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Performance Assessment and Optimisation

Race Engineering & Simulation (ACHA7026)

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Objectives

The objectives from this project are focus on develop a test plan to improve the performance of the vehicle and driver. The test plan will be performed with the use of a Driver in the loop (DIL) simulator. In addition, an initial comparison between the use of a driver and non-use will be tested to determine the difference and limitations of it.

Test plan structure

The test plan was divided in 3 sessions of 1h each of them. The characteristics of the simulator and vehicle model use are the circuit where the test plan is simulated is Donington Park with the MCR2000 car from University of Wales Trinity Saint David team. The idea of using these model and circuit is because of the access to real data from previous years to validate the use of the DIL and its correlation.

The set-up of the parameters of the model for the baseline configuration can be seen in the following figures 1 & 2.



Figure 1. Baseline set-up configuration part 1.

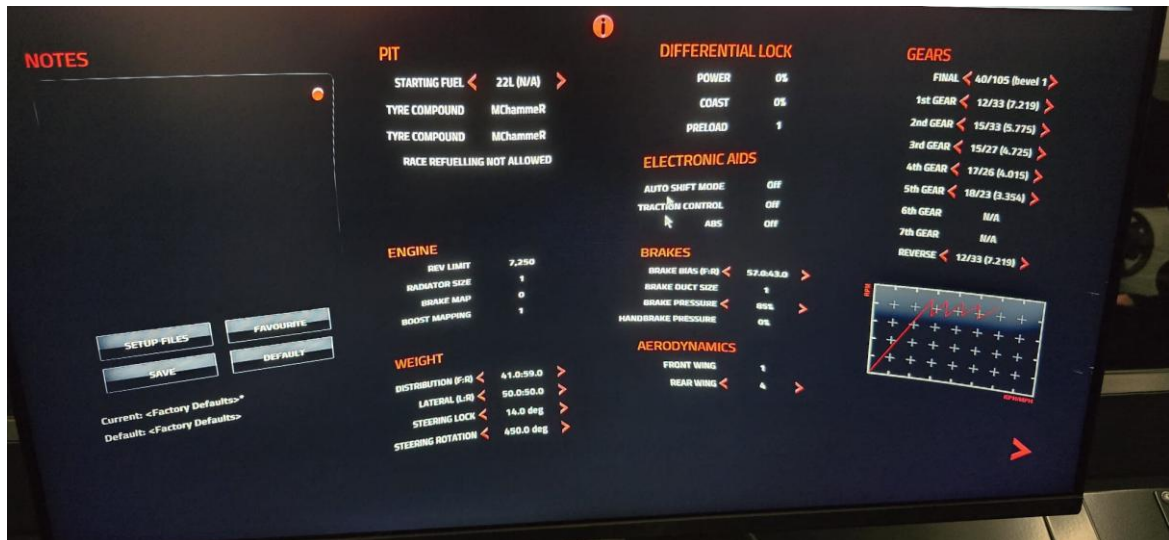


Figure 2. Baseline set-up configuration part 2.

Session 1

Methodology

For the first session, the idea was to evaluate the initial condition and performance of the car. Therefore, it was decided to do short runs of 3 to 4 laps and take the data of the car in addition with the feelings of the driver. With this strategy, it was possible to define the initial point of the vehicle, what were the feelings from the driver and define the future changes in the following sessions to upgrade the performance of the vehicle and pilot.

Furthermore, in this session it was studied the difference between the simulation laps with the driver and without the driver. This comparison will show the differences in behaviour and accuracy of the data to justify the use of a driver performance and feedback.

The structure of the session can be seen below:

- Stint 1 → Driver's run
- Stint 2 → Simulator's
- Stint 3 → Driver's run
- Stint 4 → Simulator's
- Stint 5 → Driver's run changing the ride height to 6.2 rear and 4.8 front.

After the initial plan of this session, there was enough time to carry out an extra stint with a different configuration, therefore it was decided to change the ride heights of the car.

Results

The results obtained from the first session present tendencies and conclusions that are important to highlight. Moreover, the data and driver’s feedback showed the possible changes in the following sessions to improve the behaviour and performance of both vehicle and driver.

First, comparing the data from stints 1 and 3 from the driver against the data from stints 2 and 4 from the AI of the simulator, it is possible to see the difference on how the performance and behaviour work different.

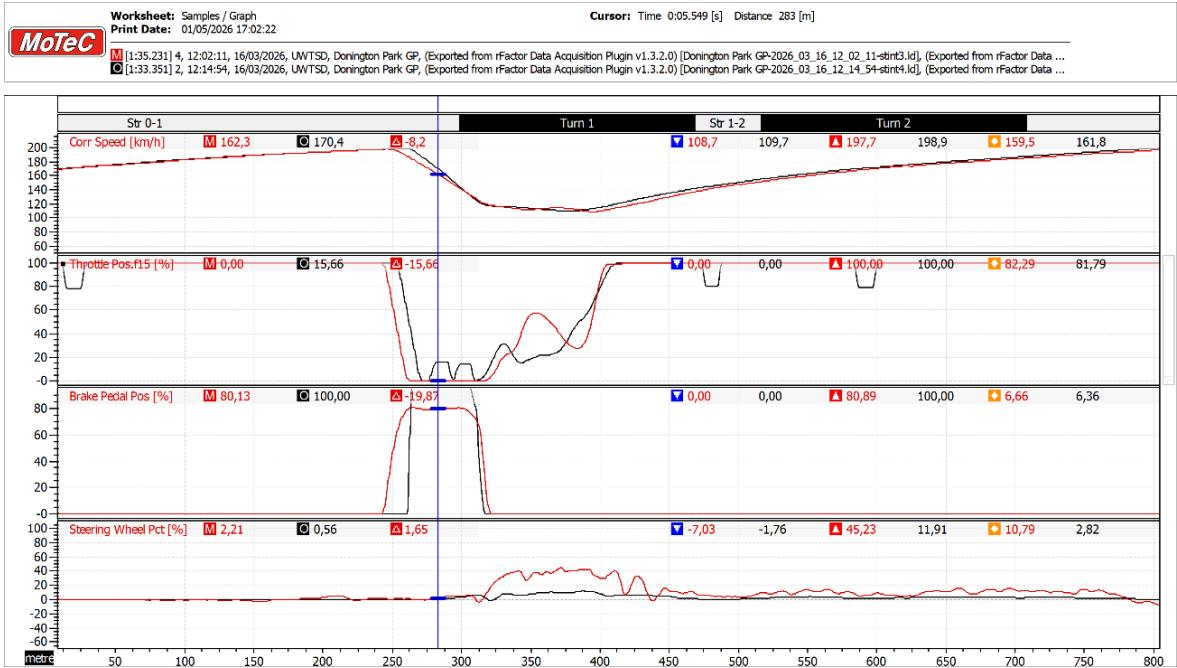


Figure 3. Turn 1 driver's performance (Red) vs AI's performance (Black)

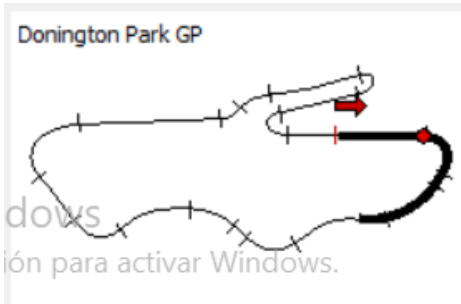


Figure 4. Donington Circuit.

The difference of the lap time in favour of the AI by 2s can be explained with the data from throttle position, brake pedal position and steering wheel percentage. Focusing on the first curve of the circuit, it is clear in the speed (Figure 3) how the driver reduces its velocity before AI at the entry of the turn; and at the exit, AI can accelerate before. This difference on the driving is explained comparing the moment the driver brakes and accelerates with the moment of the AI. However, the graphics of the values mentioned show the reason behind this great performance from AI simulator, as the throttle and brake pedal position change in an instantaneous and unrealistic way. In addition, the steering wheel percentage shows that the AI does not make significant turning in the curves as it goes to the ideal racing line. All these aspects are far from evaluate the real behaviour of the car, therefore, for this project, all the test plan was performed with the driver in the loop.

Regarding the conclusions of comparing stints 3 and 5, with the idea to evaluate the influence of changing the ride heights, despite of being an improvement on the quickest lap time (0.1s) seems to be of an adaptability from the driver to the set-up of the car, as the data presented in Figure 5, there is not a big difference on the driving performance.

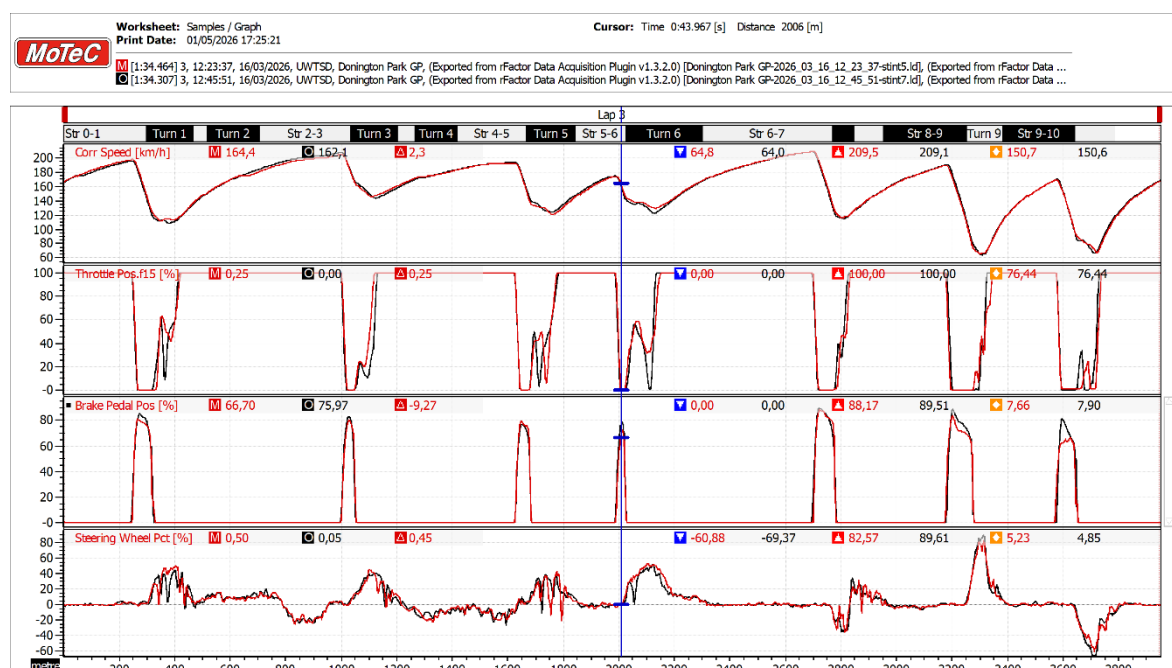


Figure 5. Stint 3 (Red) vs Stint 5 (Black) data from Session 1

Nevertheless, the driver feedback suggested that the change improved the stability of the rear part of the car, although the understeer in mid and high-speed corners kept persisting.

Session 2

Methodology

For the second session different objectives and approaches were taken. Firstly, it was decided to develop a parametric study of the front a rear spring rate with the objective of increase the stability of the car and reduce the understeer behaviour. The changes are presented next:

- Baseline → Front suspension 70 N/mm / rear suspension 80 N/mm
- Stint 1 → Front suspension 90 N/mm / rear suspension 100 N/mm
- Stint 2 → Front suspension 80 N/mm / rear suspension 90 N/mm
- Stint 3 → Front suspension 85 N/mm / rear suspension 95 N/mm

With this strategy, it was cover and get the data from all the possible configurations from softest to hardest suspension. In addition with the driver's feedback for each of them, the best set-up will be implemented it after analysing all the stints.

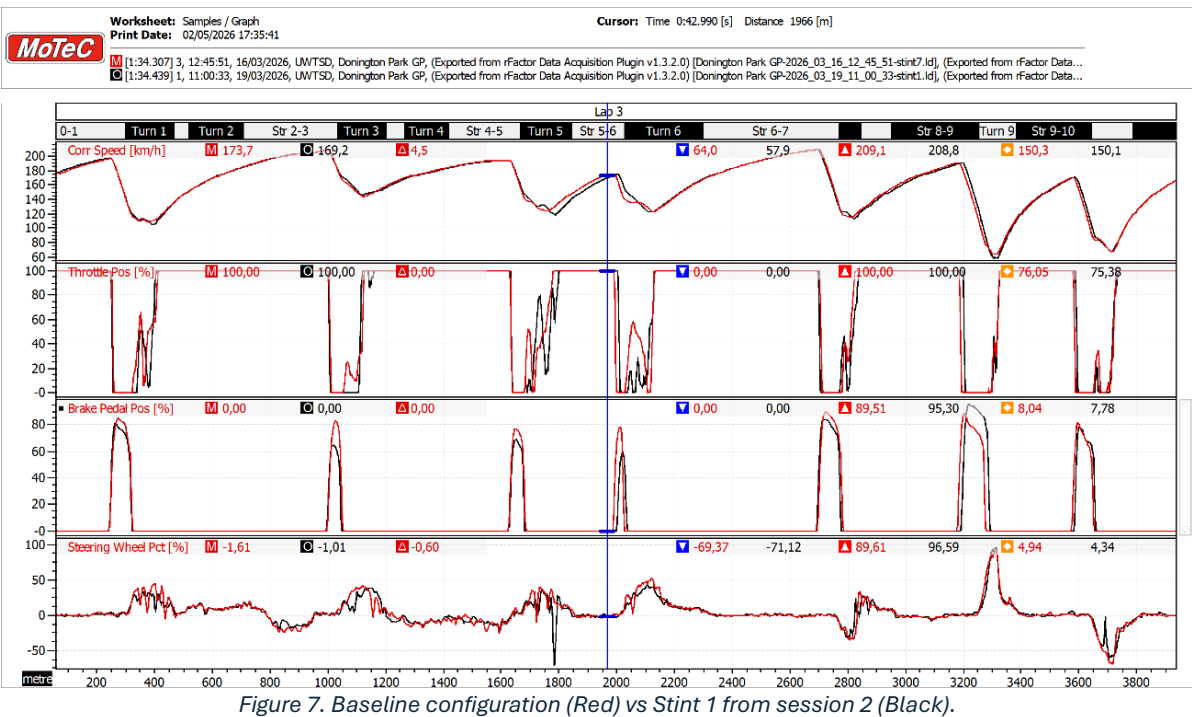
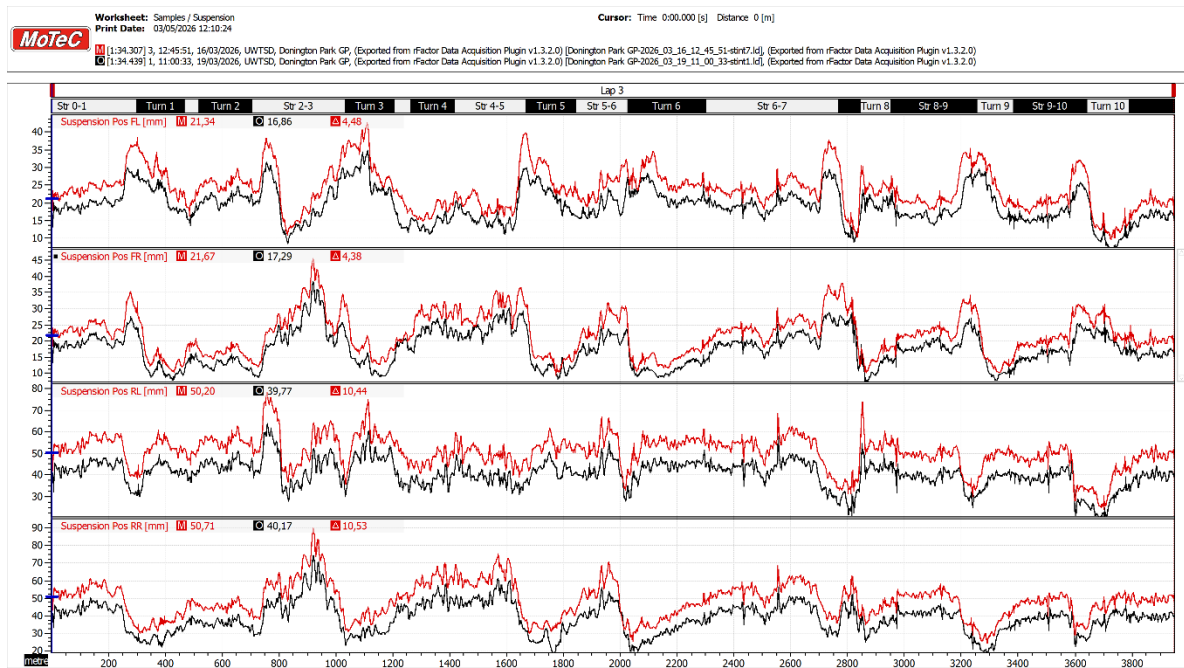
The other tests developed during this session were focus on analyse the influence of two parameters in the simulation. These parameters were the Tire pressure and the remaining fuel. For the first one, the value was changed from 95kPa to 100kPa; for the second one, the stint was performed with 13L of fuel instead of 22L as the previous stints.

Results

Analysing the data from this second session, it possible to compare each configuration with the previous one with the idea to see the influence of the spring rate values.

Comparing the last configuration of the first session with the first of this session, the fastest lap time of each of them are in a similar range (1.34.3 & 1.34.4 respectively). Although in the Figure 6 the suspension position changes less in the second set-up, this can be explained as the spring rate has a higher stiffness, therefore the vehicle is more stable. This result suggests that making the suspension harder to increase the stability does not mean an improvement on the performance.

In Figure 7, it can be seen the data from the other values of interest (speed, throttle position, brake pedal position and steering wheel percentage). The all-around data does not show significant difference apart from specific low velocity corners, where the driver could brake later with the new configuration, probably because of the stability obtained with the stiffness.



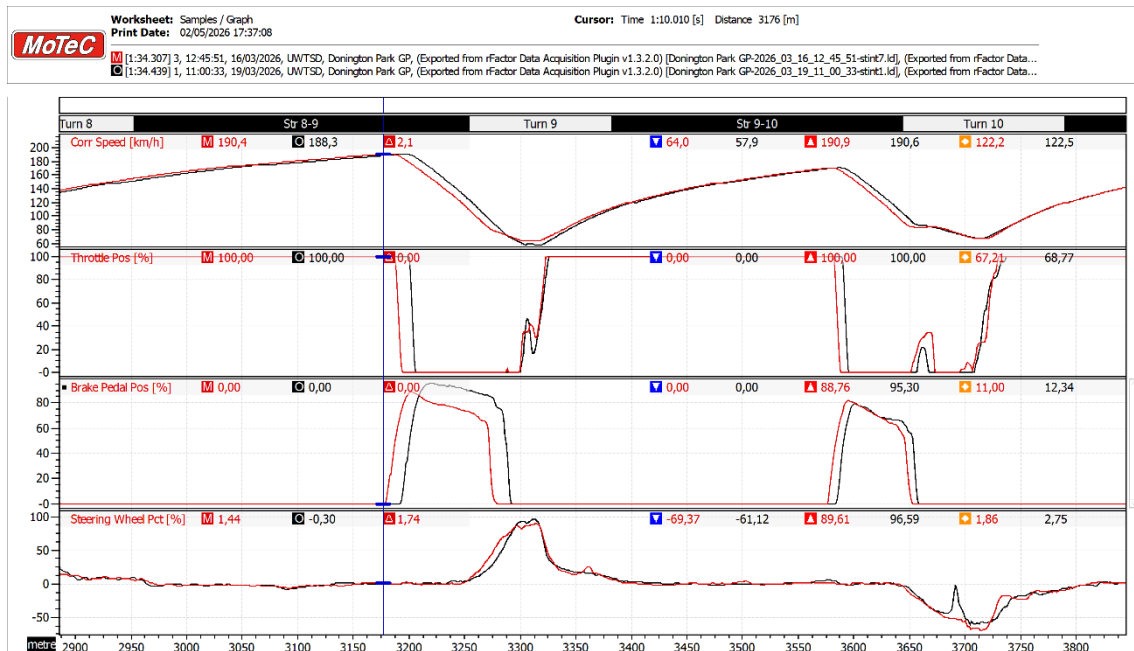


Figure 8. Baseline configuration (Red) vs Stint 1 from session 2 (Black) in low-speed corners.

However, the feedback from the driver says that this configuration was quicker than the set-ups from session 1. In addition, the driver mentioned an improve rotation of the car and more stability, this last feeling could be related with the stiffness of the suspension.

After the first stint, for the second one was decided to implement a softer spring rate configuration, but harder than the baseline set-up. At first sight, there is an improvement on the fastest lap with the new configuration, as it goes from 1.34.4 to 1.34.0. However, the data from the vehicle does not suggest a big improvement in any aspect, in fact, in slow speed corners the driver needs to brake earlier than previous configuration and it does not accelerate faster as Figure 10 shows. The only are of improvement seems to be at high velocity corner where the vehicle accelerates faster with the new configuration and the driver makes less corrections, as the steering wheel percentage keep consistent and continuous (Figure 11).

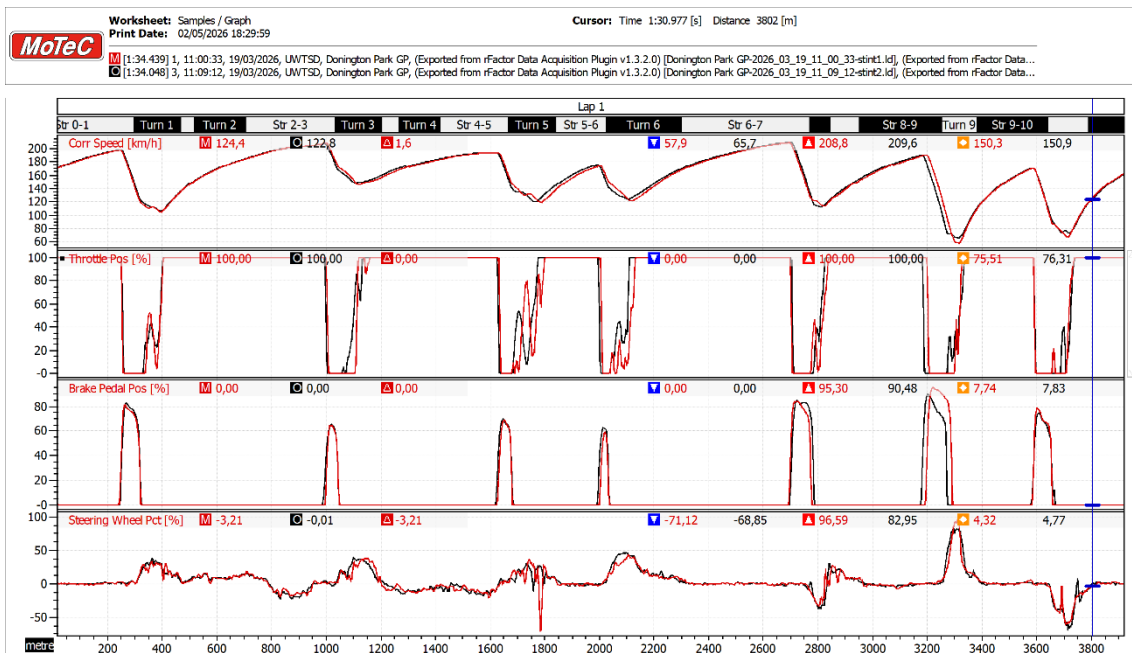


Figure 9. Stint 1 configuration (Red) vs Stint 2 configuration (Black).

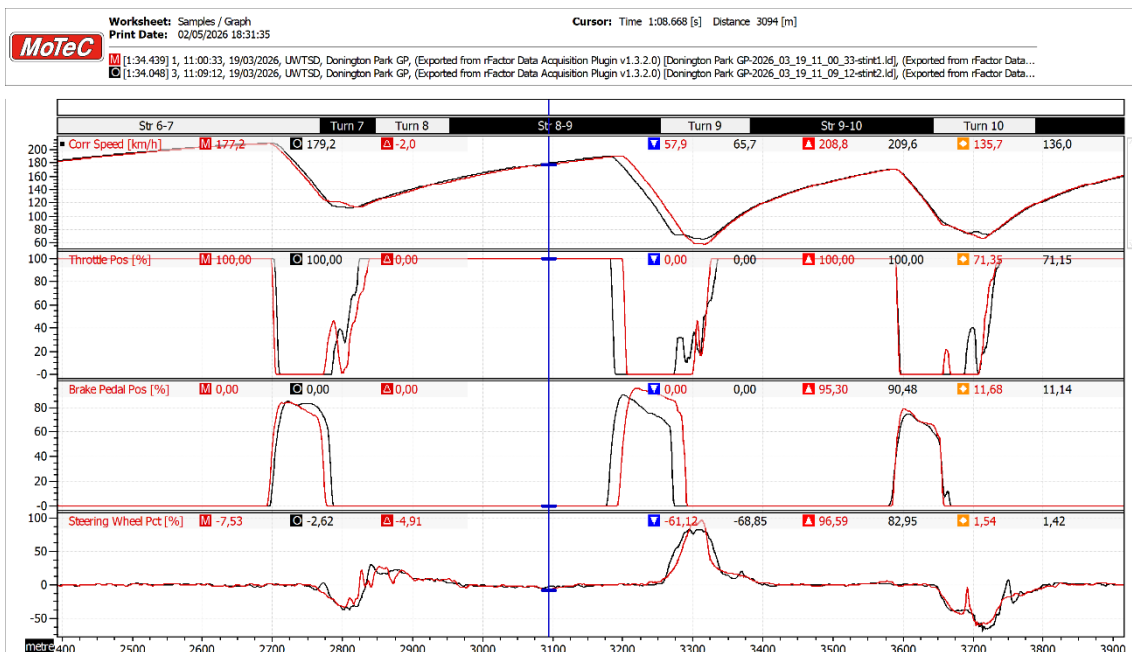


Figure 10. Stint 1 configuration (Red) vs Stint 2 configuration (Black) in slow corners.

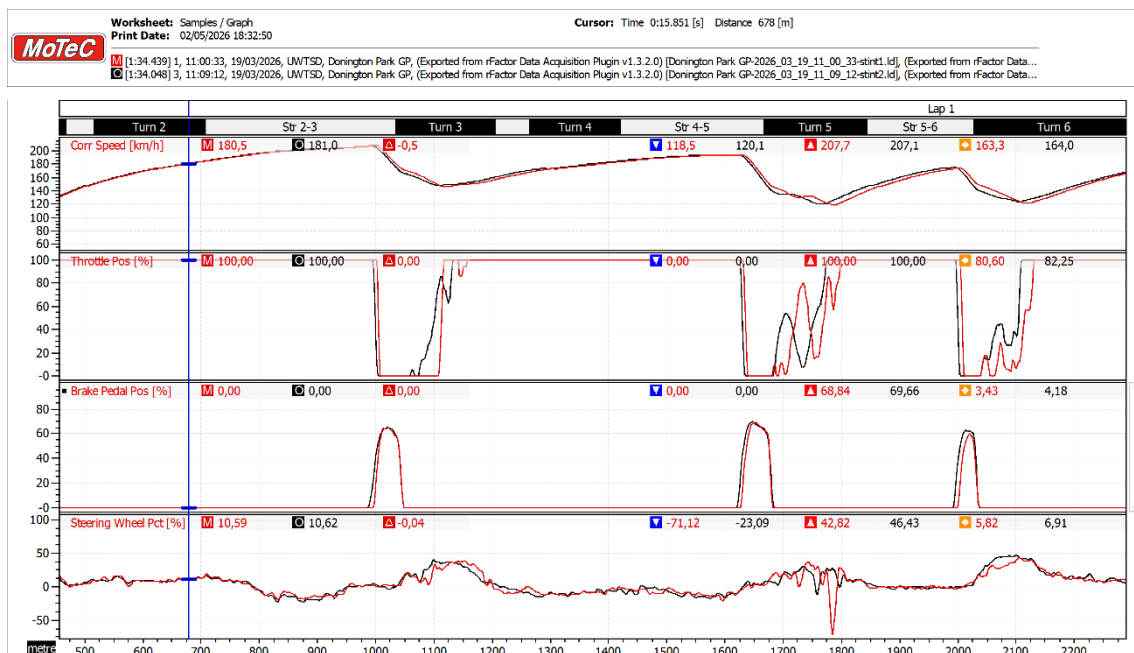


Figure 11. Stint 1 configuration (Red) vs Stint 2 configuration (Black) in high-speed corners

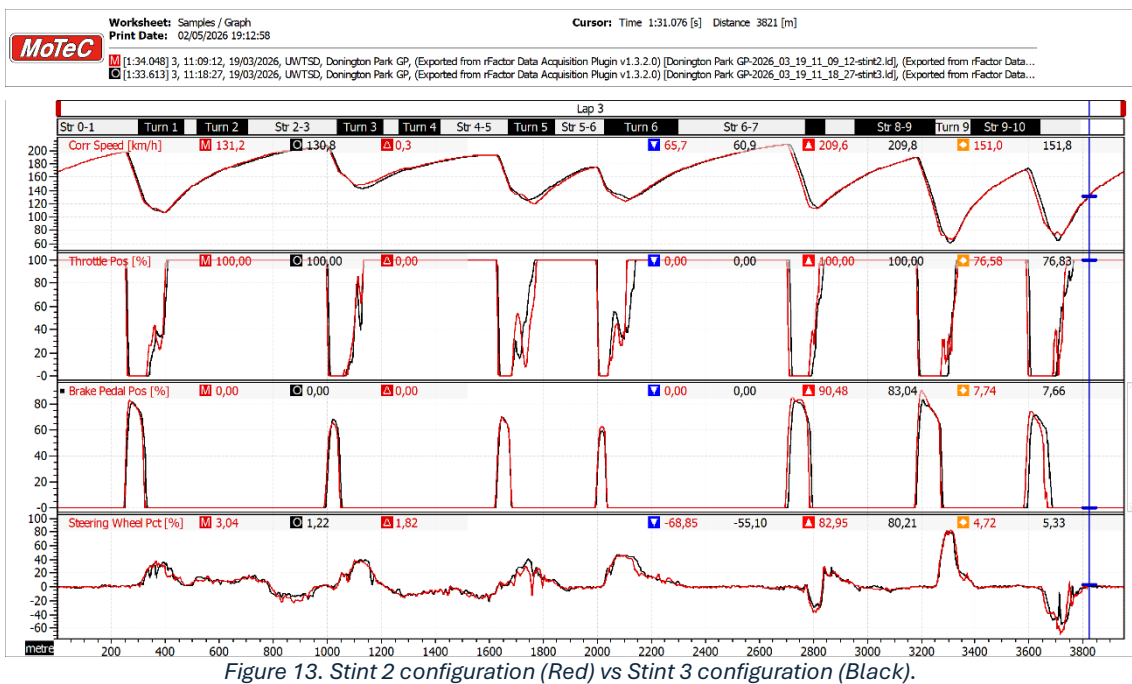
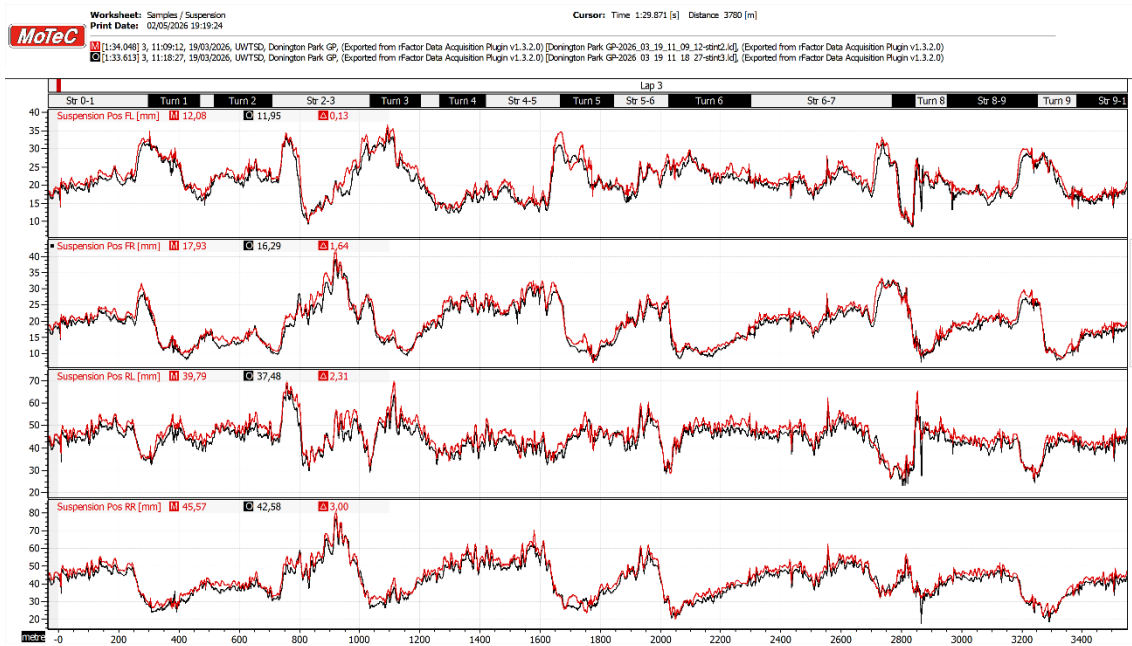
Regarding the feedback from the driver, despite improving the time, the overall feeling was worse compared to previous set-up. While the rotation keeps fine, there is a mix of understeer and oversteer depending on the corner. This can be explained with the corrections shows in figure 9 in the slow speed corner.

With the last feedback from the driver on mind, it was decided to perform another stint with an intermediate configuration between stint 1 and 2 configuration.

The data obtained from stint 3 is compared to the data from stint 2 as it was the last fastest lap. In this case, there is again an improvement on the fastest lap, going from 1.34.0 to 1.33.6. The suspension positions graph (Figure 12) shows a more stable configuration for the last one, as being harder has a similar impact as the first configuration. This could be aligned with the data showing (Figure 13) that the configuration from stint 3 allows the driver to brake later in most of the corners (Figures 14 & 15).

Regarding the acceleration at the exit of the corner, it is clear with Figures 14 & 15 that the last set-up increases the stability in the corners as the output from the throttle position is progressive without loss of velocity like the previous one.

In relation with driver's feedback, the feelings were positive, as the car was generally nice in every aspect, not understeer or oversteer experienced, which was one of the initial problems on the car; and perfectly balance without instability on the corners. Therefore, it was said there is an overall improvement on the driving and performance of the car.



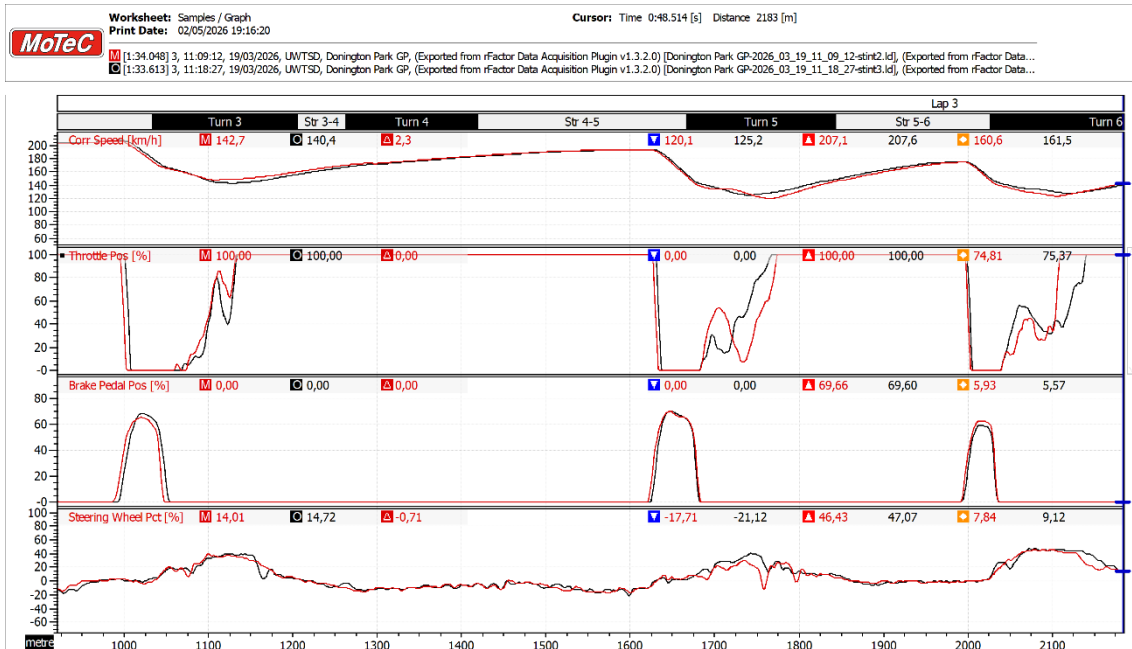


Figure 14. Stint 2 configuration (Red) vs Stint 3 configuration (Black) in High-speed corners.

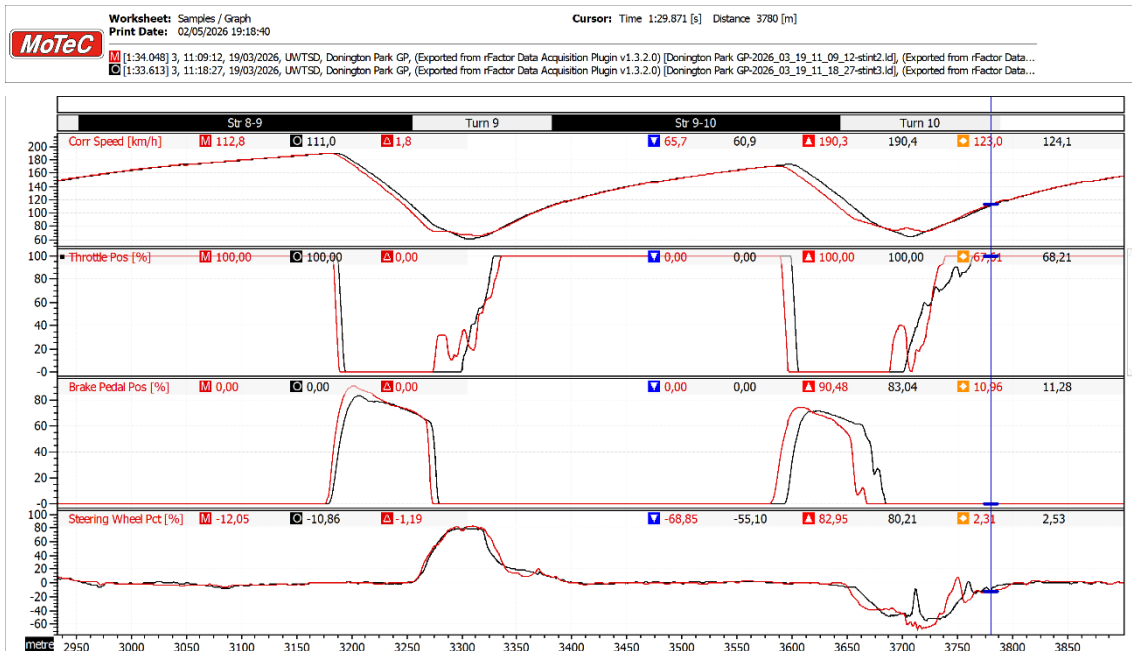
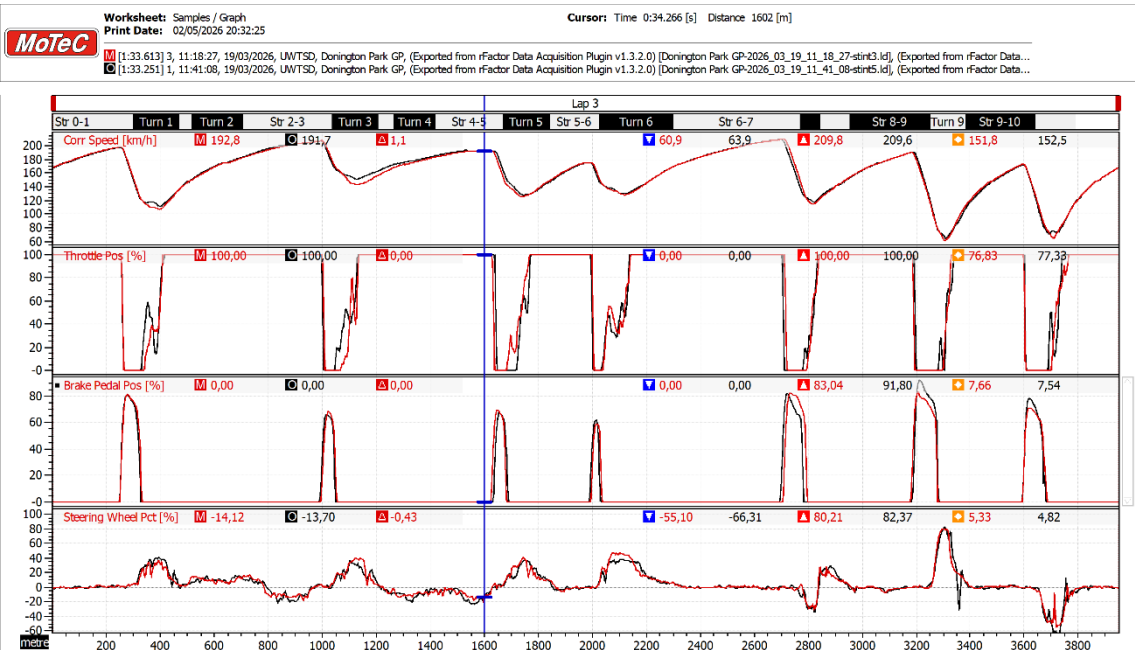
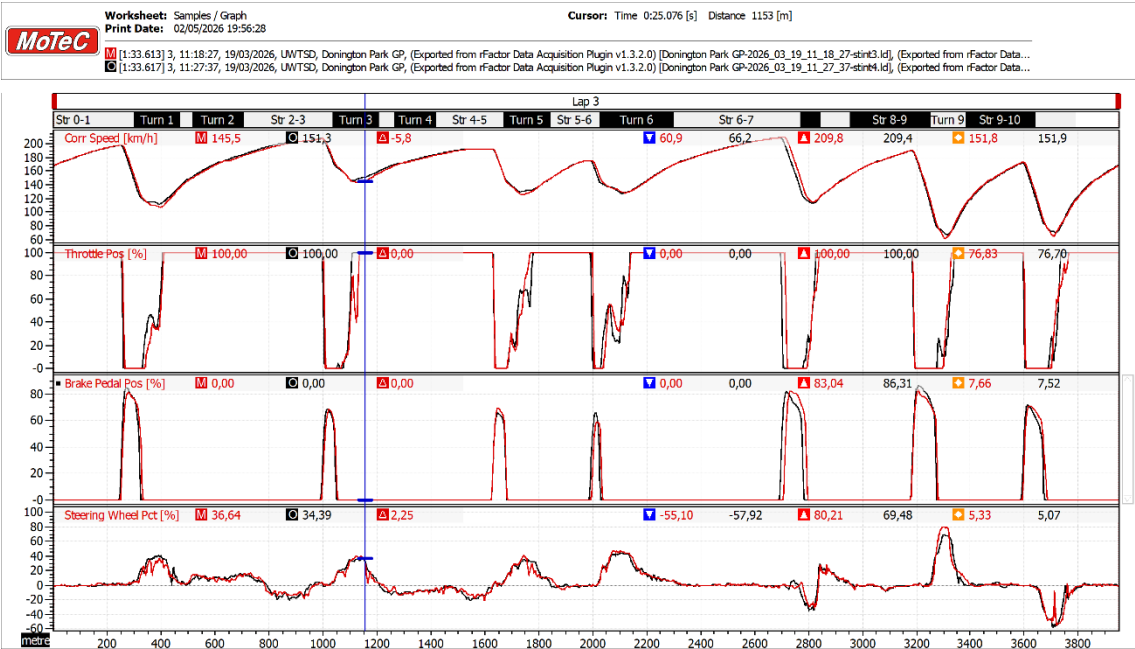


Figure 15. Stint 2 configuration (Red) vs Stint 3 configuration (Black) in low-speed corners.

Finally, the results from the last tests performed at the end of the session. Firstly, the tyre pressure modification, as the data from Figure 16 and driver's feedback suggest, there is not a big difference from one stint to another in addition with a similar time lap (1.33.6), this suggest the pressure of the tire does not make a significant impact probably because of the model from the simulator is simplify.



In relation with the fuel, the main difference to highlight in this case is the improvement on picking up speed at the exit of the corners (figure X), which make sense as the vehicle is lighter than before. This assumption is correlate with driver's feeling and with an improvement on the fastest lap time from 1.33.6 to 1.33.2.

Session 3

Methodology

The final session of the test plan consisted of a race simulation. The objective of this practice was to analyse the final configuration developed in the previous session in a real racing environment, seeking to evaluate it in different context with competitors and race evolution.

The characteristics of the race simulation were a competition with 15 AIs plus the driver racing for 21 laps. The driver started at the 12th with the idea of test the set-up in a "fighting" environment and at the end of the race in clean air.

Despite the circuit use in the previous sessions was Donington Circuit, for this session it was the Pembrey Circuit. The main reason behind this change was the time restriction for the test session, as a race of the characteristics established would have taken more time to complete it and not being able to analyse all the results that were expected. Therefore, as a shorter circuit, Pembrey was a better option. In addition, this selection gave the opportunity to test the previous set-up in a different context and prove if it could be a good baseline for future configuration.

Results

Analysing the lap times (Figure 18) from the race, there are two phases on the race. From the initial lap up to the 13th lap and from the 14th lap to the end of the race. For the first split, it was in a "fighting" context trying to overtake the competitor, that the explanation behind the alternation of the lap times with 1-2 second of difference. In the second split was the moment the driver achieved the first position and was in a clear air condition. From that point, the lap times start to improve in addition with less fuel load. This performance shows that the set up implemented works and have improved the output of the vehicle.

Laps	Time	M	O	1
Pembrey.				
UWTSD, MCR2000: Tim Tudor #40				
23/04/2026,				
12:17:24, (Exported from rFactor D				
Out Lap	1:11.248	☐	☐	☐
Lap 1	1:00.204	☐	☐	☐
Lap 2	0:59.798	☐	☐	☐
Lap 3	0:58.561	☐	☐	☐
Lap 4	0:59.093	☐	☐	☐
Lap 5	0:59.805	☐	☐	☐
Lap 6	0:58.772	☐	☐	☐
Lap 7	0:58.396	☐	☐	☐
Lap 8	0:58.313	☐	☐	☐
Lap 9	0:58.609	☐	☐	☐
Lap 10	0:58.051	☐	☐	☐
Lap 11	1:00.051	☐	☐	☐
Lap 12	0:58.982	☐	☐	☐
Lap 13	0:58.571	☐	☐	☐
Lap 14	0:58.030	☐	☐	☐
Lap 15	0:57.884	☐	☐	☐
Lap 16	0:57.670	☐	☐	☐
Lap 17	0:58.052	☐	☐	☐
Lap 18	0:57.873	☐	☐	☐
Lap 19	0:57.674	☐	☐	☐
Lap 20	0:57.482	☐	☐	☐
Lap 21	0:56.748	☒	☐	☐
In Lap	1:08.083	☐	☐	☐

Figure 18. Session 3 lap times.

Despite that one of the ideas was to compare the results with real data from the team, as the vehicle model on the simulator is from an old design and the team does not seems to have data from the years of it, evaluate the performance against a newer design will be inaccurate and difficult to obtain positive conclusions. A point of improvement would be implemented on the simulator the last design for correlation studies.

Conclusion

The first conclusion obtained from the project is the utility of the DIL technology. It gives you the opportunity to prepare the race weekend and strategies to have an initial plan to developed and analyse the context. In addition, it gives the drivers a great opportunity to train and adapt to a new circuit or new configuration on the car without having to practice on the track, therefore saving resources.

However, DIL technology have limitations, one of the most significant is the tires model, as these simulators simplify the behaviour of the wheels and its performance, which is an important aspect regarding that tires are one of the most critical parameters on racing cars.

Another important limitation is the competitors' model, as they usually do not have important parameters to modify apart from the difficulty or aggressiveness, which creates a difference with reality.

The last aspect to highlight is the performance of the drivers, in a simulation environment, the anxiety and pressure of make and error or have a problem is lower compared to the reality as the pilots feel more secure. This feature usually leads to an overperformance from the drivers compare to the real scenario.

To sum up, DIL technology is a key tool in motorsport and race strategy as it gives an alternative for the teams to prepare their competitions. Although, it is important to consider its limitations.

References

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