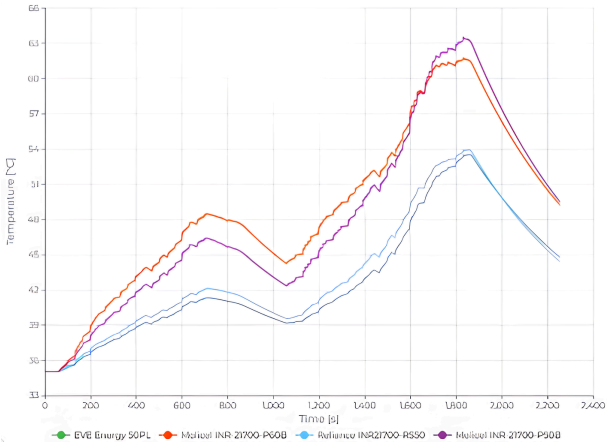


Figure 2.12: Simulated accumulator temperature for different candidate cells.

The high-voltage battery consists of 10 segments connected in series, each with cells connected 14 in series and 3 in parallel. This gives the battery a maximum voltage of 588 V and a capacity of 7.56 kWh.

| | | | |
|---|---|---|---|
| **RS50**<br>RELIANCE INR21700 | **588 V**<br>MAXIMUM VOLTAGE | **7.56 kWh**<br>CAPACITY | **40 kg**<br>BATTERY MASS |

This configuration allows an efficient layout and a mass of 40 kg while providing a high current capability (70 A continuous per cell). Laser-welded copper interconnects, 3D-printed cell spacers and a simplified cooling strategy continue to ensure mechanical robustness and thermal reliability.

## HOUSING

Compared to last year, the housing was modified to accommodate the new segment configuration, and the entire high-voltage battery was made narrower to meet the requirements of the chassis department. We still use aluminium panels for optimal mass and flexibility.

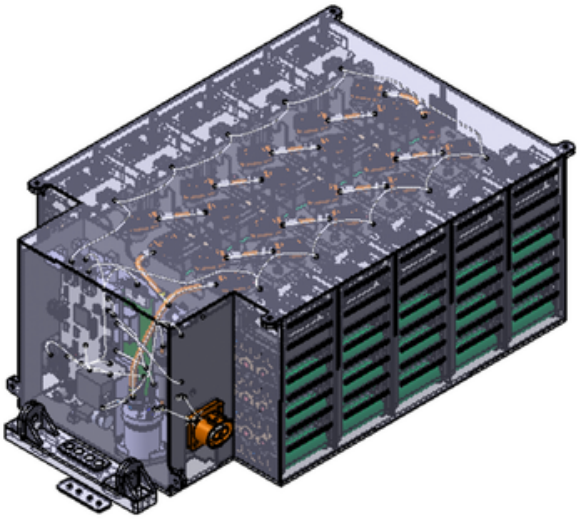


Figure 2.13: 3D model of the battery.

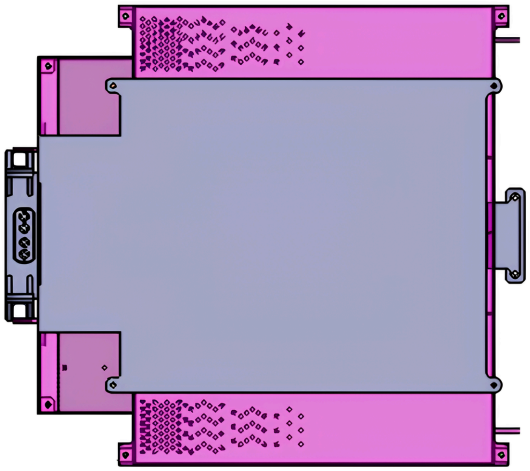


Figure 2.14: Comparison with last year's battery.



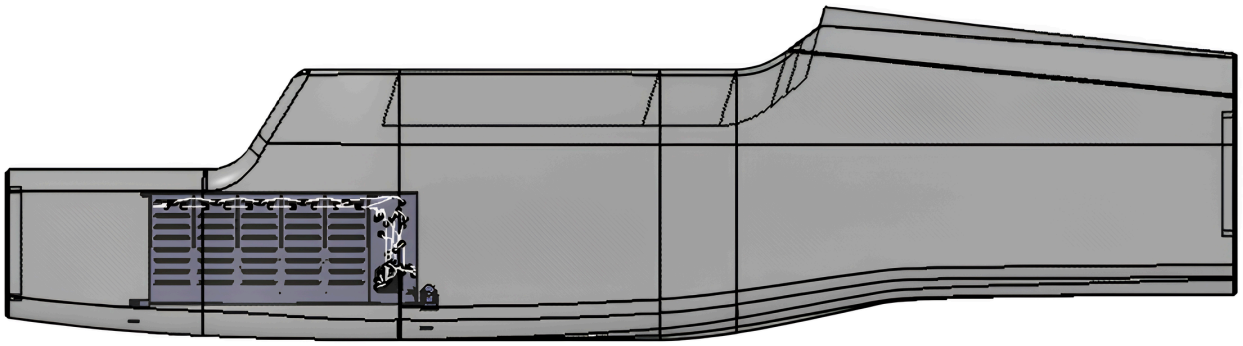
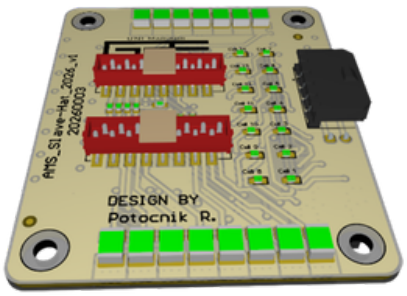
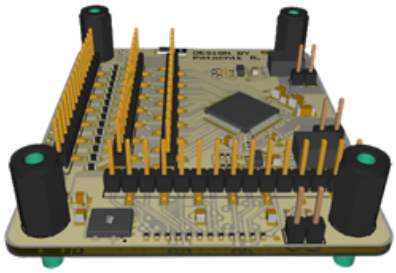


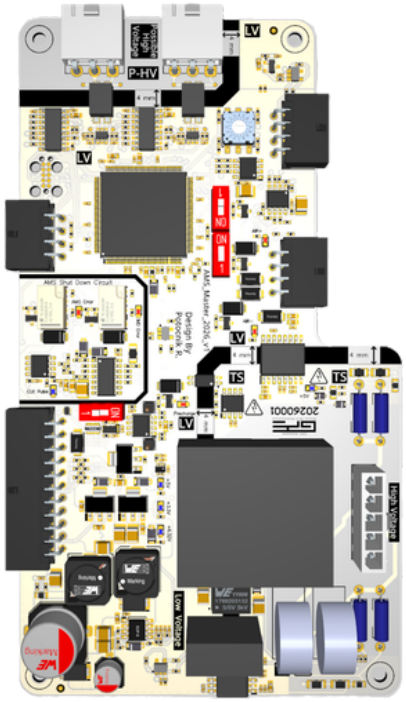
Figure 2.15: Placement in the chassis.

## HIGH-VOLTAGE BATTERY ELECTRONICS




We also developed a new version of the AMS. The main AMS PCB is the central control unit, combining several key functions, including the precharge circuit and the relay logic for the IMD and AMS. Each battery segment contains slave modules that enable accurate temperature and voltage measurement on every cell, while flexible circuits connect the boards to the cells.





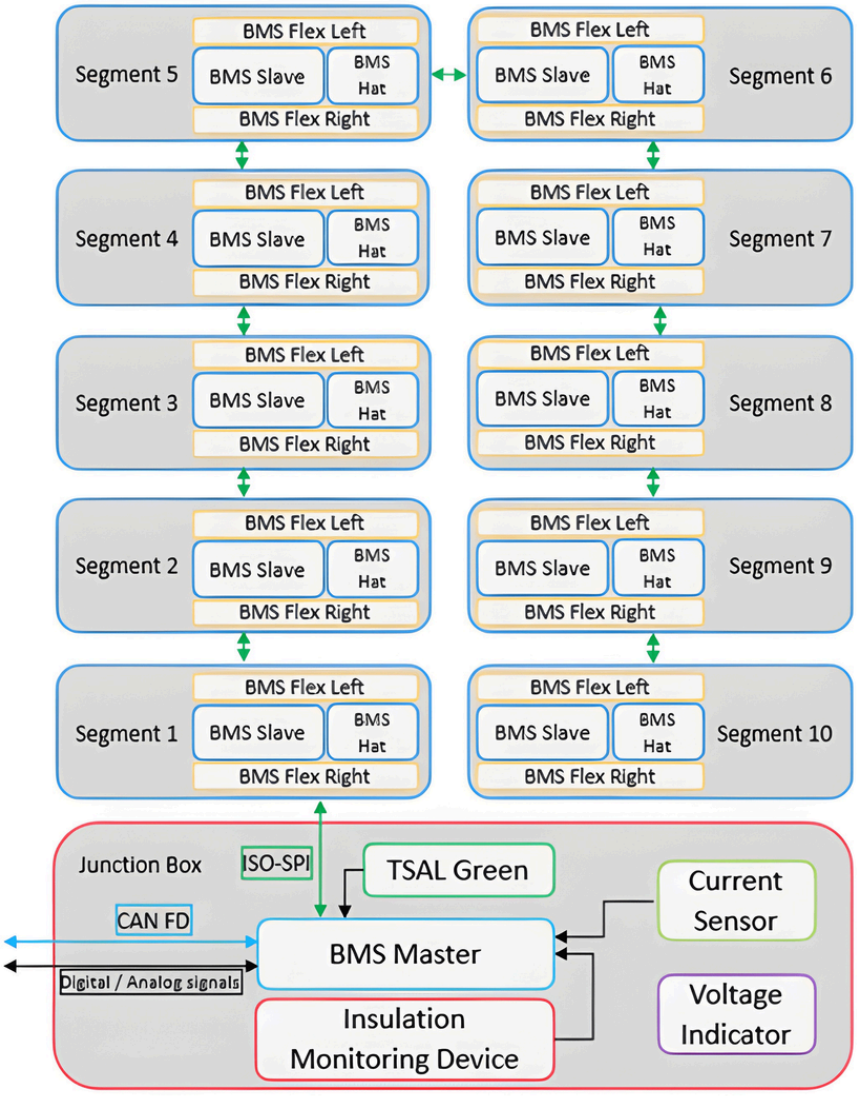



Figure 2.16: AMS system.

# 2.5 INVERTER

This season brought a completely new powertrain concept for the car. Instead of a single motor driving the rear wheels, we moved to four independent electric motors, which also required the development of four in-house inverters. This change was one of the electrical department's biggest development undertakings of the season.

## REQUIREMENTS

The starting point for the inverter design was the requirements of the selected Fischer Elektromotoren motor: a maximum torque/phase current of 20 Nm / 41 Arms, a maximum speed of 20,000 rpm, corresponding to an electrical frequency of 1333 Hz, and a continuous power of 20 kW per motor. The inverter had to withstand a DC voltage of up to 600 V, and its mass was limited to 3–5 kg. Due to space constraints and for simplicity, we opted for air cooling.

## COMPONENT SELECTION

For the switching elements, we chose a three-phase SiC MOSFET bridge, which allows higher switching frequencies and lower losses than conventional IGBTs. Phase current is measured via a shunt resistor combined with an isolated operational amplifier, and the DC link is smoothed by 12 film capacitors rated at 20 µF and 1100 V. Rotor position is sensed with a Hall-effect rotary encoder. Control is handled by an STM32H7 microcontroller, and communication with the other vehicle systems runs over a CAN FD bus.

## COOLING

The inverter is designed for air cooling. Our analysis showed that at 5 kW of effective (RMS) power per motor, the cooling system has to dissipate approximately 200 W of heat loss per inverter. The heat sink design was verified with CFD simulations (Ansys) and then confirmed on a physical prototype.

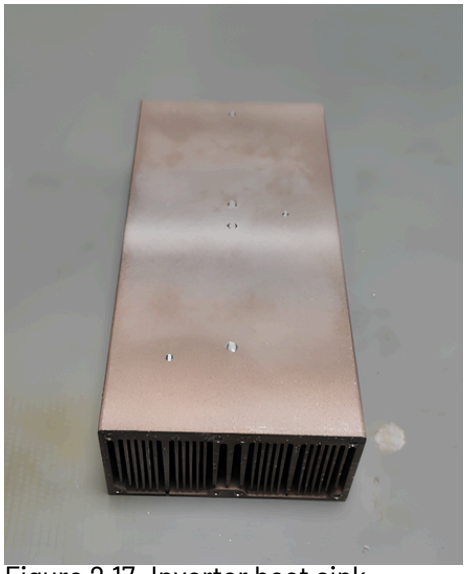


Figure 2.17: Inverter heat sink.

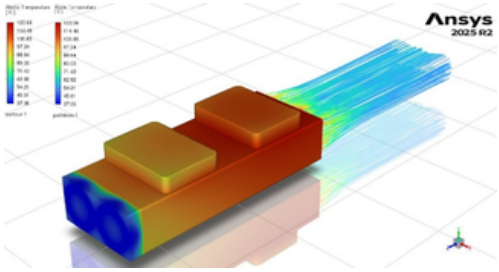



Figure 2.18: Heat sink simulation.

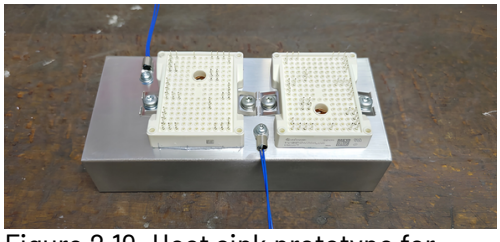


Figure 2.19: Heat sink prototype for simulation validation.

## INVERTER CHARACTERISTICS

The finished design achieves a peak phase current of 44 Arms and a peak power of 27.5 kW, while withstanding a DC voltage of up to 800 V, a considerable margin above the original 600 V requirement. A pair of inverters (for two motors) weighs only 2.35 kg in total, which corresponds to a gravimetric power density of 23.4 kW/kg.

## PRINTED CIRCUIT BOARDS

The inverter consists of three interconnected printed circuit boards: the power board, which connects to the high-voltage battery and the motors; the control board, which carries the microcontroller and manages the inverter; and an interface board, which connects the two boards while isolating them from each other.

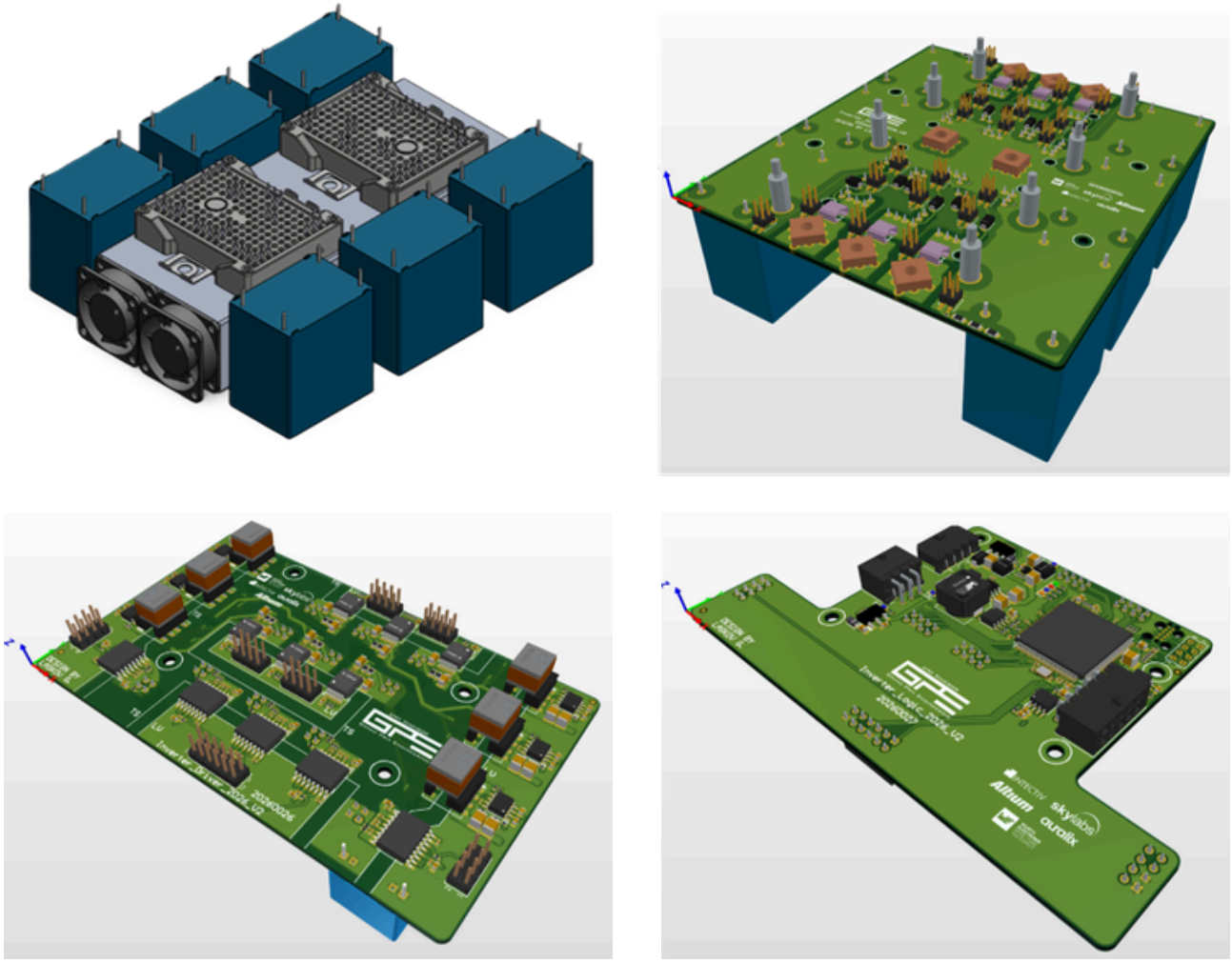


Figure 2.20: Individual inverter PCBs.

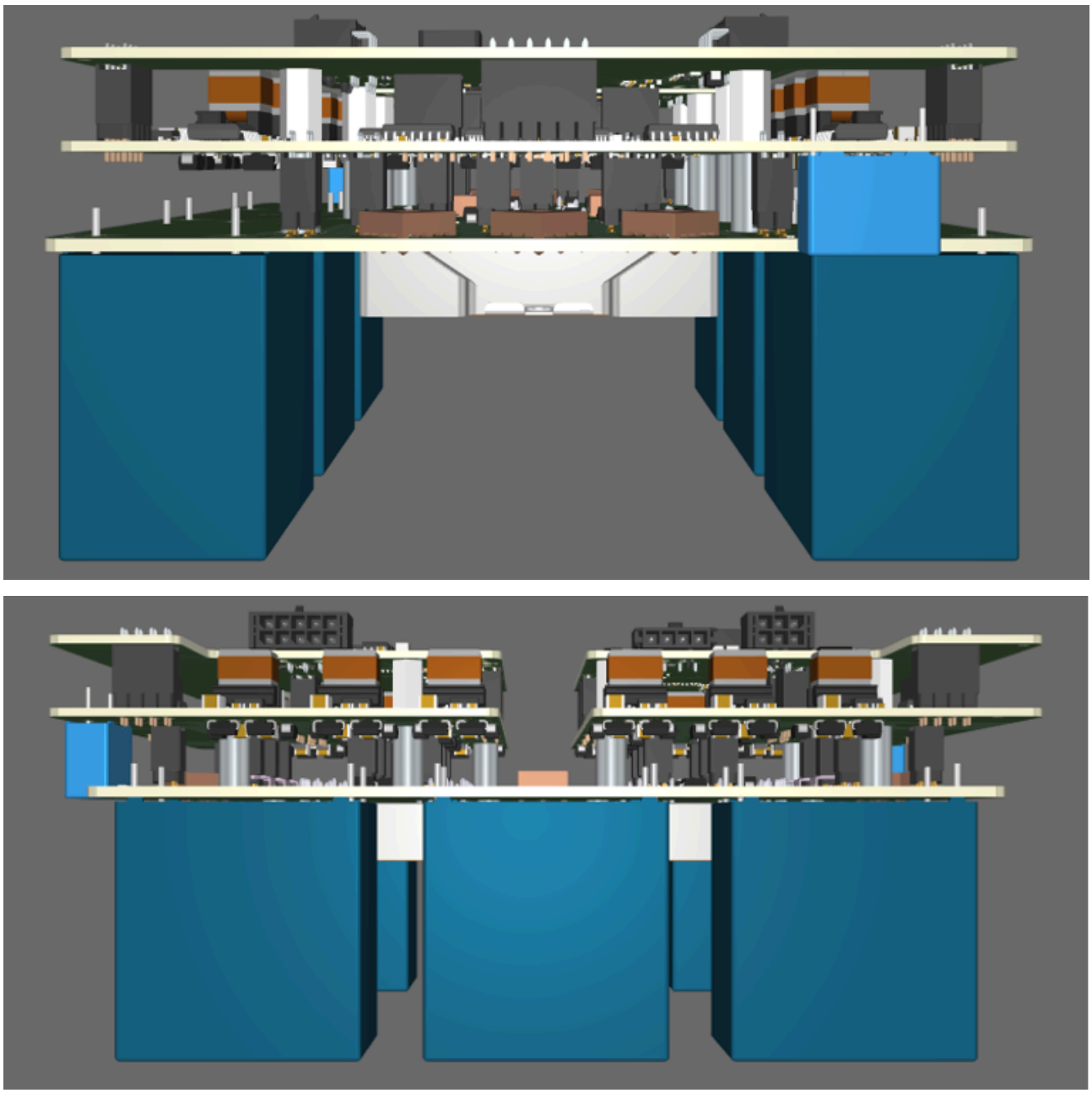


Figure 2.21: Side views of the assembled inverter.

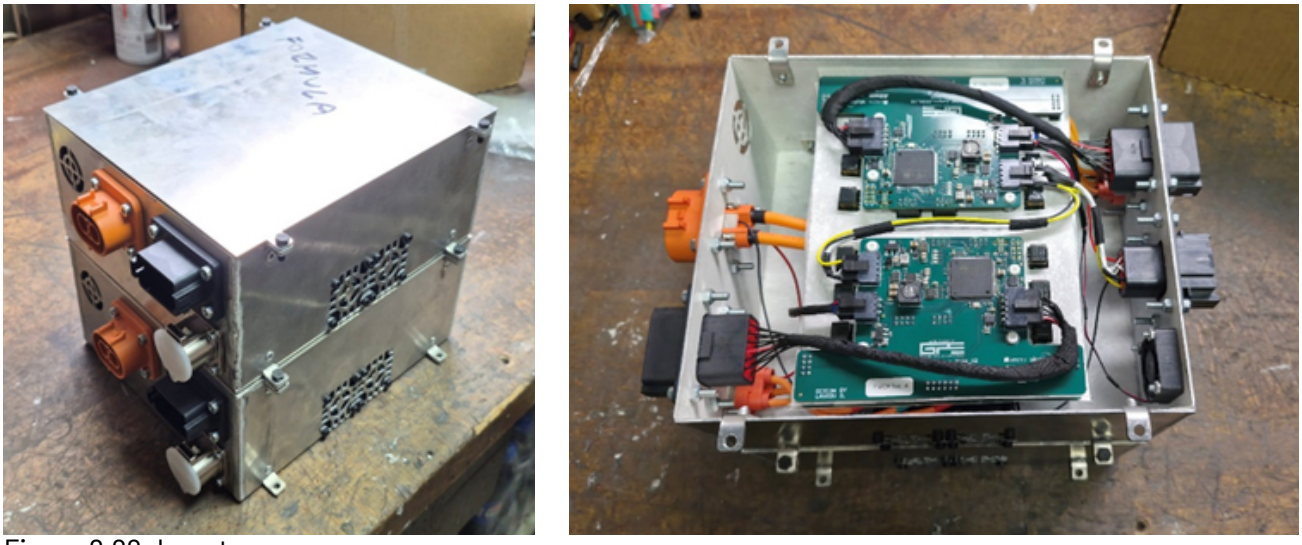


Figure 2.22: Inverter.

# 3. ELECTRONICS

The electrical department is divided into three sub-departments: electronics (printed circuit boards), wiring harnesses and software. Last season we laid solid foundations for the electrical system, and this year we built on them and improved them further in all three areas.

Rather than extensive development of new electronic systems and mass reduction, this season we focused primarily on improving the reliability of existing systems. We therefore avoided introducing new solutions unnecessarily and concentrated on eliminating shortcomings and improving proven designs. This reduced the scope of new development and allowed us to devote more time and resources to other key systems of the car.

Our goal was to build an electrical system that is simpler to use, easier to diagnose and, above all, more reliable throughout testing and competitions.

## 3.1 PRINTED CIRCUIT BOARDS AND CONTROL SYSTEMS

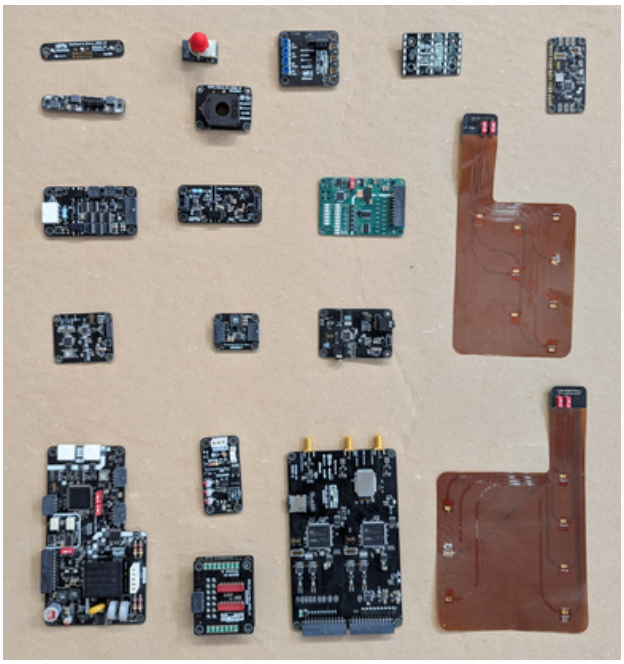


Figure 3.1: The new printed circuit boards.

This season, PCB development built on the experience and issues we identified on last year's car. In total, we designed 20 new printed circuit boards, most of them aimed at fixing faults, improving existing designs and increasing the reliability of the electrical system. We kept the proven functionality of the previous design and adapted it to new requirements where necessary.

**20**

NEW PCB DESIGNS

The only major new development in the PCB area was the inverter boards, developed as part of this year's powertrain redesign. We also thoroughly redesigned the AMS (Accumulator Monitoring System) boards, mainly due to changes in the accumulator design and the requirements of the new powertrain. Both systems are therefore described in more detail in the powertrain chapter.

We manufactured all our PCBs in-house. Assembly is done with a pick-and-place machine and a vapour-phase soldering oven, enabling precise, repeatable production and better quality control.

IN-HOUSE PCB DEVELOPMENT

PICK & PLACE ASSEMBLY

VAPOUR-PHASE SOLDERING

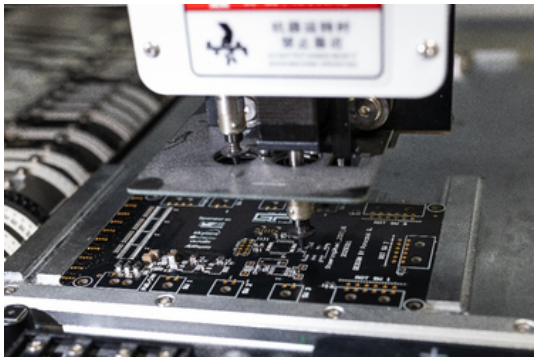


Figure 3.2: Placing PCB components.

## 3.2 SOFTWARE

In software development, we focused mainly on improving the existing monitoring and data acquisition systems. We redesigned the application for monitoring the state of the HV battery and adapted it to the new system requirements.

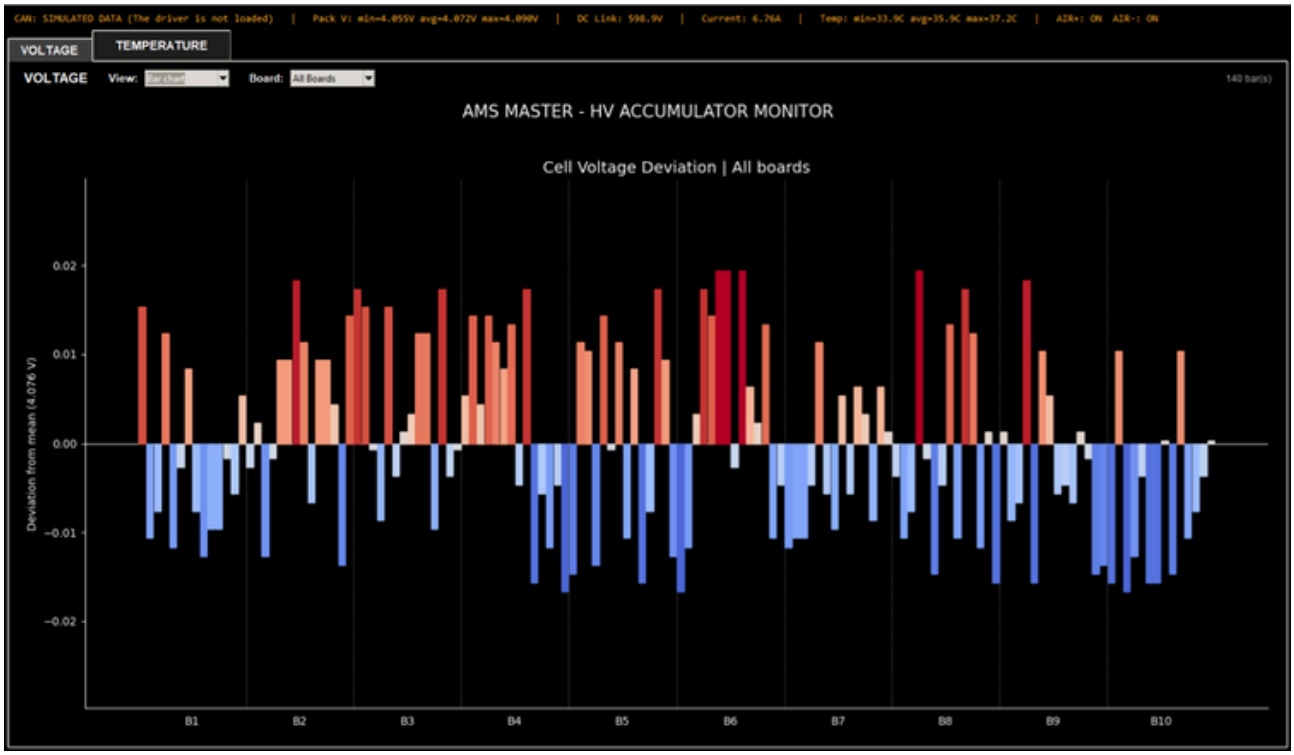



Figure 3.3: HV battery monitoring application (with mock data).

We also improved the SD card data logging system. Logging was made faster and optimised so that every message transmitted on both of the car's CAN buses is stored on the card. During driving, the data is stored in raw form: it is held temporarily in a memory buffer and then written to the SD card in larger blocks.

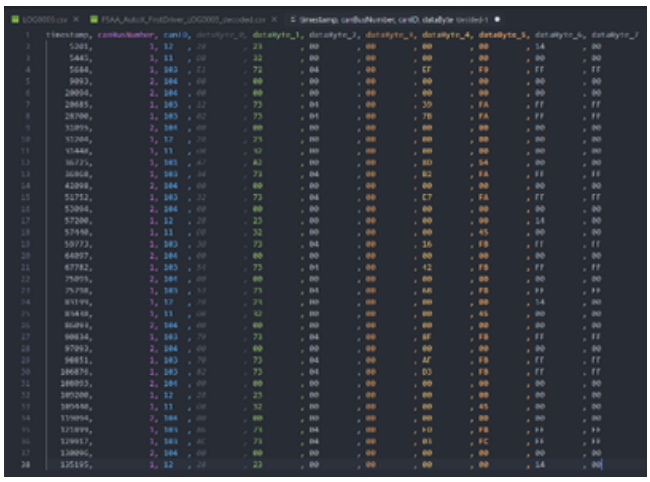


Figure 3.4: Raw CAN bus data.

After a run, the raw CAN data is processed on a computer, where it is converted into usable data for analysis. This shifts most of the processing from the car to the computer, reducing the processor load while driving.

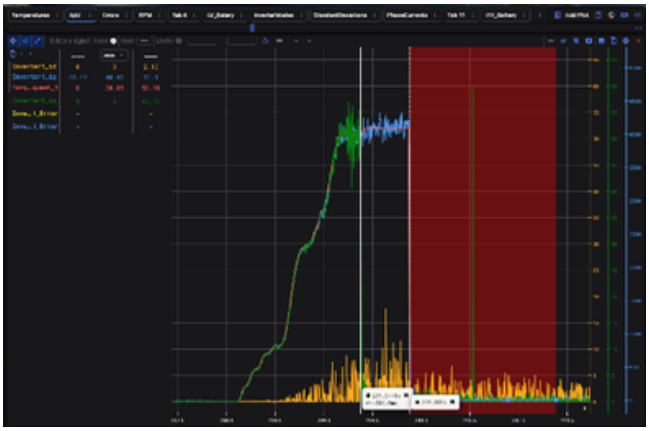


Figure 3.5: Display of logged data.

We kept the live telemetry from the previous season but changed the way data is displayed. Instead of our own application, we now use Foxglove, which offers a clearer view of larger amounts of data and makes it easier to monitor the car during testing.



Figure 3.6: Live data display.

# 3.3 WIRING HARNESS

The wiring harness design was adapted to the car's new monocoque and the revised component layout. Because of the changed vehicle geometry, cable routes had to be redefined and cable lengths adjusted. The biggest changes were in the high-voltage wiring, as this year we had to connect all four motors for the first time, whereas last year's design connected only one.

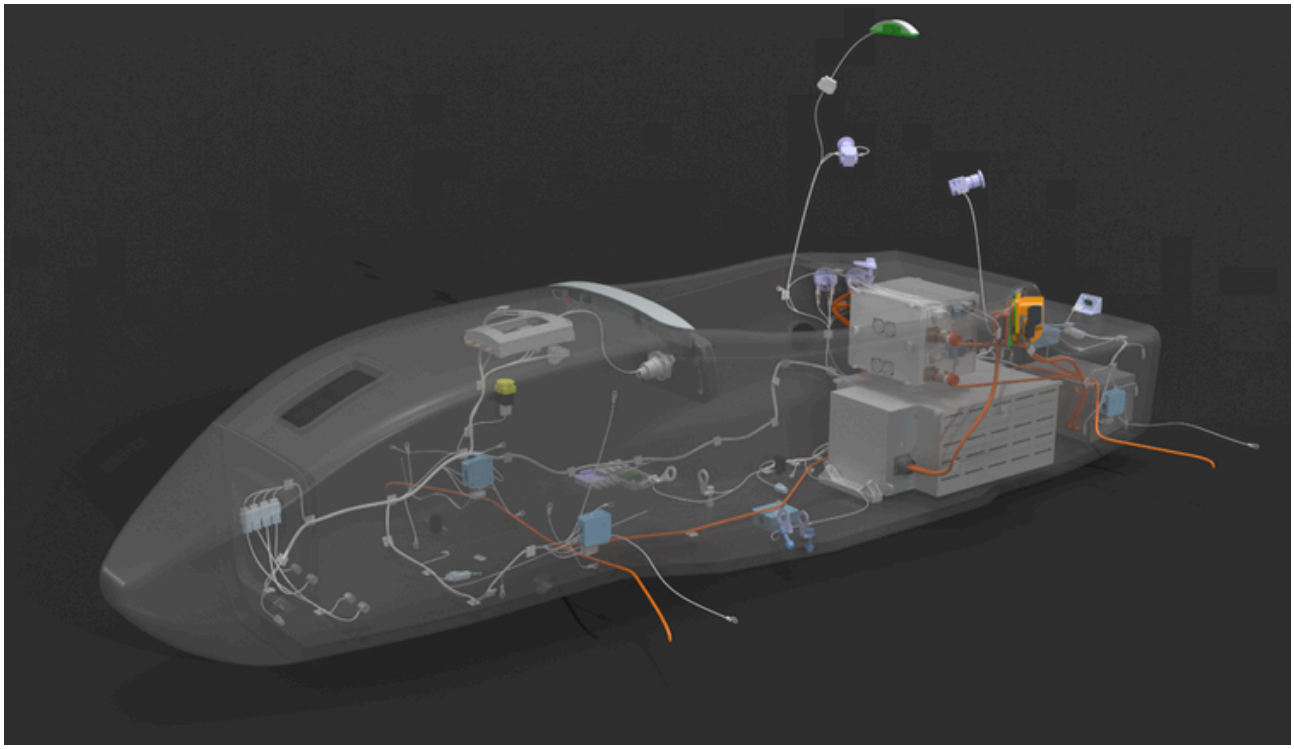


Figure 3.7: 3D model of the wiring.

As in previous years, the design process began with a 3D model of the wiring harness placed within the 3D model of the whole car. From the final 3D model, we created a flattened layout ("flattening"), which we used to build the harness. The flattened layout was printed at a 1:1 scale, allowing us to determine the length of each wire accurately and build the harness repeatably.

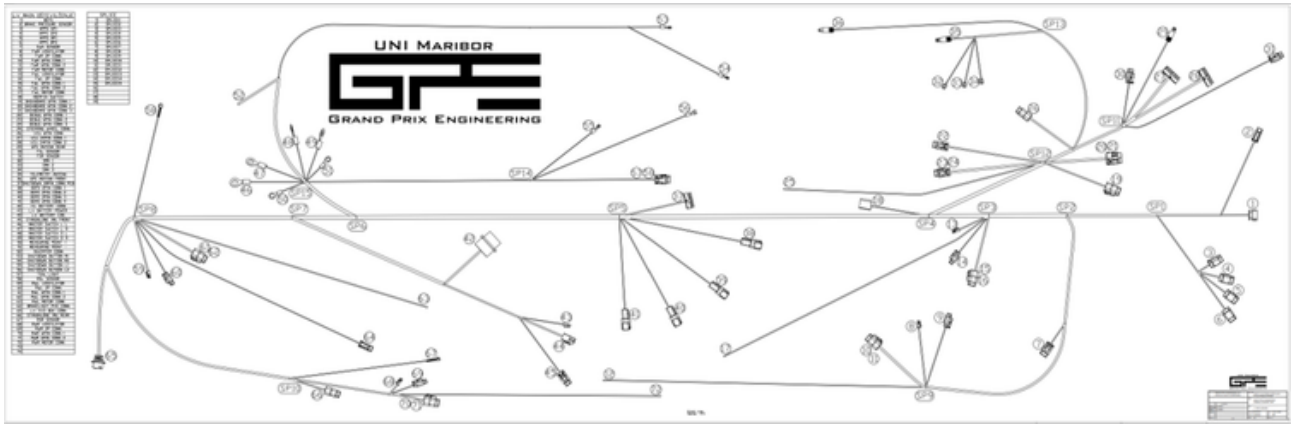



Figure 3.8: Flattened wiring layout.

# 4. SUSPENSION AND VEHICLE DYNAMICS

## 4.1 INTRODUCTION AND SEASON GOALS

In the 2025/26 season, suspension development was driven mainly by the need to adapt to the car's new powertrain. Our starting point was the experience from previous seasons. We approached the development of geometry and suspension systematically: from tyre and kinematic analysis to evaluating the effect of changes on the balance of the whole vehicle.

Our aim was not simply to find the optimal value of each individual geometric parameter. The main goal was to align tyre behaviour, suspension kinematics and vehicle response so that the driver gets a stable, predictable and consistent car. An important part of the season was also the implementation of a new front suspension system, which had to make the intended geometry feasible in practice.

### KEY DEVELOPMENT GOALS

| | |
|---|---|
| 01 | Ensure stable and predictable vehicle balance through corners. |
| 02 | Improve tyre operating conditions with appropriate camber and toe curves. |
| 03 | Implement a new front suspension system. |
| 04 | Eliminate or reduce the understeer tendency of previous seasons. |

# 4.2 DEVELOPMENT APPROACH AND GEOMETRY

## 4.2.1 TYRES AND DEFINING TARGET PARAMETERS

Tyres are the car's only contact with the road, so geometry development was closely tied to understanding their behaviour. Because the new powertrain increased the demand for grip, the GPE26 moved to the wider version of the Hoosier LC0 tyre (from 6" to 7.5" width).

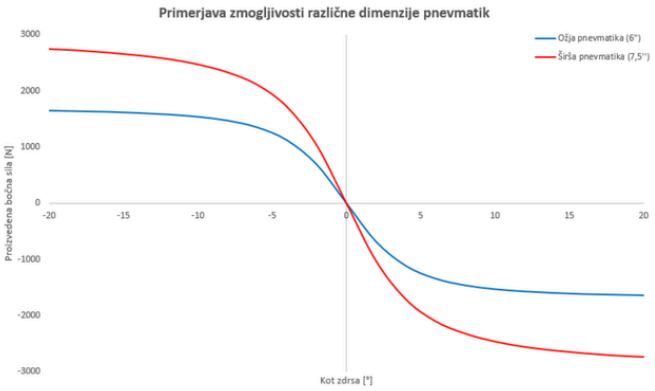



Figure 4.1: Performance of the 6" vs. 7.5" tyre.

In OptimumTire2, we analysed how vertical load, slip angle, camber and other parameters affect the tyre's ability to generate lateral and longitudinal forces, and compared the results with the narrower tyre from previous seasons. The aim was not merely to increase peak grip, but to ensure the most favourable and consistent tyre operating conditions in the range actually seen on track.

We used the results to define the target camber curve through suspension travel. At the same time, we monitored toe, as unwanted toe changes can cause bump steer and reduce the car's predictability.

**6" → 7.5"**

## 4.2.2 SUSPENSION GEOMETRY DEVELOPMENT

The front and rear axle geometry was developed in OptimumKinematics. Particular emphasis was placed on parameters that directly affect tyre utilisation and vehicle balance: camber gain, toe gain, and roll centre position and migration. What mattered was not only the static setup, but above all how each parameter changes throughout the working suspension travel.

At the front axle, the geometry was developed with the clear goal of increasing front tyre utilisation and thereby reducing understeer. Changes to pickup point positions were therefore evaluated by their combined effect on camber, toe and roll centre rather than in isolation. The final solution was a compromise between the desired kinematics, the available space and the design requirements of the new suspension system.

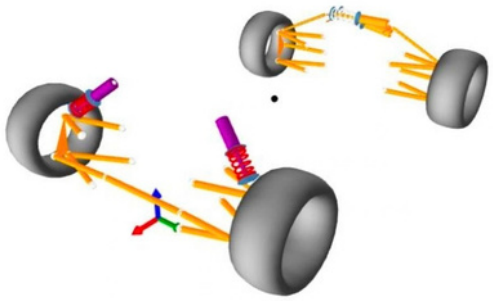


Figure 4.2: GPE26 geometry in OptimumKinematics.

# 4.3 SUSPENSION DESIGN AND VEHICLE BALANCE

## 4.3.1 NEW FRONT SUSPENSION SYSTEM

One of the main development goals of the season was implementing a new front suspension system. The new design had to deliver the geometry defined in the kinematic analyses while meeting the car's packaging, structural and serviceability requirements.

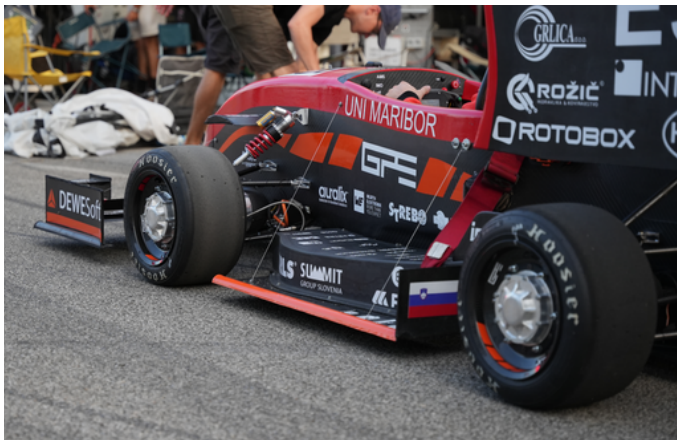


Figure 4.3: New front suspension system.

The positions of the links, mounts and suspension elements were chosen so that the system delivers the desired camber and toe curves while remaining stiff and reliable enough for track use. Another important feature of the new system is improved driver visibility, as the main spring and damper elements have been moved from the top of the chassis to its side. The new system also saved mass and reduced the complexity of the required components.

## 4.3.2 VEHICLE BALANCE ANALYSIS

After developing the kinematics, we evaluated the effect of the new geometry at the full-vehicle level. For this we used OptimumDynamics to analyse the distribution of lateral forces between the front and rear axles and the resulting yaw moment. The key tool was the Yaw Moment Diagram (YMD), which allows different geometries and setups to be compared in terms of vehicle balance.

Since previous cars tended to understeer, we looked for solutions that would make better use of the front axle and shift the balance in the desired direction. The aim was not to create a distinctly oversteering car, but to achieve a stable and predictable response through the different phases of a corner. The YMD allowed us to link kinematic changes directly to their effect on the car's behaviour.

We also used the simulation results as the basis for choosing setups before testing.

# 4.4 CONTROL SYSTEMS

This season's biggest step in vehicle control systems was the switch to a four-motor powertrain with independently driven wheels. This layout allows us to actively control the car's cornering behaviour, since the torque at each wheel can be set separately. The goal of the control systems department was to develop our own torque vectoring system together with traction control, and to validate both in a simulation environment.

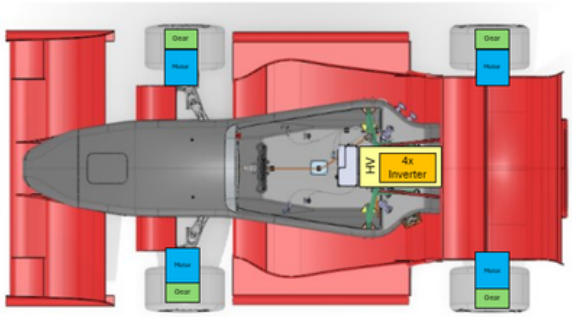



Figure 4.4: GPE26 powertrain.

## 4.4.1 CONTROL SYSTEM ARCHITECTURE

The control algorithm consists of three sequential blocks: the reference model, the controller and the torque distribution.

The inputs to the reference model block are the steering shaft angle, from which the actual wheel angle is calculated, and the current vehicle speed. Based on these two values, the model determines the reference value, i.e. the desired yaw rate of the vehicle.

The controller receives the reference value from the reference model and the actual value measured by a sensor on the car. It compares the two and, after processing, outputs a corrective torque.

The corrective torque then enters the torque distribution block, which, together with the driver's torque request, distributes it appropriately among the four wheels. The architecture of the algorithm is shown in Figure 4.5.

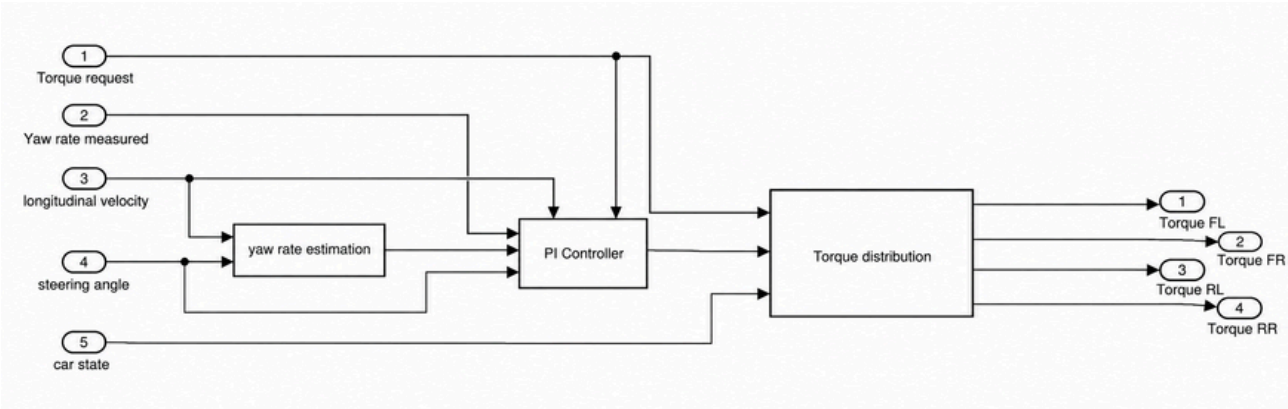



Figure 4.5: Algorithm architecture.

## 4.4.2 TORQUE VECTORING

The torque vectoring system matches the car's actual rotation to the desired one: by distributing torque between the wheels, it reduces the difference between the two and thus improves agility and cornering stability. From the steering angle and current speed, the reference model calculates how the car should rotate under ideal conditions. We call this the desired yaw rate. For this purpose we chose a linear single-track vehicle model, as it is fast enough to compute in real time while describing the car's behaviour sufficiently well.

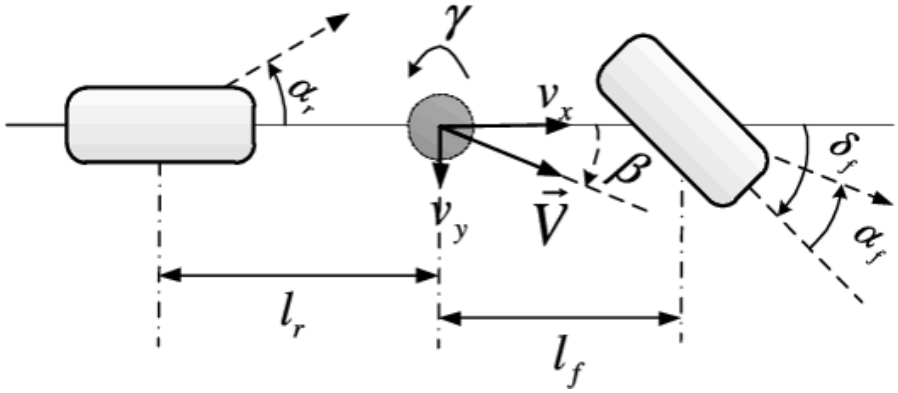



Figure 4.6: Linear single-track vehicle model.

The controller compares the calculated desired value with the actual measured yaw rate and uses the difference to detect whether the car is understeering or oversteering. Since the car responds differently at different speeds, we used speed-based gain scheduling so that the response remains equally reliable at low and high speeds.

Based on this difference, the system determines a corrective torque that "rotates" the car in the right direction: when understeering, it adds more torque to the outer wheels, and when oversteering, to the inner wheels. In the final block, torque distribution, the corrective torque and the driver's request are distributed among the four wheels. The same block also handles traction control: if a wheel spins faster than the available grip allows, its torque is limited accordingly, maintaining grip and stability under acceleration. The result is a more predictable and agile car that follows the driver's inputs more precisely through corners and contributes to faster lap times.

## 4.4.3 SIMULATION AND VALIDATION

The entire control algorithm was developed and tested in MATLAB/Simulink. In the first phase, we tested the system on a simplified vehicle model that allowed fast computation and therefore a large number of iterations, which was ideal for initial controller tuning and debugging. Once the system worked reliably at this level, we connected Simulink to IPG CarMaker, whose more detailed vehicle and tyre models provide a much more accurate representation of the car's behaviour.



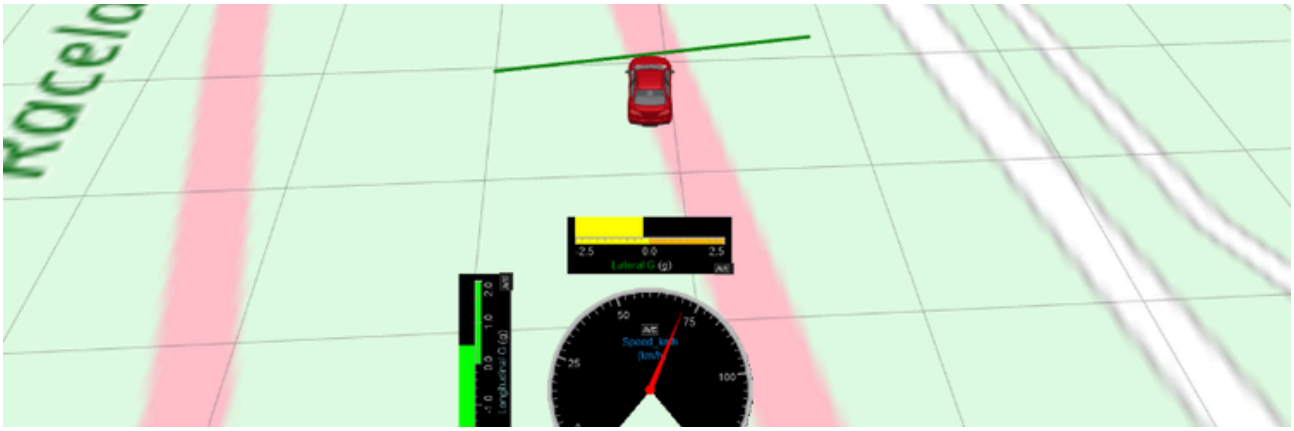
Figure 4.7: IPG CarMaker simulation environment.

We tested the system on standard manoeuvres, such as driving on a circle (Skidpad), acceleration and an Autocross track, observing how well the car followed the desired yaw rate and how the traction control performed. This approach allowed us to fully tune and verify the algorithm in a safe and repeatable virtual environment before transferring it to the real car.

# 4.5 TESTING AND SEASON REVIEW

## 4.5.1 TESTING AND VALIDATION

Due to the major changes to the car concept and the large amount of work involved, simulation validation and test data acquisition are continuing after the season. Here we rely on DEWESoft measurement equipment and, as a new addition, the Polygon plugin within DEWESoftX. It enables automatic start and stop of data logging based on location, easier comparison of selected parameters on chosen track sections, automatic sector and lap timing, and much more. All of this lets us focus on the car setup itself much more easily and in greater detail during testing.


Figure 4.8: Testing with DEWESoftX Polygon.

## 4.5.2 SEASON REVIEW AND FUTURE DEVELOPMENT

The main progress of the 2025/26 season was a more integrated suspension development process and a deeper understanding of the car's behaviour. We used the tyre analysis to define kinematic requirements, carried these requirements over into the new geometry and front suspension system, and verified the effect of the final design with a full-vehicle dynamics model. This allowed us to address the understeer problem directly, instead of optimising individual components without a clear link to vehicle behaviour.

In future development, the main focus will be on quantitative model validation and the development of our own simulation tools, particularly a lap time simulation, which will give us an even more objective and clearer insight into how individual changes affect the ultimate goal: the fastest possible lap time.

# 5. AERODYNAMICS

In the 2026 season, the aerodynamics department consisted of nine members, six of them new and three experienced. The experienced members covered three key areas of work: CFD simulations and geometry optimisation, design and manufacturing, and design and cornering simulations.

Midway through the previous season we switched from Ansys CFX to Ansys Fluent, but only refined the accuracy of our simulations towards the end of the development phase. For the 2026 season, we therefore set the following goals:

| | |
|---|---|
| 01 | complete the transition to Ansys Fluent as our main simulation tool, |
| 02 | establish a procedure for cornering simulations, |
| 03 | establish a procedure for cooling simulations, |
| 04 | adapt to the new competition rules, |
| 05 | a new undertray concept. |

The undertray, which was already the central component of the aerodynamic package last year, was completely redesigned, completing a concept that had been in development for two years. The front and rear wings were then matched to the undertray.

# 5.1 SIMULATION PROCEDURE

This year, all simulations were run in Ansys Fluent, which we used from the very beginning of development. We developed separate procedures for simulating straight-line driving and cornering.

## STRAIGHT-LINE DRIVING

For straight-line driving, we use a half-car simulation in steady-state RANS mode with an inlet velocity of 14 m/s. The wheels rotate and the road moves, replicating real ground conditions. Turbulence is modelled with the SST k-ω model. The mesh is of the poly-hexcore type and has approximately 17 million elements, with refinement zones around the aerodynamic elements. The y+ value is approximately 1, meaning that the boundary layer is resolved directly.

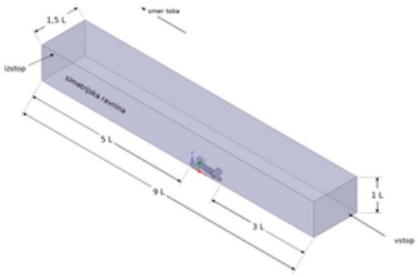


Figure 5.1: Computational domain.

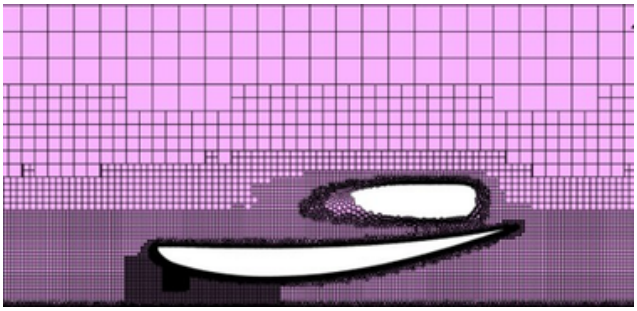


Figure 5.2: Mesh around the wing profile with refinement zones.

## CORNERING

For the first time, we also established a procedure for simulating cornering. The computational domain is shaped as a ring sector that follows the car's circular path. In addition to the overall loads and airflow under these changing conditions, the simulation shows the downforce distribution between the front and rear axles and between the left and right sides of the car.

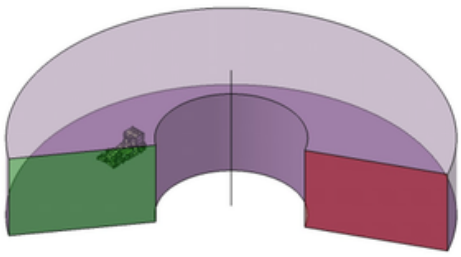


Figure 5.3: Cornering simulation domain.

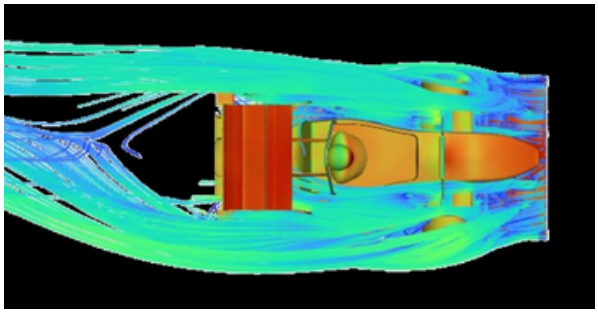


Figure 5.4: Streamlines around the car.

In corners, the aerodynamic balance shifts further rearwards (31.7/68.3 %) than on straights (40/60 %), which is important information for the vehicle dynamics department when setting up the suspension.

## 5.2 FRONT WING DEVELOPMENT

The front wing was designed with a low profile and smaller flaps to reduce the components' sensitivity to ride height. It was developed together with the nose of the car, since the flow shaped by the wing directly determines the flow to the undertray. We therefore treat the wing and nose as a single unit. In the end, we chose a design with three main elements and one smaller element on each side, which helps us achieve the aerodynamic balance of the car.

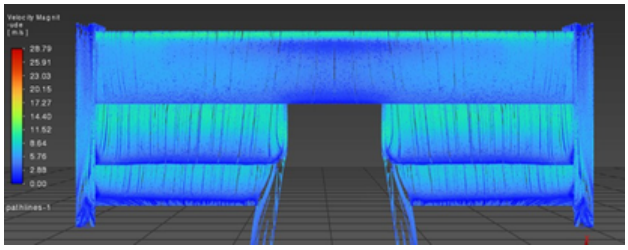


Figure 5.5: Front wing – streamlines.

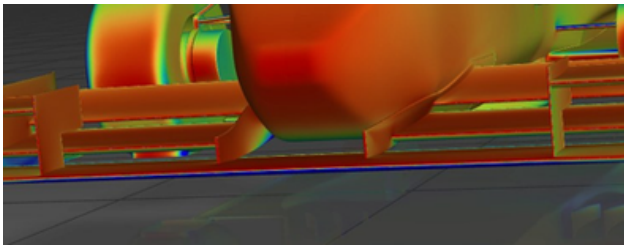


Figure 5.6: Pressure distribution around the nose.

## 5.3 UNDERTRAY DEVELOPMENT

Under the new concept, the undertray remained the central element of the package. It consists of two Venturi channels, which accelerate the flow under the car and create low pressure, and a diffuser, which gradually slows the flow and guides it out behind the car. We added 3 vortex generators to each tunnel to strengthen the low-pressure region, and an icebreaker element to redirect the airflow into the channels. After 63 iterations, we arrived at a working concept that is not overly sensitive to changes and still has plenty of room for improvement.

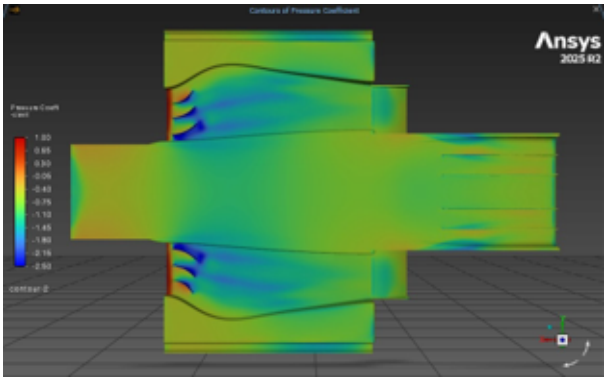



Figure 5.7: Undertray – pressure coefficient Cp distribution.

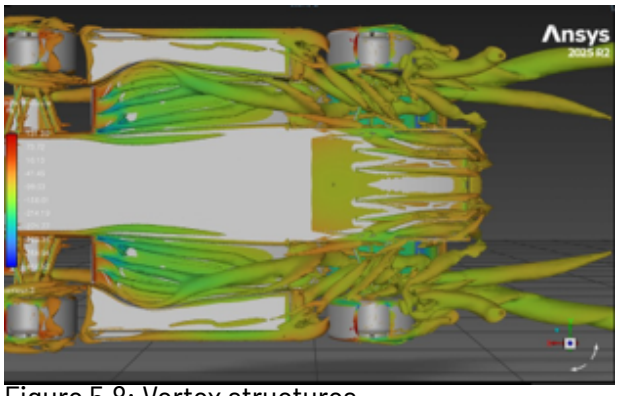



Figure 5.8: Vortex structures.

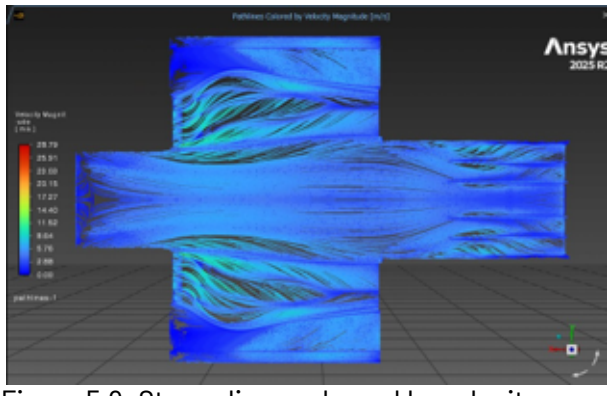



Figure 5.9: Streamlines coloured by velocity.

## 5.4 REAR WING DEVELOPMENT

Due to a rule change, we had to lower the rear wing by 10 cm, so in addition to the rear wing itself, we also focused on controlling the airflow around the rear of the chassis. This led us to add a rear suspension cover. The rear wing consists of a three-element main wing and a two-element slat, topped by a "ducktail" cover. The active DRS reduces drag by **34 %**.

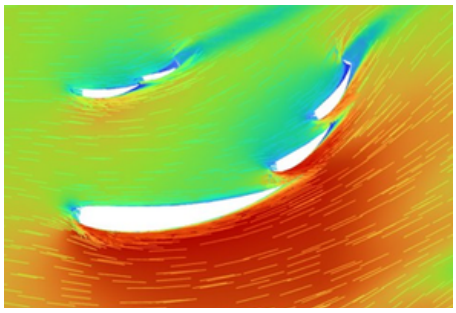


Figure 5.10: Rear wing – velocity field around the profile.

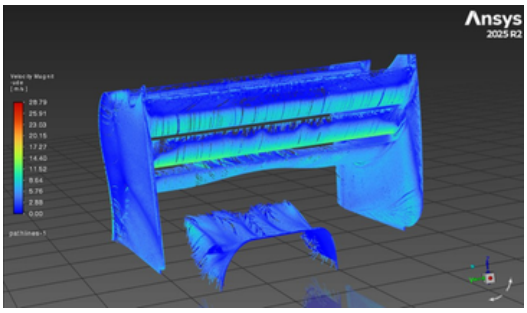



Figure 5.11: Pressure distribution.

## 5.5 AERODYNAMIC PACKAGE RESULTS

At 14 m/s, the aerodynamic package generates 420 N of downforce at 160 N of drag, giving an L/D ratio of 2.54. The downforce distribution between the front and rear axles is 40/60 %.

Table 5.1: Aerodynamic properties of the GPE26 at 14 m/s.

| Drag [N] | Downforce [N] | Cd | Cl | L/D | Distribution front / rear [%] |
|---|---|---|---|---|---|
| 160 | 420 | 1.34 | 3.4 | 2.54 | 40/60 |

According to the lap time simulation, the lap time is **67.4 s** with the aerodynamic package and **69.8 s** without it. Aerodynamics therefore gains us 2.4 s per lap, or approximately 3.4 %.

Data from the 2025 season cannot be compared directly with this year's, as it was obtained with CFX, which, according to the validation results (Section 5.6), overestimated downforce.

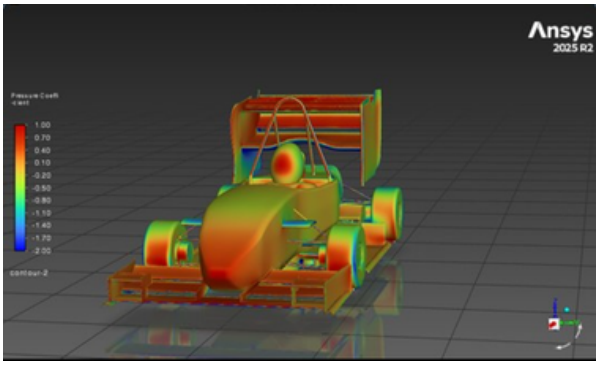



Figure 5.12: Pressure coefficient Cp distribution on the GPE26.

## 5.6 VALIDATION

The simulation procedure was validated on last year's car, the GPE25, using wool tufts and load cells. The measured downforce was 394.1 N. Fluent predicted 440.8 N, which is 46.7 N (approximately 12 %) more than measured, while CFX predicted 540.5 N, which is 99.7 N (approximately 25 %) more.

Table 5.2: Comparison of measured and simulated downforce for the GPE25.

| | Measured | Fluent | CFX |
|---|---|---|---|
| Downforce [N] | 394.1 | 440.8 | 540.5 |
| Deviation from measurement [N] | / | +46.7 | +99.7 |
| Deviation from measurement [%] | / | +11.9 | +25.3 |

Fluent is therefore significantly closer to the real values than CFX, which confirms the decision to switch. The remaining deviation will be taken into account when interpreting simulation results.

## 5.7 CONCLUSION

In the 2026 season, we designed a new aerodynamic package consisting of a low front wing, an undertray with Venturi channels, vortex generators and a diffuser, and a rear wing with a three-element main wing and a two-element slat. At 14 m/s, the package generates 420 N of downforce at 160 N of drag and, according to the lap time simulation, gains 2.4 s per lap.

Beyond the package itself, we also refined our workflows: we fully switched to Fluent, validated it against measurements on the GPE25, and established a cornering simulation.

# 6. MARKETING

In our team, marketing connects members, partners and the wider public. It promotes the project, acquires and informs partners, organises events, runs our social media and prepares the Business Plan and Cost and Manufacturing static events. As 2025/26 was the team's most technologically demanding season to date, we wanted as many people as possible to hear about our work.

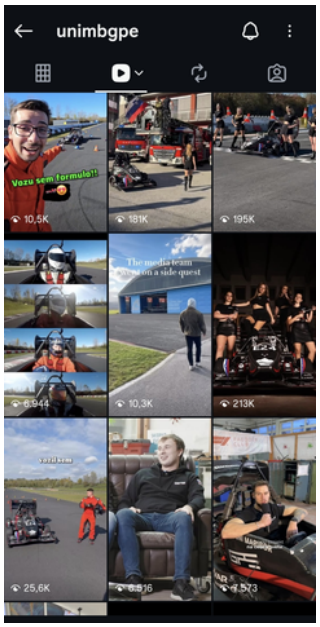
The season was marked by the slogan "From Idea to Formula", which sums up what we do as a team. Under this slogan, we also ran a recruitment campaign, which we promoted at the faculties, at every promotional event we took part in, and on social media. Our posters emphasised that working in the team brings experience for both career and life, and a QR code allowed students to quickly sign up for the team or find us on Instagram. The marketing team alone gained 9 new members this year, so we were able to share the work among more people and carry out more activities than in previous years.



Figure 6.1: Poster.

We put a lot of effort into acquiring new partners, as the project would not be possible without their support. Developing four-wheel drive required many new materials, components and services, which made working with companies especially important this year. During the season we gained more than 60 new sponsors, bringing the total number of partners supporting us to more than 100. We kept in regular contact with all of them, updated them on the team's progress and invited them to our events.




Our newsletter was a great help here. We started it last year, and this year it was published every month, sometimes even twice a month. It kept team members, sponsors and the faculties up to date on what we were doing, from the development of individual systems to events and competitions. We also made good progress on social media. An average post on our Instagram profile reaches around 40,000 views, and the most viewed posts around 200,000. This has brought the project to a much wider audience.

Figure 6.2: Newsletter and Instagram profile views.

We showcased the car at numerous events. At the Science Festival, the UNI-SI Festival, the Academy of Mechanical Engineering and the Career Fair, we presented the project to young people and potential new members. At the automotive events ABL Hidden Exotics, ABL Trackside Thrills, Auto Motor Show, WRC Croatia Rally and Donut 7, we showed it to car and motorsport enthusiasts. We also attended several fairs and conferences, namely the Green Energy Fair in Zagreb, the International Industrial Fair, the International Crafts Fair, the Dewesoft measurement conference and the RISK conference, where we connected with companies and industry professionals. We also promote the project with our own driving simulator, which lets visitors experience what it is like to sit behind the wheel of a formula car. The simulator also helps us test the car and its vehicle dynamics setup.



Figure 6.3: Highlights from the Career Fair, WRC Croatia Rally and the RISK conference.

We were also featured in, or hosted by, various media outlets and podcasts, including Dostop.si, Atmosferci, Furaj s stilom in Jerry, and Matjaž Tomlje. We are especially proud of the documentary film Do ciljne črte (To the Finish Line), made about our team by a student of the Faculty of Electrical Engineering and Computer Science. The film premiered at a preview screening at FERI.




Figure 6.4: Atmosferci podcast.

The marketing team was also responsible for the visual identity of the team and the car. We designed the livery for Roxy, applied the full wrap and sponsor logos, produced the GPE 2026 calendars and new team apparel. The highlight of these activities was the GPE26 Rollout, which we organised on 23 July 2026 at FERI. There, we presented the car to the public for the first time and revealed its name. The event was attended by the Rector of the University of Maribor, the Deans of the Faculty of Mechanical Engineering and the Faculty of Electrical Engineering and Computer Science, professors, sponsors, project supporters and friends of the team. The band Štala made sure the atmosphere was great.

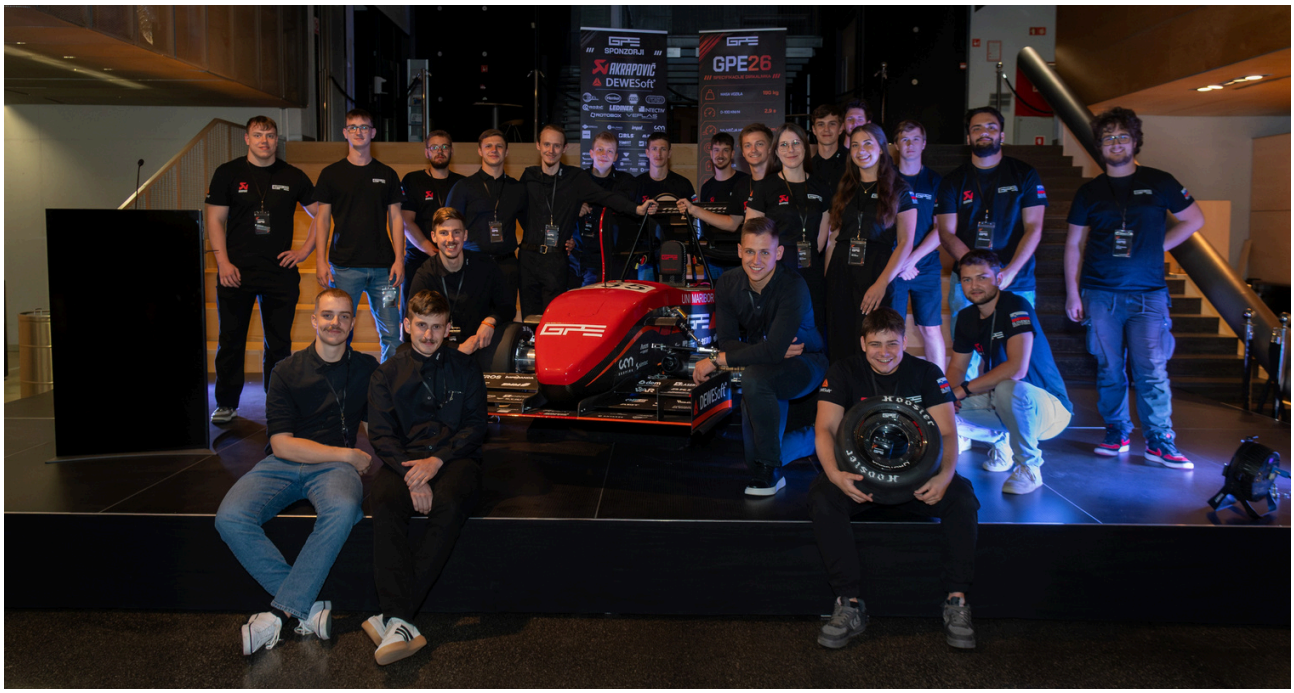


Figure 6.5: GPE26 Rollout.

In the static events, this year we developed the business idea Grid Ghost for the Business Plan. It is a virtual race engineer, a platform for amateur and semi-professional drivers that combines a telemetry device, artificial intelligence and simulator integration. The device collects data while driving, and the platform processes it and advises the driver on where they can improve braking, racing line, throttle application and consistency. We offered users two subscription plans, Enthusiast at €19.99 and Pro at €79 per month, with the business plan projecting break-even as early as the second year of operation. The idea stems from our work with telemetry on the car and shows how the team's know-how can be turned into a real product.

For the Cost and Manufacturing event, we prepared a cost report for the car, presenting the costs of individual components and their manufacturing processes. The main theme at this year's competitions was the Engine and Tractive System, i.e. the car's powertrain, which was a great fit for our season, as this is exactly the part of the car we had developed entirely from scratch. This allowed us to present in detail the costs and manufacturing of the electric motors, planetary gearboxes, inverter and high-voltage battery, and to show how much work and knowledge went into each component.

Going forward, we want to grow our number of partners, publish the newsletter regularly, be more present on social media and attend more events. This will strengthen the visibility of the team as well as that of our supporters.

# 7. COMPETITION REPORT

Due to extensive technological development and limited time, in the 2025/26 season we took part in only two competitions: Formula Student Alpe Adria in Croatia and Formula Student Poland in Poland. The two competitions took place in consecutive weeks.

This year, our results in the dynamic events were heavily affected by inverter issues. Because of its oscillations, we had to limit the car's top speed to approximately 60 km/h, as higher speeds would have caused a fault. This was most noticeable in Acceleration, where the car accelerated very quickly up to 60 km/h but then drove to the finish at the limited speed. The limit also affected Autocross, Endurance and Efficiency, so our placings in these events do not reflect the car's true performance.

## 7.1 FORMULA STUDENT ALPE ADRIA

The first competition of the season took place from 18 to 23 August 2026 at the Bugatti Rimac Test Track in Croatia, where 42 teams competed in the electric class. We are particularly proud of our scrutineering result, as we passed all inspections at the first attempt. Since the car was entirely new, with four-wheel drive and a 600 V high-voltage system, this is a great compliment to the team and proof of sound engineering work and a thorough knowledge of the rules.

In the static events, we placed 18th in Engineering Design with 96.1 points, 13th in Cost and Manufacturing with 79.8 points, and 25th in the Business Plan Presentation with 55.4 points.

In the dynamic events, our best result came in Skidpad, where we placed 11th with a time of 5.341 seconds. This event puts the greatest emphasis on suspension geometry and vehicle dynamics, and it is driven at lower speeds, so the speed limit did not hold us back here. In Acceleration we placed 20th with a time of 6.371 seconds, and in Autocross 23rd with a time of 81.106 seconds.



Figure 7.1: Competing at FS Alpe Adria.

We completed Endurance without any issues in a time of 27 minutes and 12 seconds, placing 13th with 41.5 points. Only 14 of the 42 teams finished the race, which shows just how demanding this event is. In Efficiency, we placed 11th with an energy consumption of 4.418 kWh. The speed limit slowed us down in the race, but the car and its new powertrain went the full distance.

In total, we scored 344.7 points and placed 15th out of 42 teams.

Table 7.1: Results from FS Alpe Adria.

| Event | Place | Time / Result | Points |
|---|---|---|---|
| Business Plan | 25th | / | 55.4 |
| Cost & Manufacturing | 13th | / | 79.8 |
| Engineering Design | 18th | / | 96.1 |
| Skidpad | 11th | 5.341 s | 40.1 |
| Acceleration | 20th | 6.371 s | 3.8 |
| Autocross | 23rd | 81.106 s | 10.0 |
| Endurance | 13th | 27:12.533 | 41.5 |
| Efficiency | 11th | 4.418 kWh | 18.2 |
| **TOTAL** | **15th** | **/** | **344.7** |

# 7.2 FORMULA STUDENT POLAND

Just two days after the end of the competition in Croatia, we competed at Formula Student Poland, held from 25 to 29 August 2026 at the Autodrom Słomczyn circuit. The competition was attended by 30 teams, 20 of them in the electric class. Once again, we passed all technical inspections at the first attempt.

In the static events, we placed 12th in Engineering Design with 80.51 points, also 12th in the Business Plan Presentation with 42.68 points, and 13th in Cost and Manufacturing with 48 points.

Our best result of the competition came in Skidpad, where we placed 6th with a time of 5.480 seconds, once again confirming the car's well-designed vehicle dynamics. In Acceleration we placed 11th with a time of 5.298 seconds, and in Autocross 12th with a time of 78.948 seconds.

We also completed Endurance without any issues, in a time of 29 minutes and 26 seconds, placing 9th with 25 points. Only 9 of the 20 teams finished the race. With this, we completed every endurance race of the season for the first time in the team's history. In Efficiency, we used 3.459 kWh of energy, but despite finishing the race we did not receive any points, as the result is compared against the best teams and a team that falls too far behind scores zero. This gap, too, was mainly a result of the speed limit.

In total, we scored 192.40 points and placed 13th overall.










Figure 7.2: Highlights from FS Poland.

Table 7.2: Results from FS Poland.

| Event | Place | Time / Result | Points |
|---|---|---|---|
| Business Plan | 12th | / | 42.68 |
| Cost & Manufacturing | 13th | / | 48.00 |
| Engineering Design | 12th | / | 80.51 |
| Skidpad | 6th | 5.480 s | 38.21 |
| Acceleration | 11th | 5.298 s | 3.50 |
| Autocross | 12th | 78.948 s | 4.50 |
| Endurance | 9th | 29:26.530 | 25.00 |
| Efficiency | / | 3.459 kWh | 0.00 |
| **TOTAL** | **13th** | **/** | **192.40** |



Figure 7.3: Team photo from FS Poland.

# 7.3 ANALYSIS OF COMPETITION RESULTS

This year's results need to be seen in the context of an entirely new car. At both competitions, we passed all technical inspections at the first attempt and finished both endurance races, which demonstrates the reliability of the car as a whole. Our placings in the dynamic events were largely a consequence of the reduced top speed caused by the inverter oscillations. We are also proud that, with four-wheel drive and our own electric motors, air cooling, planetary gearboxes and inverter, we have joined the few teams in the world that have all of this built into their car. We achieved this despite having significantly fewer financial resources than those teams.

We will therefore continue testing with Roxy, with the main focus on eliminating the inverter oscillations and refining torque vectoring. Once the speed limit is removed, the car will be able to show its true potential.

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