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Le Mans Hypercar

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The London E-Prix was held in July and hit the headlines for all the wrong reasons as the winner was excluded, leaving Alex Lynn to take the flag for Mahindra Racing. Mercedes-EQ Formula E driver Nyck de Vries finished second (pictured)

LAT Images

Leadership

Sometimes there are lessons to be learnt from looking outside your sport

This year marks 10 years since I won Le Mans outright as a race engineer with Audi Sport Team Joest. One thing remains very clear in my memory of that weekend and that was the weight of leading my team in the run up to the race, as well as the approach I chose to prepare the group. I was reminded of this during the recent Euro 2020 final between England and Italy, especially in light of the criticism the team and manager received right after.

A huge part of a race engineer's job is like being the conductor of an orchestra, where organisation and preparation are key to a successful race weekend.

Typically, a works team has three to seven engineers per car, along with eight to 10 mechanics and drivers. Although I had learnt the ropes from Howden Haynes as his assistant race engineer, when it came to running my own car and team, much of the skills I applied were ones I developed as I went along. Key to performance, was communication and trust.

Under pressure

Going into Le Mans in 2011, there was exceptional pressure on all of us to perform. I had realised that much of the lack of performance up to that point had come from my own lack of preparation, so attention to detail had to increase. In that respect, all issues encountered in the run up to Le Mans had to be addressed to find the cause and then a solution found.

I made myself unpopular by requesting extra parts changes in practice a few weeks before the pre-test, and then double checking all prepared spares with number one mechanic. I chose not to take the upset personally because it was the team performance at stake. I also had to actively choose to take *any* criticism as constructive, though I did choose to filter out any influence of criticism from those outside Audi Sport who didn't have all of the information.

Where a team is concerned, there are a few elements any leader needs to accept:

- You can't be an expert in everything, so trust the team members around you who have the experience and knowledge.
- With that trust comes an acceptance that if someone makes a mistake, it isn't intentional, and you need to support that team member through thick and thin. Standing by your team members means they feel supported and builds their confidence.
- As a leader, you need to take the first hits of criticism before your team members, almost protecting them from harsh words. That is hard at times as it means sometimes intentionally putting yourself into the firing line.

The position of leadership requires a certain amount of stepping back and not micro-managing, which is harder said than done, especially as engineers as generally we all like fiddling. This, however, has the opposite effect where you can quickly end up down a rabbit hole, chasing a solution that brings little reward.

XPB

To be a great leader, one must have a great team, and the two have to work well together

In the years since that 2011 win, I have tried to keep a number of skills that I learnt at the core of how I operate my team. Is that the right approach? I'm not sure, but I do know what works and how I can formulate the basic structure to then expand it. It does rely on everyone in the team buying into how *you* want to do things, but taking their experience of how things were done in different teams helps evolve your 'new' team.

The ability to adapt, learn from mistakes, learn from experience and move forward is how a team goes from being just okay to being great and, hopefully in any sport, successful and dominant.

I have continued to filter external criticism to this day, and now only respond to that from within my team, because they are the ones with first-hand knowledge of most of the parameters that affect our performance.

That may seem to some like I don't care, but there is an element of survival at play. Sometimes I do need to remind myself of this because it is easy to be distracted.

Almost as soon as the football final was over, I saw messages online and from friends about how Gareth Southgate had got it wrong when it mattered. It seemed everyone's anguish at losing needed to be directed towards an individual, and for one person to carry a country's blame and disappointment in a final.

Share the knowledge

So many people apparently knew so much better that I do question why more people don't put themselves forward for that job, or share their knowledge with England team managers on a one-to-one basis.

Southgate had taken an unusual approach of bringing in non-football experts to help condition, train and progress the team's approach to the championship, and I commend him for that. Sometimes, looking outside of your field of expertise can yield different approaches that can be adapted to your sport. I certainly learnt something from him for my own approach to managing a team.

Football is a highly emotive sport, for many reasons, and any England manager will always be in the firing line. I hope Southgate and his whole team have been able to put their devastation aside and look objectively at what was good and bad about their recent championship and that final. I hope they have also pushed aside the external critique to filter what is important.

They don't need to be told the nation was disappointed. They were, too. Filtering means their approach to the next big championship, which happens to be the World Cup, will be easier and more successful. Hopefully, fans and critics alike will also have learnt from their harsh assessment of both and will fall back into supporting the team.

Leena Gade is race engineer at Multimatic Engineering UK

The ability to adapt, learn from mistakes, learn from experience and move forward is how a team goes from being just okay to being great

Judgment days

Poor sportsmanship, poor decisions and poor Mercedes

Why can't today's F1, F2 and F3 drivers stay within the confines of track limits? I've previously acknowledged the difficulty the sheer cornering speed of current F1 projectiles must present in placing them within inches, when just a twitch of too much torque application can change trajectory, but this applies less to lower-performance single seaters.

I can understand occasional errors, but I can't make out how these can be continually repeated, often two or three laps in a row. Even the best drivers have been guilty.

The oft-quoted observation that street circuit Armco doesn't permit such dalliances with the green stuff is as true now as it's ever been. So, what's the problem with kerbs, especially as deleted lap times convey no benefits? Apart from the pressure of grid positions decided by thousandths of a second – tighter than they've ever been – I suspect that over the years young drivers in junior formulae have become increasingly accustomed to abusing the limits without penalty. Consequently, this has stayed with them during their progression through the ranks. Just as professional football players regularly now get away with shirt grabbing and deliberate pushing to get at the ball. It's been a gradual lessening of fair rules application over the years. Familiarity breeds contempt, they say, but so does weak enforcement.

When push comes to shove

However, enforcement is one thing, unreasonable application is another. At the latest (at time of writing) GP at Red Bull Ring, F1 race director, Michael Masi, defended, without discussion, the awarding of penalties for what was judged as pushing a rival car off the track. This may or may not have been justified, but to give drivers penalty points on their licences, *as well as* time punishment has no justification.

Had the incidents concerned ended with the other car heavily damaged, and the intent clearly deliberate, it would be understandable. But that's very different from a brief trip over the gravel.

Similarly with Bottas' peculiar half-spin in the pit lane. While perplexed that a driver of the Finn's calibre didn't handle a 50mph tank slapper, one penalty would have been understandable. A three place grid drop and penalty points, however, was in my opinion grossly unjust.

There was risk to McLaren personnel, granted, but probably less than a car locking, or losing, brakes and overshooting on pit entry.

Such decisions are the responsibility of the race stewards, but Michael Masi undoubtedly has considerable influence upon the process.

The increasing issue of Technical Directives, together with the farcical inability to come up with a clear and consistent track limit rule is frustrating the teams. The impression is inevitably forming that Masi is letting authority go to his head, and acting outside of his race director brief.

XPB

Overtaking rules have been clarified, as has the issue of 'bendy' wings, but neither make particular sense

Conversely, failure to firmly clamp down on tyre preparation backing up / weaving on track (surely classifiable as deliberate blocking?) shows a worrying lack of awareness of the real dangers involved. Dare I say that Charlie Whiting would have managed these matters more deftly?

I doubt, though, that I should point a finger at Masi for the recent 'bendy wings' farce. Suffice to observe that due to just *one* driver throwing suspicion on a competitor's rear wing flap deflection, the attention of the FIA was brought to bear, and a raft of new rear wing compliance regulations introduced at short notice. Only subsequently for the revelation that *most* rear wings, including, amusingly, the complainant's, did exactly the same thing.

Tens, maybe hundreds, of thousands of pounds are consequently being wasted on re-designing and modifying / manufacturing assemblies that were perfectly legal and posed no safety issues. Why? I thought only the latter reason, or deliberate cheating, called for in-season technical regulation changes, especially given the emphasis on reducing expenditure.

As with needlessly carting around a heavy, tyre-degrading fuel load for half the race instead of permitting refuelling, having fixed aerodynamics that create a great deal of drag on the straights (adding to the fuel consumed) is counterproductive in terms of efficiency.

DRS should not be needed if the 2022-regulations F1 cars meet expectations of allowing close-following cars to be less disturbed aerodynamically, but a similar system could be retained for use whenever drivers want, rather than for overtaking in a specific zone, as now.

On the sauce

Ah, moveable aero devices… the mind starts to boggle. Power for auxiliaries such as PU fans and pumps slipstream-generated by little turbines located in ducts in high-pressure areas? Shutting down radiator and cooler intakes at high speed? Brake ducts, too? How about jet fighter-style pop-up air brakes? Gain vs drag and weight permitting, of course.

It's okay, I'm off the sauce now and I'm back on the sensible pills, but just for a while there…

To more prosaic, yet still highly significant matters. The budget cap. It fair made my heart bleed when Toto Wolff complained about the cost of Bottas' major crash with Russell at Imola, and the financial effect on Mercedes' car development. After years of outspending almost everyone else, Wolff is now having to get used to the world almost all other teams inhabit. The budget cap is doing what it was intended to do, to level the F1 playing field.

Mercedes' admitted necessity to stop development on this year's car because its focus has to be on 2022 supports the point. It's no coincidence, to me, that they are finally being beaten by Red Bull, which is continuing to improve its 2021 design. Only time will tell if this hurts Mr Mateschitz's team long term.

Pre-budget cap, Mercedes would simply have added resources and personnel to work on both projects in parallel. Reality has arrived with a bump for Ferrari too, except that, unlike the Black Arrows, it wasn't using its vast expenditure very effectively. About time, now.

Familiarity breeds contempt, they say, but so does weak enforcement

On target

In the second part of Racecar's analysis of LMH, we use lap time simulation to quantify and understand how the new cars are expected to perform

By ANDREA QUINTARELLI


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In last month's issue, Le Mans Hypercar (LMH) class regulations were reviewed, highlighting what, in the author's view, are the most significant points. Rules related to performance-critical areas like powertrain, aerodynamics and tyres will be analysed in more detail here to understand how the rulebook should lead to cars achieving the targeted lap times of 3m30sec in Le Mans race trim.

In this instalment, we will perform an in-depth analysis using lap time simulation to quantify and understand how LMH cars are expected to perform.

The tool employed for this investigation was coded by the author and is based on a quasi-static approach; each small section of a track is analysed assuming a constant acceleration and that the vehicle is in static conditions. The four-wheel vehicle model incorporates full aeromaps, suspension kinematics, corner and heave springs, bump stops for each axle and anti-roll bars.

The powertrain model inputs include a torque curve, gearbox efficiency, gear ratios, the portion of driving torque applied to each axle and shift time.

The tyre model is similar in structure to a Pacejka one, but with each effect modelled separately, including those of load, slip, camber and vertical characteristics (stiffness and expansion with speed).

Simulation output results include more than 100 channels, covering all areas of the car. The correlation against real world is good, despite the simplified approach, and the author feels it can be used with confidence for both predictive analysis and general studies.

Pre-study calibration

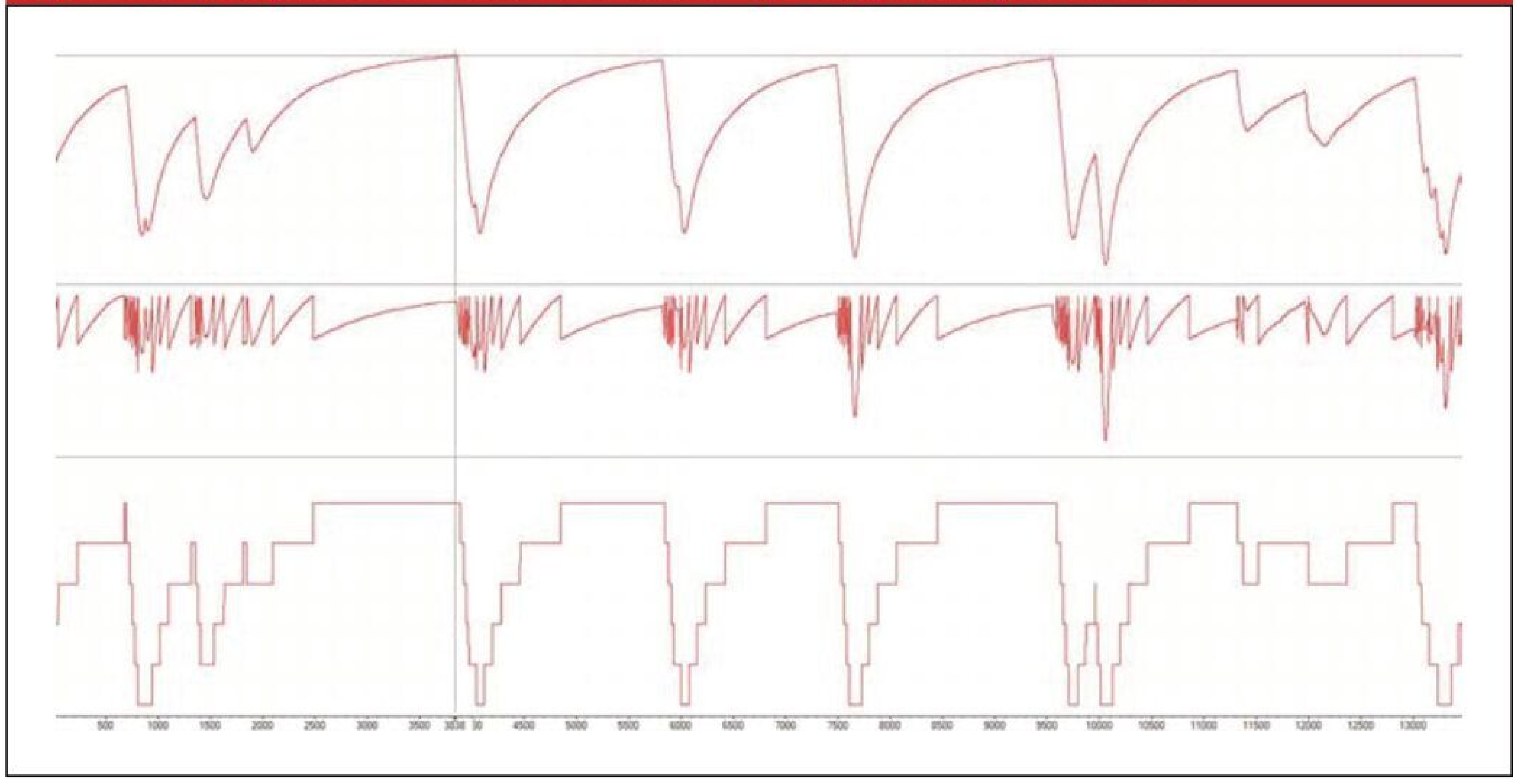
Before modelling a representative LMH car, some simulations have been run in Le Mans with an LMP2 vehicle model, in 2020 specification. The goal of this 'pre-study' was to calibrate and 'sanity check' simulation results by using a vehicle the author knows well and has a significant amount of data on. This phase is also instrumental in verifying the quality of the track model, which is normally generated using real world, logged data.

The LMP2 vehicle model used was set up in Le Mans configuration, in qualifying trim (relatively low fuel load) and with a previously tested set-up.

The simulation output was a lap time of 3m23.734s, only slightly faster than 2020 LMP2 pole position time of 3m24.528s. The relative difference between the two is about 0.4 per cent.

Considering the six fastest cars in qualifying, the average lap time is 3m25.237s. Comparing this with simulation results gives a delta of 0.73 per cent. This number will be used again later in the article as a factor to correct LMH simulation results.

Figure 1: Key outputs for the simulation model – speed, rpm and gear selected



Beside the sole lap time, simulations output a top speed of 326kmh, which closely matches the publicly available data relative to the six best qualified crews, whose highest top speeds were between 325 and 330kmh.

Figure 1 shows a plot of some key simulation outputs. The first trace is the car's speed, second is rpm and third is gear selected. Covered distance is used for the horizontal axis.

After comparing the simulation results with a known model, the characterisation of an LMH vehicle model, basing on the available information, is the next step.

The LMH vehicle model

For this study, a non-hybrid Le Mans Hypercar was considered. The main features of the simulated LMH vehicle are as follows:

- Mass without driver and fuel: 1030kg
  Mass with driver and fuel in qualifying trim: 1130kg
- Wheelbase: 3000mm
- Front track width: 1670mm
- Rear track width: 1660mm
- Four 31/71-18 tyres with the same dimensions and characteristics
- Powertrain power curve as the upper limit provided by the rules (both 500kW and 520kW cases have been considered)

Before modelling a representative LMH car, some simulations have been run in Le Mans with an LMP2 vehicle model, in 2020 [Le Mans qualifying] specification

- Aerodynamic efficiency slightly above four, as an average of the complete aeromap (regulations data about aerodynamics is not publicly available)
- Downforce coefficient set at the lowest allowed value, to emphasise top speed
- LMP-like suspension design
- Gearbox with seven forward gears, ratios optimised for engine power individually

Car set-up and aerodynamic balance have been subject to changes to achieve handling and stability comparable to the reference LMP2 car. This is unlikely to be the fastest set-up in the simulation environment but should produce more realistic results in comparison to real car performance, as

Hypercar and LMP2 achieved an acceptable class stratification at Monza, but it was the first time this year

Figure 2: Summary of initial simulation runs in Le Mans qualifying trim

Power	Sim Lap Time	Corrected Lap Time	Top Speed
500 kW	202.936	204.417	327 kph
520 kW	201.359	202.829	331 kph

Figure 3: Comparison between the results relative to a power of 500kW (red) and 520kW (blue)

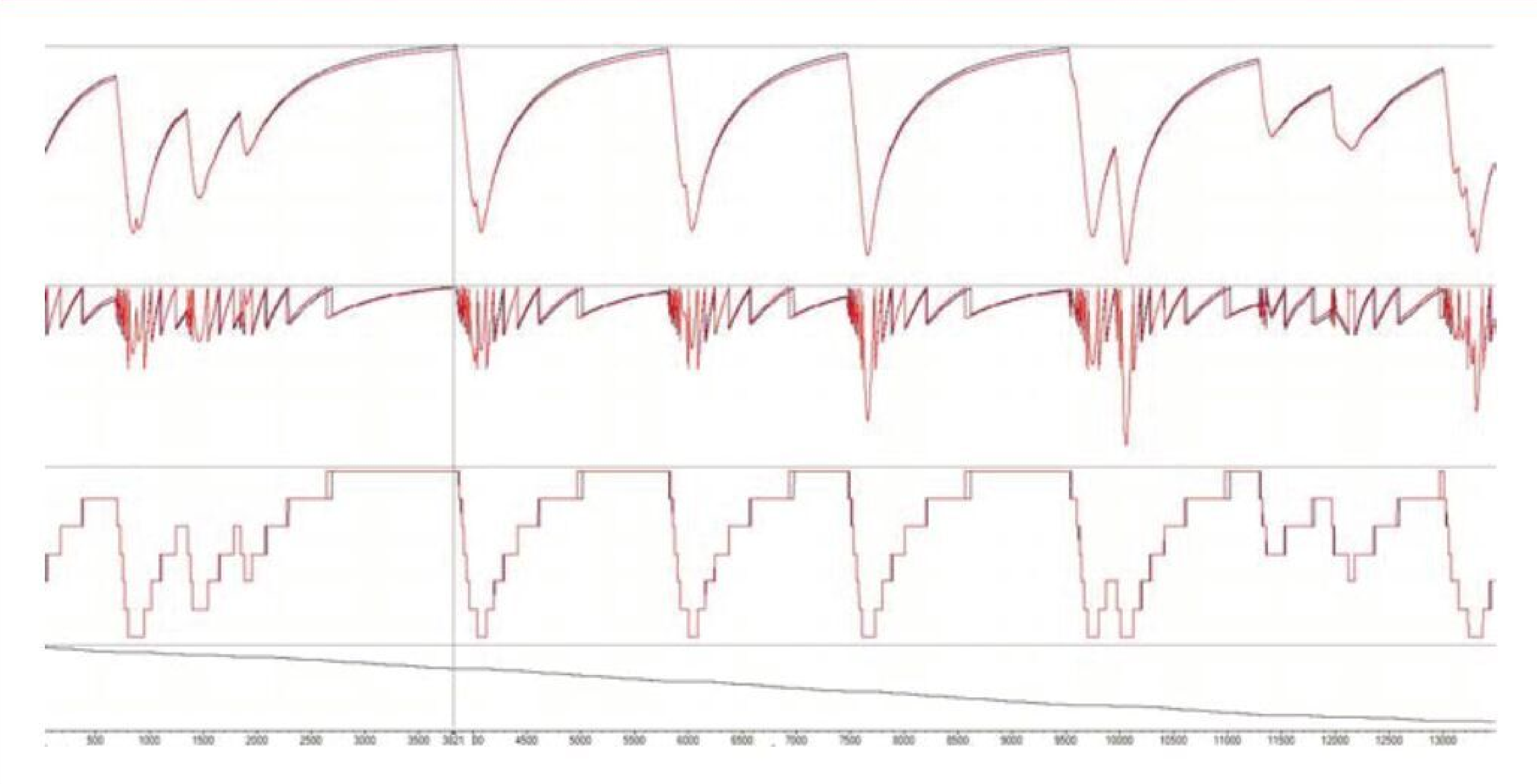
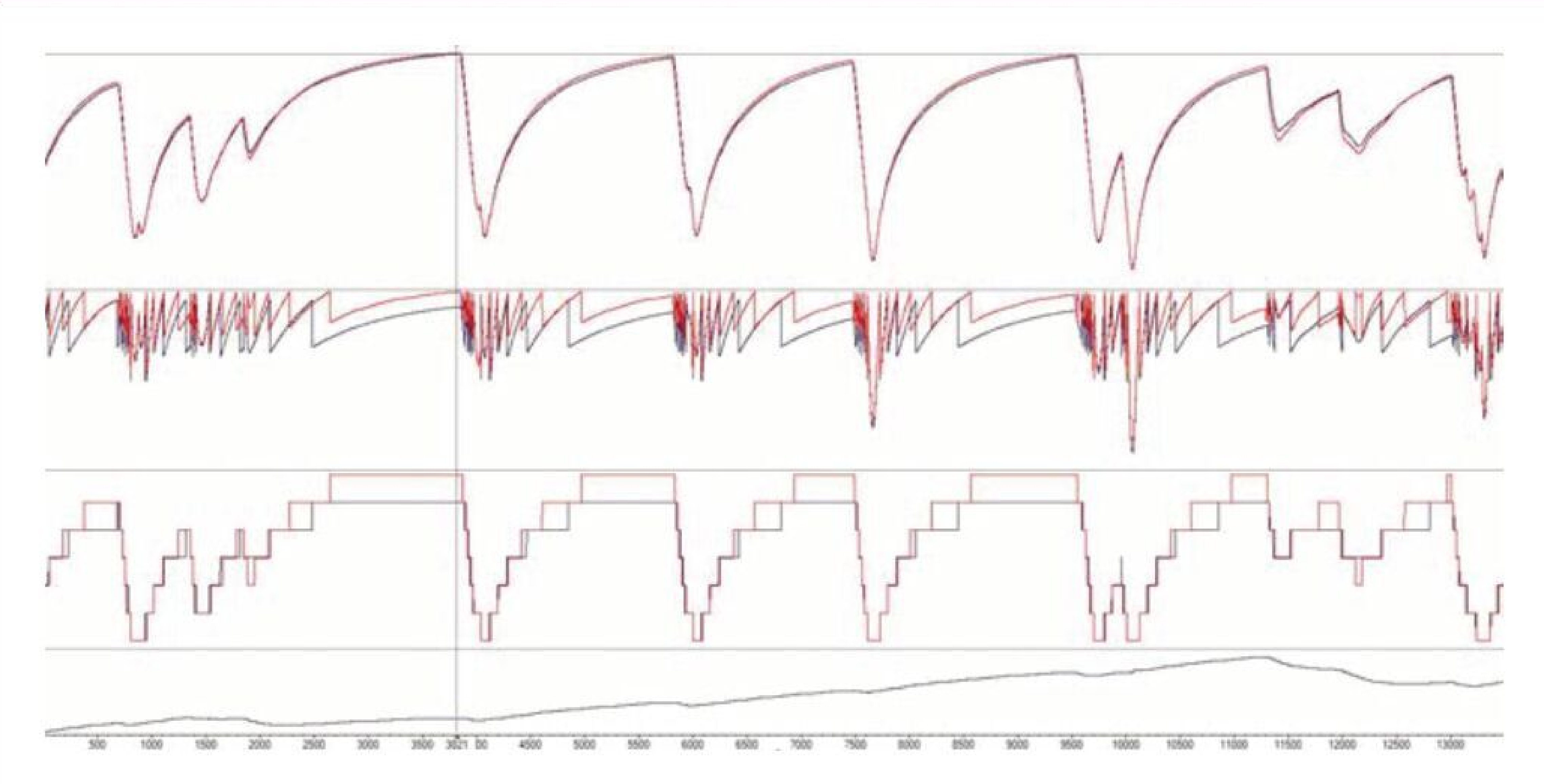


Figure 4: A comparison of the 500kW LMH run (red) with the 2020 LMP2 run (blue)



the result will be based on a configuration that would allow a real driver to explore the car's full potential with confidence.

A major parameter difference between the simulation and the real car is the simulated version uses the same tyres on the front and rear axle, which drives a different handling characteristic than in an LMP2 car, where front and rear tyres are different.

Using four tyres with the same characteristics for a non-hybrid car is probably not the most realistic approach. As discussed last month, it would likely be more effective employing bigger tyres at the rear, for a rear-wheel driven car, as this option is allowed by the rules. This would suit the non-hybrid car's weight distribution and the larger stress faced by the rear tyres as the propulsion power is handled only by the rear axle.

Employing four identical tyres was done for the sake of simplicity, and because this enabled the use of well-validated data relative to LMP2 rear tyres, which have the same dimensions as the mandated LMH tyres and were designed for similar loads.

The aeromap was derived from data of existing Le Mans Prototype cars, scaling the magnitude of drag, downforce and aerodynamic efficiency to meet regulations targets. Two different aeromaps with different characteristics have been considered, and we'll come back to this later.

In all simulations, aerodynamics and powertrain performance were not adjusted for the effects of ambient conditions. Pressure, temperature and humidity all influence air density and, therefore, the magnitude of aerodynamic forces and engine power.

The first simulation runs with the car in qualifying trim, and with a maximum power of 500kW, produced a lap time of 3m22.936s, while the same car with 520kW achieved a lap time of 3m21.359s.

Applying the correction of 0.73 per cent derived in the calibration phase with the LMP2 vehicle model, a lap time of 3m24.417s and 3m22.829s could be considered realistic for power outputs of 500 and 520kW respectively. The car achieves a top speed of 327kmh with the lower power output and 331kmh with the higher output. This is summarised in **Figure 2**.

Target acquired

One thing to note here is that at Le Mans a difference of 20kW of maximum power means a lap time delta of about 1.6 seconds, with this specific car. Also, the predicted lap times are indeed very close to the performance of 2020 LMP2 cars, with a power of 500kW. This explains the need to slow this class down significantly, to achieve what the FIA / ACO calls stratification.

Figure 3 offers a comparison between the results relative to a power of 500kW (red) and 520kW (blue). The first three traces are again speed, rpm and engaged gear, while the fourth one is the 'compare time' that indicates how much gap exists between the two runs in a certain point of the track, in seconds.

Minimum corner speeds do not change in the two runs, because no handling-related parameters were modified. As expected, the bigger engine power produces better acceleration and top speed, both of which are so important at Le Mans. A comparison of the 500kW LMH run with the 2020 LMP2 one is shown in **Figure 4**, where the same channels as in **Figure 3** are plotted. The LMH is shown in red, the LMP2 run in blue.

The LMH car is slower than the LMP2 in every corner, with a bigger difference in fast bends where the much higher weight and lower downforce play an important role. This is particularly evident in the Porsche Curves, towards the end of the lap.

Despite the higher mass, the LMH has a stronger acceleration in each power-limited section, thanks to the much higher power and seven gears instead of six. The compared lap time confirms this, dropping in every corner and growing on straights.

Race pace

It is harder to extract race pace out of simulation because it is not only influenced by car parameters, but also by factors like traffic, weather conditions, rubbering of the track and, of course, the driver.

To quantify the influence of a full tank of fuel in terms of performance, a simulation run with 45kg more (without changing weight distribution, for the sake of simplicity), has been performed for both the 500 and 520kW configurations. The results are in **Figure 5**.

The penalty in terms of lap time produced by a full tank is about the same with both power figures, and amounts to around 1.7 seconds, or a relative delta of 0.82 per cent.

Focusing on the 500kW configuration, and on the corrected lap times, these results would suggest a potential race pace around the 3m26.1s with a full tank of fuel. Though remember, this does not consider tyre degradation, nor traffic. Looking at some statistics relative to previous editions of the 24 Hours of Le Mans and dry condition lap times, it seems realistic to assume a delta between two and 2.5 per cent between qualifying performance and race pace.

In 2018, for example, the pole-sitting Toyota achieved an overall best lap of 3m15.377s in qualifying, while the average of the best 50 and 100-race lap times were respectively a 3m19.575s (delta of 2.15 per cent) and a 3m20.134s (delta of 2.43 per cent).

Considering a lap time deterioration of 2.4 per cent on top of the qualifying corrected lap time of the 500kW LMH car (3m24.417s), leads to a race average lap time in the region of 3m29.3s, which is not far from the FIA / ACO targeted race pace of 3m30.

As for qualifying performance, this is close to the race pace shown by LMP2 cars in the most recent editions of the 24 Hours of Le Mans. LMH could be affected by traffic more than LMP1 because the powertrain maximum power is now limited by the rules and cannot be boosted by the electric drive system. Keeping in mind that the vehicle model this study is based on was built on the author's assumptions, and no data relative to an existing LMH was available, it looks like the rule makers defined the key performance parameters correctly, with respect to the targeted race pace.

That said, there are some open points that need to be considered with caution, and which could open the door to some hidden performance potential, or alternatively could be used effectively by the FIA / ACO to apply Balance of Performance, if necessary.

Aerodynamics potential

The author understands that the process carried out by FIA / ACO to verify LMH cars' compliance to aerodynamic targets includes a wind tunnel test to derive an aeromap, and applying a weighted average over the range of tested ride heights (considering other parameters, like roll or yaw) to define the coefficients of downforce and drag that will be compared to the rule targets. Some regions of the aeromap could well have a higher weighting because they are more critical for overall performance.

How this weighted average is calculated is not publicly known and so, for this article, the models have been calibrated scaling drag and downforce on the whole aeromap ride height range to obtain mean map values equal to the targets. Assuming this is representative of what the rules mandate, if the variation of downforce and drag with respect to ride heights is higher in one car than another, one could effectively work in a more efficient part of the aeromap, while both would still meet the given requirements.

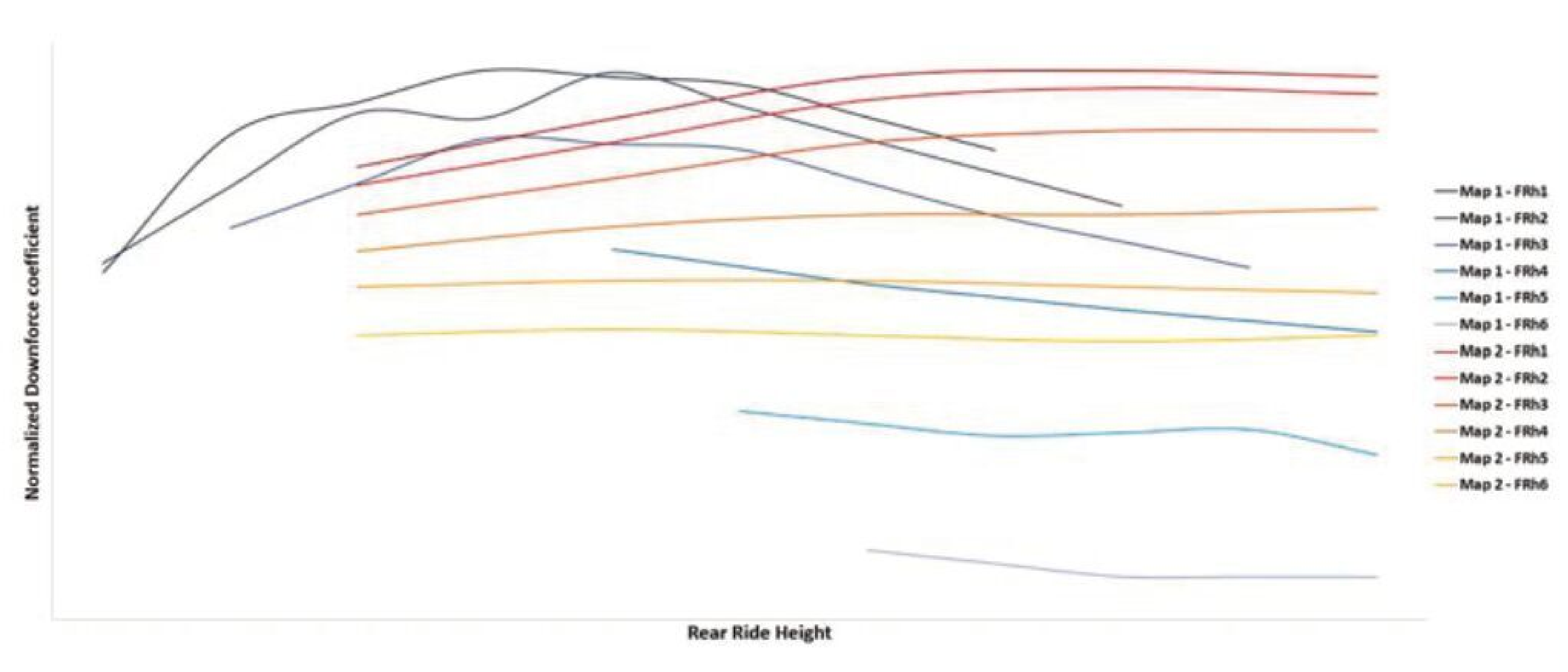
For example, taking the 500kW model used so far in this article as the baseline, another model was built with a lower aerodynamic sensitivity to ride heights. To do so, the author took a reference aeromap of another Le Mans Prototype, scaling it to meet the regulations' aerodynamic targets. The two aeromaps, both normalised with respect to their maximum value, are shown in **Figure 6**, with the downforce coefficient on the vertical axis. The aeromap using blue tones (map 1) is the one employed so far. The one using red tones (map 2) is the one with lower ride height sensitivity. Each line is relative to a certain front ride height, while rear ride heights are on the horizontal axis.

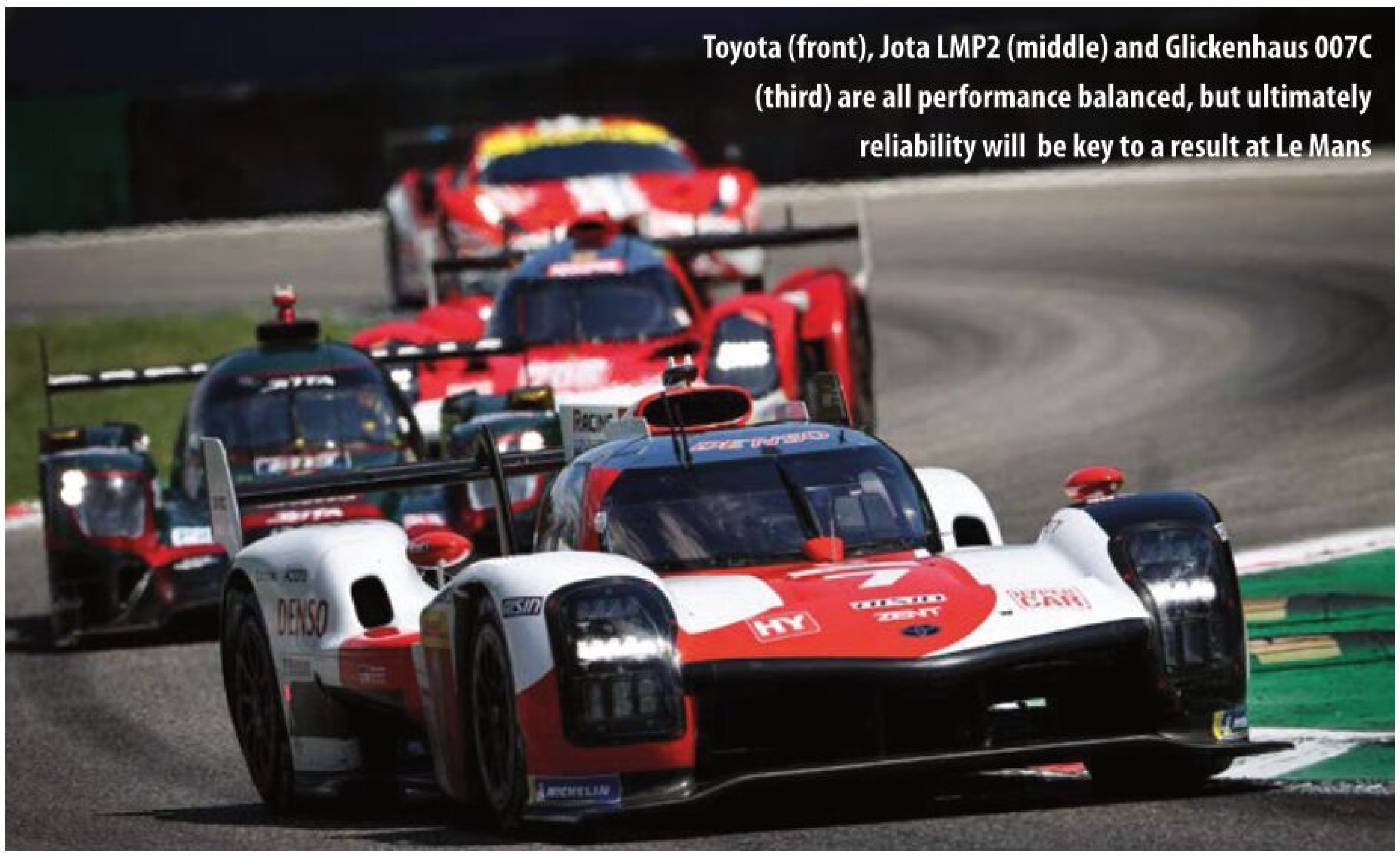
Map 2 has a much lower sensitivity to both front and rear ride heights. To understand the difference produced by the two aeromaps in terms of performance, some simulation runs have been performed progressively reducing static front and rear ride heights and increasing suspension vertical stiffness by acting on third element bump stop free gaps and on springs rates. The aim was to keep the minimum dynamic ride heights during a lap constant, as being too low could cause damage to the car in the real world.

Figure 5: Performance runs with 45kg more weight, to simulate a full tank of fuel

Power	Fuel Load	Lap time	Corrected Lap Time	Delta [sec]	Delta [%]
500 kW	20kg	202.936	204.417	Ref	Ref
500 kW	65kg	204.605	206.099	1.669	0.816%
520 kW	20kg	201.359	202.829	Ref	Ref
520 kW	65kg	203.026	204.508	1.667	0.821%

Figure 6: Aeromaps showing sensitivity to ride height of the 500kW model





Toyota (front), Jota LMP2 (middle) and Glickenhaus 007C (third) are all performance balanced, but ultimately reliability will be key to a result at Le Mans

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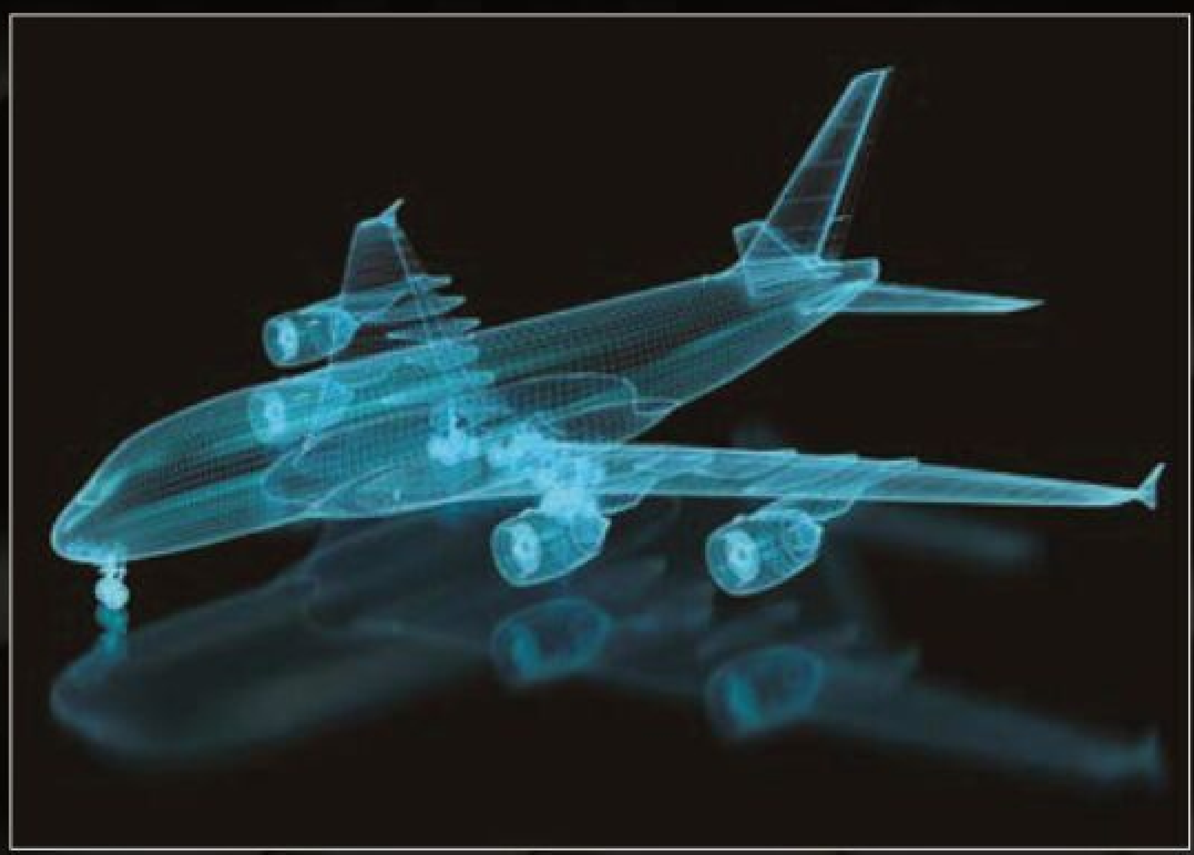

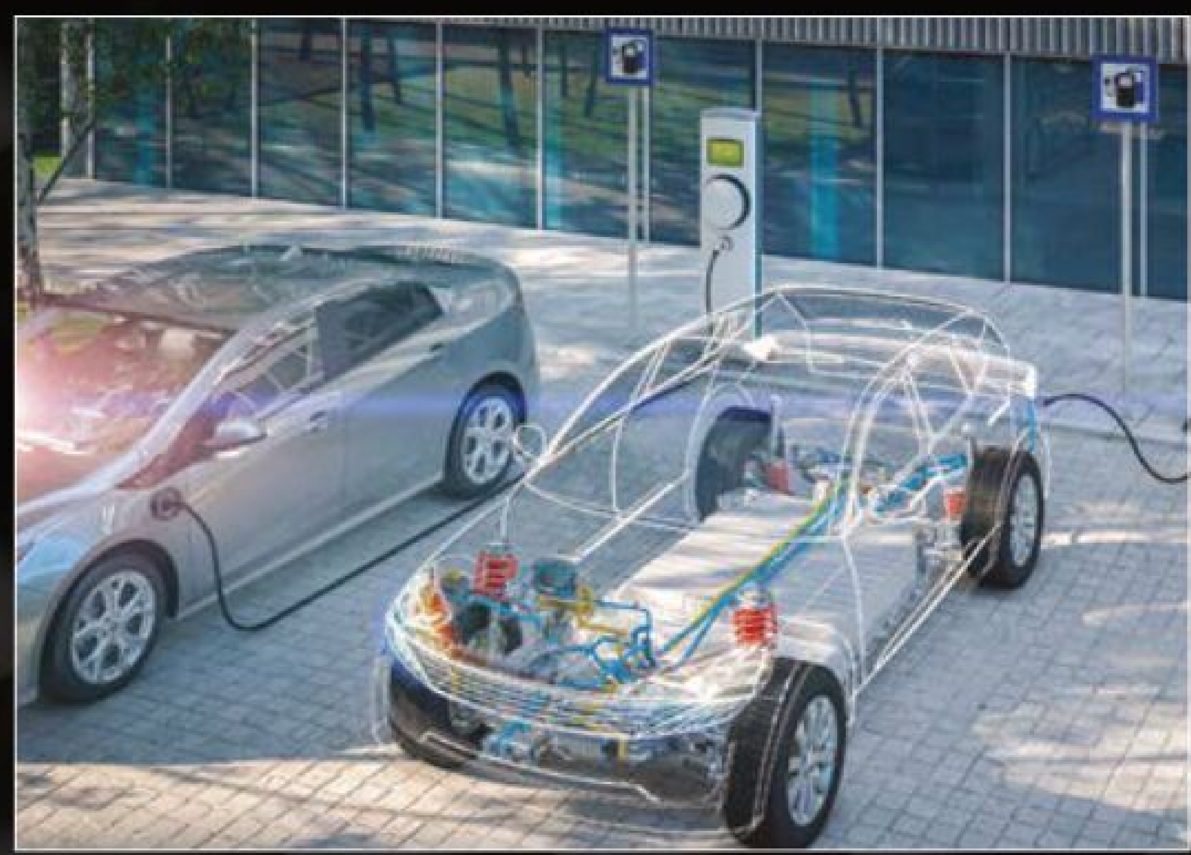

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It seems the LMH class did not yet exploit its full performance potential and more could be shown at Le Mans with a little development and optimisation

The results of these simulations are summarised in **Figure 7**.

The lap times produced with the two aeromaps and the standard set-up are very similar. As the car's set-up changed, switching to lower static ride heights and higher suspension stiffness, map 1 produces a bigger improvement than map 2. Conversely, it is reasonable to consider that if static ride heights were increased and suspension stiffness decreased (this would make sense on a bumpy track or following BoP actions) map 1 would lead to a bigger performance deterioration than map 2.

The key message here is that a more 'peaky' aeromap could have better performance than expected, if used in the right window (above all, on smooth tracks). Despite producing average aerodynamic forces that respect the regulations, a peaky car would lose more performance if the car runs out of said window, which is likely to happen on less smooth surfaces.

Figure 8 offers a comparison between the results obtained with map 1 (red) and map 2 (blue), both with the baseline car set-up. The first trace is speed, the second downforce coefficient, the third aerodynamic balance and the fourth the compare time.

The difference between the two speed traces is small, with the exception of some fast corners like the Porsche Curves. But dynamic downforce and aero balance are significantly different. In particular, with map 2 the car experiences much lower variations of these two parameters over a lap. The difference in speed between the two aeromaps with the stiffer suspension set-up and lower static ride heights is more sensible. As in **Figure 9**.

A speed difference between the two runs is now easier to spot, both in fast corners and in top speed. The latter also identifies a higher ride height sensitivity of map 1 in terms of drag. On the map 2 run, dynamic downforce coefficient not only has a smaller variance over a lap but is also now sensibly lower than the one of map 1, despite the two aeromaps having the same average downforce.

Figure 7: Simulation runs at progressively reducing static ride heights

Aeromap	Ride heights	Front bump stop gap	Rear bump stop gap	Front stiffness	Rear stiffness	Lap time	Delta %
Map 1	STD	STD	STD	STD	STD	202.936	REF
Map 1	-2mm	-2mm	-2mm	STD	STD	202.569	0.18%
Map 1	-3mm	-2.5mm	-3mm	+27%	+7%	202.397	0.27%
Map 2	STD	STD	STD	STD	STD	202.974	REF
Map 2	-2mm	-2mm	-2mm	STD	STD	202.777	0.10%
Map 2	-3mm	-2.5mm	-3mm	+27%	+7%	202.671	0.15%

Figure 8: Comparison between aeromap 1 (red) and aeromap 2 (blue) with the baseline car set-up

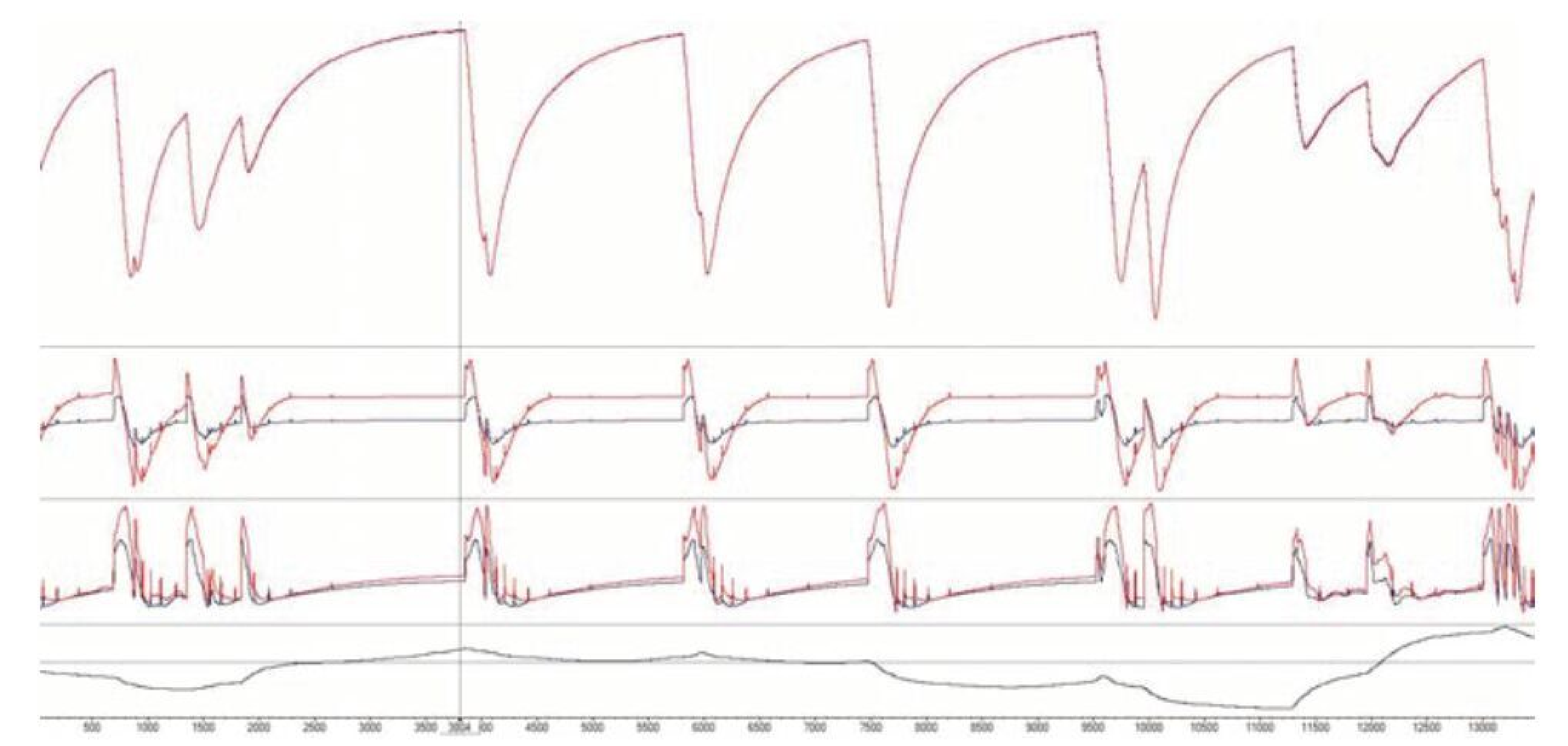
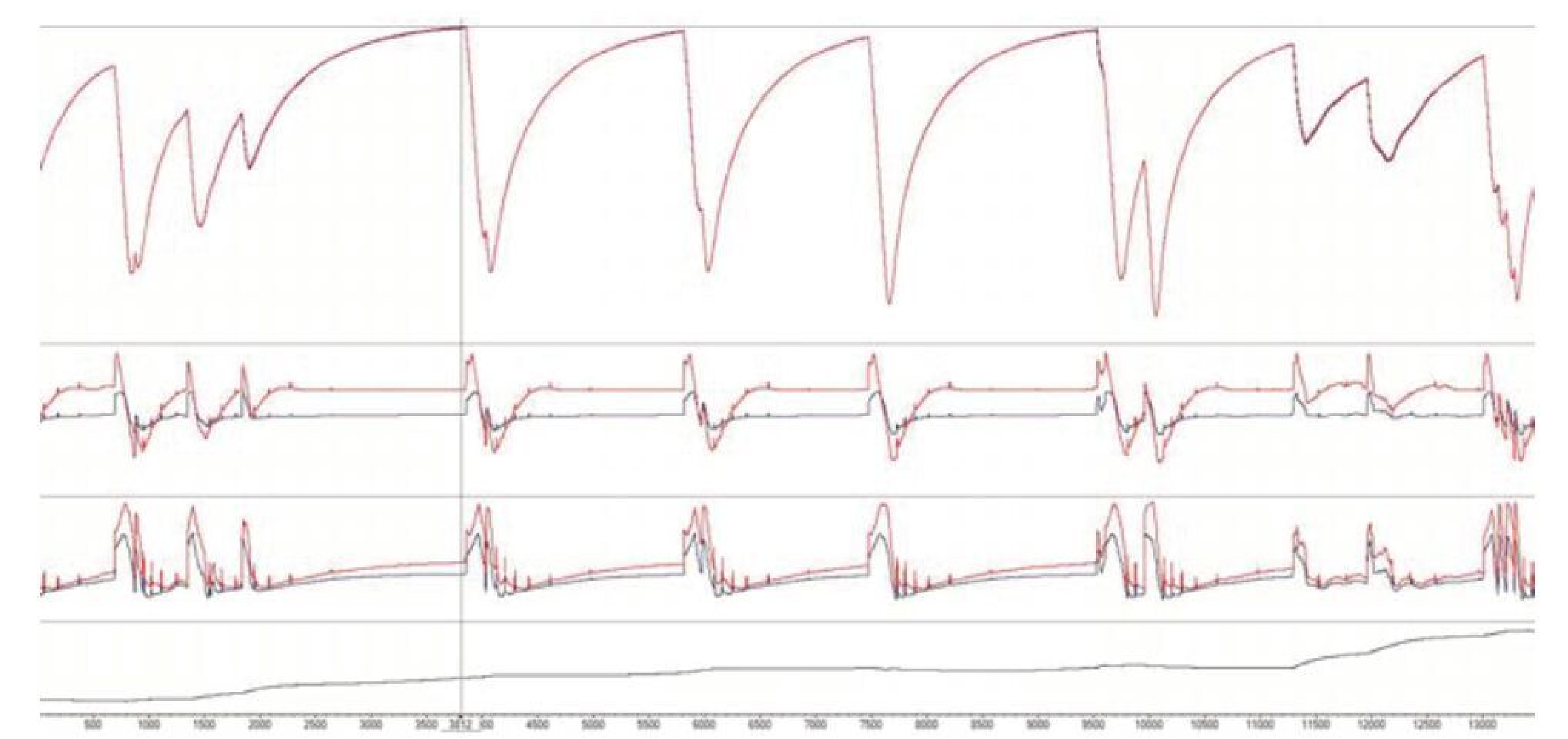


Figure 9: Difference in speed between aeromaps 1 and 2 with the stiffer suspension set-up and lower static ride heights



At time of writing, data relative to the first races of the season was available and could be used to understand how close our predictions are to actual LMH performance on track. Here, Spa-Francorchamps is a reference as this race was often a preparation for Le Mans.

Race context

In 2021, Toyotas set pole position with a lap time of 2m00.747s. It is worth noting that Toyota was allowed a weight of 1040kg and a power of 520kW for the Belgian race. The results of simulation runs performed with the same vehicle model employed for the Le Mans analysis, with a weight of 1130kg and without any set-up modification to suit Spa-Francorchamps, produced lap times between 1m59.6s and 2m00.1s with 500kW, and between 1m58.9s and 1m59.4s with 520kW.

For context, the LMP2 vehicle model used to calibrate the Le Mans simulation runs, set up with sprint gear ratios and settings suited to Spa, produced lap times between 2m02.970s and 2m03.392s, closely matching race weekend qualifying performance (on pole was United Autosport with 2m02.404s, with G-Drive in second on 2m02.984s). If our assumptions for the LMH vehicle model are correct, it seems the LMH class did not yet exploit its full performance potential and more could be shown at Le Mans with a little development and optimisation.

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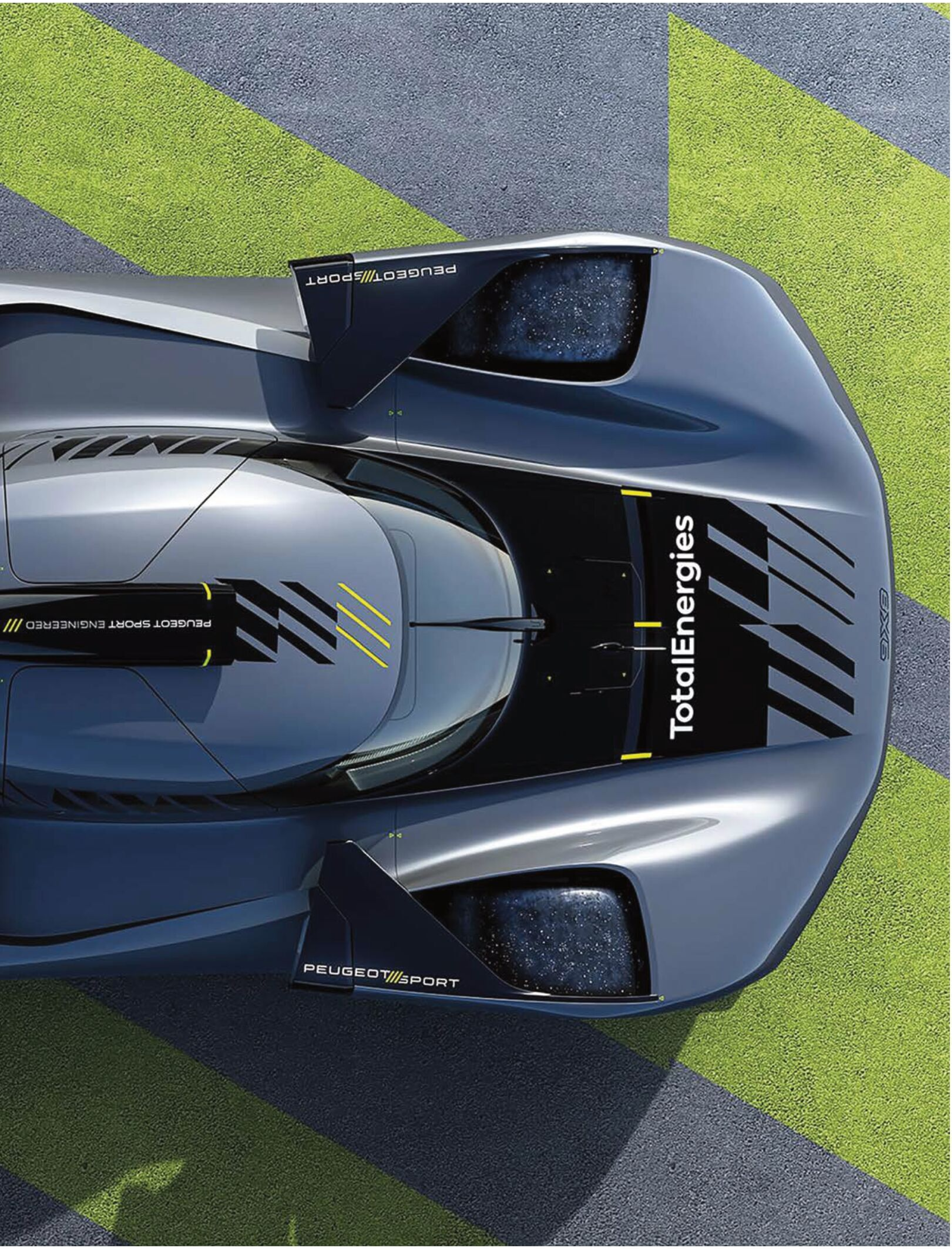
The new Peugeot 9X8 has taken full advantage of the reduced aero targets to build a radical Le Mans Hypercar

By ANDREW COTTON

Ground effect


PEUGEOT SPORT
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9X8
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Peugeot will field a full ground-effect Le Mans Hypercar when the French manufacturer returns to endurance racing in 2022. The company revealed its challenger, the 9X8, early in July and presented a show car at the third round of the FIA World Endurance Championship at Monza a few weeks later.

The most striking element of the car is the lack of rear wing, the design team having established the maximum downforce levels early on in the design process using underfloor aero marrying up with the flow over the rear deck. It therefore did not need an additional downforce generator at the rear.

Also clear in the design is the relationship with the production cars, a feature that is made possible by the Balance of Performance system for the top category that does not penalise styling cues.

Elegance in design

Although only in mock-up form for the launch, the final car is expected to closely match what the company has presented, running with only a modest fin over the engine cover. The elegant design and lack of aggressive aero set tongues wagging, and arguments raged over whether or not the car would run in this form. Peugeot is confident in its figures, and while it says it will switch tactic if necessary, rival designers don't believe the car will need a wing. Track validation will provide final confirmation.

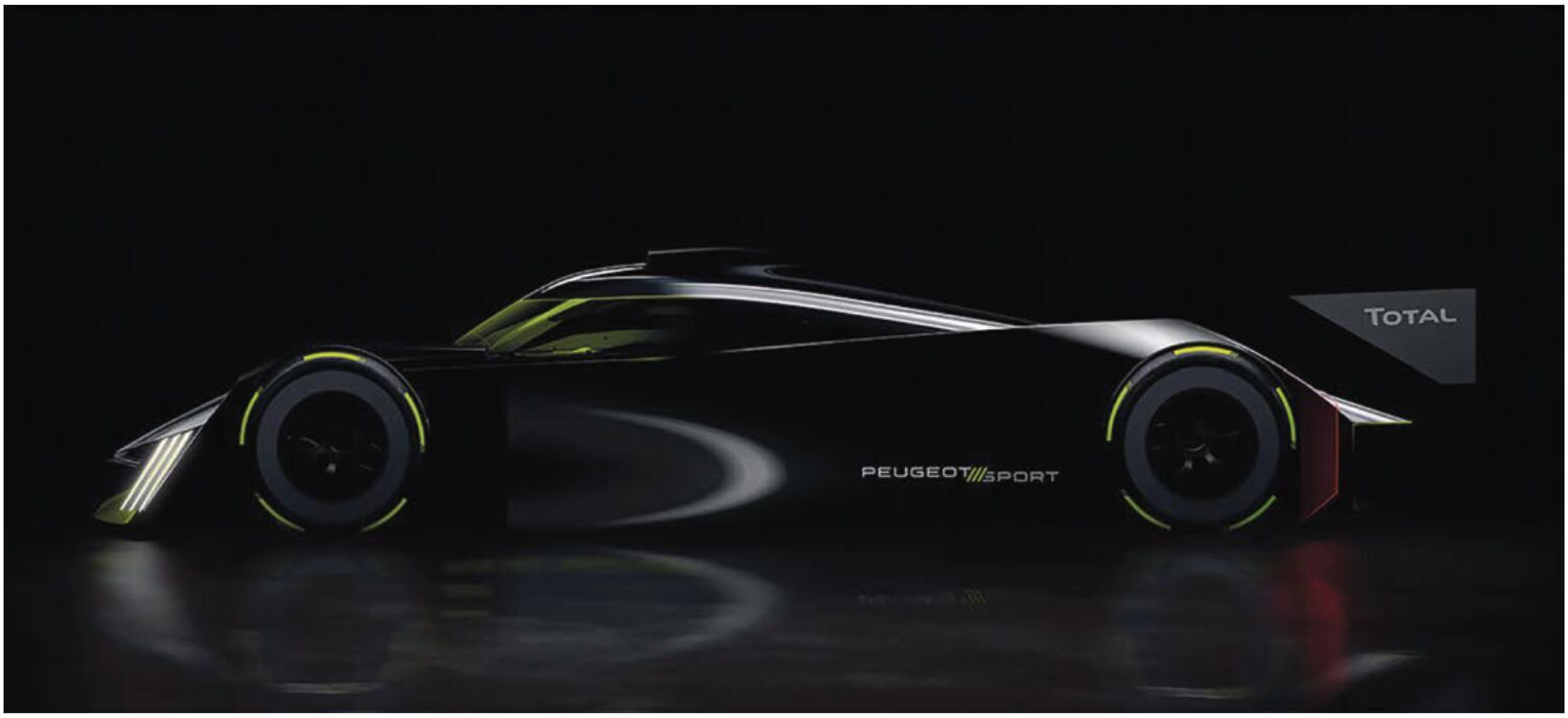
The old LMP1 cars had their aero packages defined in the wind tunnel. Not only was tunnel time costly, it also produced rather ugly and complicated cars. Steps were therefore taken to reduce the number of body kits LMP1 manufacturers could develop, but the Hypercar regulations have gone a step further. They stipulate maximum downforce at around two thirds of the old LMP1 target, and minimum drag levels. Once these are achieved, there is no point trying to change them dramatically.

While Toyota looked to maintain the family relationship with its GR010 compared to the TS-generation cars, and Glickenhaus designed a more traditional Prototype shape, Peugeot has pushed the boat out, and says it has done so with ease. Having validated its figures in simulation and the Sauber wind tunnel that is also used for homologation purposes, Peugeot says track testing will provide the detail to finalise its concept.

Race debut

The car is scheduled to race before Le Mans in 2022, likely at Spa in May, although the calendar has yet to be released, but the timing of its debut will depend on whether or not the on-track testing, due to start in December of this year, is successful.

The concept car displayed has no rear downforce generator, though the finished racecar is likely to have a flap at the back to help trim and balance the car as the race team seeks to control the ground effect and maintain optimum downforce in all conditions



Perhaps just to keep its competitors guessing, the car shown at the concept launch in 2020 did have a rear wing, even though at this stage the design team already knew the car didn't need it

With LMH regulations allowing a lot of freedom in design, Peugeot has played heavily on its brand identity, producing a car with multiple styling cues from its current road car range

'The 2022 season was supposed to start in July, now it is February or March,' says the team's technical director, Olivier Jansonnie, referring to the original winter schedule on which the WEC was based when Peugeot launched its programme.

'It is not even being able to start in June, it is starting at Le Mans in June, the most difficult race. You don't want to be there for three hours. The interesting thing for us is to build experience. We have to be there, not pretending that we can win, but just to increase our experience.'

The likelihood is the car will not debut at the Sebring race scheduled for March, but will have to do a race pre-Le Mans to give the ACO and FIA technical teams the chance to balance the performance of the car ahead of Le Mans. For Peugeot, the timing is tight but, with a tail wind, it could do so.

Details already announced by Peugeot confirm the 9X8 will be powered by a 2.6-litre, twin-turbo V6 engine and will be four-wheel drive, the front wheels powered by an MGU-K. The electrical system will be 900V, in line with modern trends in electric and hybrid production cars, which helps to size the battery, but the team was not willing to put a capacity figure on the battery, only hinting it will not be a large one.

'The regulation allows for 200kW on the e-motor at the front, so you need to achieve this from the battery, or maybe a little more with the efficiency drop. Once you get this, you get a nominal capacity,' explains Jansonnie. 'With the cells that are on the market, and since we are working with TotalSaft, we have access to some sophisticated components and cells and we have a good ratio of capacity and power.

'We did not push too much on the energy side because that would have meant extra weight for us, and the way we think the regulation is going to be it doesn't make much sense to do that.'

Efficiency ratio

'The efficiency ratio of the electrical systems is very high, and the difference for those is more the operating temperature. So if they are able to operate at higher temperature, then you can have smaller coolers.

'The energy dissipating is low anyway, as is the temperature, so you are dissipating some energy at 45degC ambient and keeping the system at 55-60. The difference is not high.'

Cooling comes via two large scoops just behind the cockpit, a feature the design team acknowledges is a little more risky due to the increased potential for debris ingression, particularly from tyre marbles and general rubbish around a street circuit. However, it says it has learned from mistakes in the past and is confident it can protect the radiators.

'On cooling, we have an air pick up for the radiator that is quite forward and high, and that is something we need to avoid debris in the cooling,' says Jansonnie, who was involved in the old diesel 908 programme. 'We had bad experience from that in the past.

'It is just the engine air inlet above the cockpit, the side is for the cooling. You need a lot of cooling requirement on the cars when you put together the ERS system, the 500kW engine and so on.'

By far the most striking element of the car, though, is the aerodynamics. The team has only reached the stage of bench testing its powertrain so far, but has run the car in the simulator since March with its factory drivers.

'This concept does not achieve maximum downforce. If we wanted to achieve that… we would have done something completely different'

Olivier Jansonnie, technical director at Peugeot Sport

'We put in the aeromap on the simulator without the wing, they drove it, they developed it, we made changes, did some proper development work on the simulator and then they found out that they didn't have a wing,' says Jansonnie proudly.

The car will have to run with one adjustable aerodynamic device, but the team has not yet decided whether it will be mounted at the rear, like Toyota, or at the front as per the Glickenhaus 007C. It seems most likely that part of the rear deck will be adapted to run with an adjustable flap, although it will be to trim and balance the car rather than to provide additional downforce.

'This concept does not achieve maximum downforce,' explains Jansonnie. 'If we wanted to achieve that, or even maximum efficiency, LMP1-style, we would have done something completely different, and probably had a rear wing on the car.

'I don't think you can understand what we are trying to achieve unless you understand the work that has been done with the LMH regulation. There have been different

readings of the LMH regulation, and we are not sure we have the right one, but we have spent a lot of time on this.'

More freedom in the design of the floor allowed Peugeot's designers to create a rear diffuser that reduces the amount of air entering the critical area to create the downforce. That, coupled with an air stream flowing through the nose and exiting just behind the front wheels, is intended to reduce air coming into the underfloor area ahead of the rear wheels and should allow the ground effect to work.

Brand identity

Peugeot has proven the design in concept, and in the wind tunnel and has achieved the airflow that it was after. 'You needed to channel a lot of air with the old LMP1, but you were exceeding downforce of 5.5 to six, we are on the level of four,' says Jansonnie.

'Overall, the aero downforce generated is lower. It took us three weeks to achieve the downforce we wanted. But just achieving downforce is not the point. Making it stable is the point, and to try to make something that is not only a racecar, but also something that we can identify as a brand. And to see whether we can use this regulation to achieve the same level of performance as everyone, just adding more of the brand elements of the car.'

Stablising the downforce generated under the car is the key to making it work, hence the likelihood the rear deck will feature a flap. Downforce is also generated *over* the body, and the relationship between the two will, hopes Peugeot, work in the real world.

'What is interesting in these regulations is that you have to achieve three different things at the same time. You can do performance checks in simulation, that is most of the work I would say, but you also need to do some measurements in the wind tunnel, precisely the one that is used in the homologation because every tunnel has bias due to build or whatever. That was something we had to be careful with. And, of course, at the track, and we don't know that yet. That's where the final answer will come from.

'At this stage, we trust our simulation and measurements, we think that it is going to work and do what we want it to do but the final validation will come from the track.'

Clearly, generating downforce from the underfloor means careful channelling of the airflow is critical, yet the car will be subjected to the bumps of Sebring, the road course section of the Le Mans circuit and potential kerb strikes on each of the circuits in the FIA WEC. With convergence (see sidebar on p24), the car could also compete in the IMSA series in the United States, either under the Peugeot banner or one of the Stellantis Group sister companies.

Large scoops behind the cockpit serve for cooling purposes, although debris ingress is a primary concern for the design team

Garish cockpit colours were deliberate as the design teams preferred to have the cockpit easily identifiable by design rather than a dashboard sticker

'We have to be careful to avoid too many fragile parts on the underside of the car that can get damaged and change the balance,' admits Jansonnie. 'It is part of the game to keep something that is strong enough in terms of performance, but also reliable enough and robust enough for the 24 hours and the other races.'

Yaw control

One of the other key elements of the car is the absence of a large rear fin on the engine cover. While this has been kept by both Toyota and Glickenhaus on their respective designs, Peugeot has gone for a rather more elegant approach that is considerably smaller than its rivals' solutions.

The regulations demand that the manufacturer show in CFD studies that the car is stable in high yaw conditions and, while Toyota initially sought to rid itself of the fin, in the end it decided it was the most efficient way of achieving that goal.

'Just achieving downforce is not the point. Making it stable is the point, and to try to make something that is not only a racecar, but also something we can identify as a brand'

Olivier Jansonnie, technical director at Peugeot Sport

'Our target with regard to our energy requirements is flawless reliability and perfect control'

Jean-Marc Finot, motorsport director at Stellantis Group

For Peugeot, it was indeed complicated to try to run the car without it, as Jansonnie explains: 'The fin is something we investigated at some point. We have to demonstrate in calculation in CFD that the car is stable in side wind, 90 degrees, and pass a complete demonstration from zero to 180 degrees. To be fair, it is the most challenging part of the regulation, and it took us quite a lot of time to achieve that.

'In concept, we had a much bigger fin plate at the back, and it is possible that we will have to extend that on the racecar we take to the track once again.

'In LMP1 the dimension was specified, while here we are free to do what we like, but we have to prove the stability. We have the vertical winglets on the inner part of the rear wheelarches, which are also helping to stabilise the car. As a total, we have a similar effect but with a smaller engine cover fin.'

Shot in the arm

While Peugeot says Le Mans is 'not compulsory', and is dependent upon track testing, rivals believe the French have time to prepare for Le Mans. For Peugeot, and for the race, it would be the shot in the arm they both need ahead of a mass influx of manufacturers for the centenary year in 2023.

It is the first time since the programme was abruptly halted in January 2012 that Peugeot will race in endurance sport, and it has taken new rules and a very close relationship to convince the Stellantis board that now is the time to return.

'Our target with regard to our energy requirements is flawless reliability and perfect control,' says Stellantis Group motorsport director, Jean-Marc Finot. 'Le Mans has become a 24-hour sprint race that can be won or lost by the number of times you pit.

'The exceptional energy efficiency of the new Hypercars prefigures what we will see shortly in the world of road cars. That consideration had a fundamental influence on all our work on the Peugeot 9X8 package, every aspect of which needs to contribute to the common goal of achieving hyper efficiency from its powertrain and aerodynamics.'

Convergence

The FIA World Motorsport Council approved rushed-through agreements between the FIA, ACO and IMSA to allow Prototypes to compete globally.

The FIA / ACO regulations permit Le Mans Hypercars to run with or without hybrid systems but, if they choose to run one, it must power the front wheels, effectively giving the Le Mans Hypercar Prototypes four-wheel drive.

The IMSA regulations are designed to permit LMDh cars, which feature a spec hybrid system on the rear axle only.

Balancing the two will be tricky with totally different characteristics for either concept, but an agreement has been put in place that cars which compete in the FIA WEC and at Le Mans will be tested in the Sauber wind tunnel, while cars that compete in the US will be tested at Windshear.

The braking capability has been addressed, with all-wheel drive and rear-wheel drive concepts balanced on application of torque, while the front differential will have a zero-lock mechanism on coast. The idea is to limit the advantage of a front axle motor on braking, turn in and acceleration.

'If you want perfect balance between the two concepts then you need to give the same tools or possibilities to the different concepts,' explains Olivier Jansonnie of Peugeot Sport. 'I think we will find something that will make sense for everyone. You have some possibilities on the rear-wheel drive that we don't have, and we have stuff they don't have, so together we have to make it work.

'I think what is important is the understanding that the cars have to race together, perform at the same level and the key is to achieve that while keeping the DNA of the regulations.'

'I think we will find something that will make sense for everyone'

Olivier Jansonnie, technical director at Peugeot Sport

This intention is echoed by Marek Nawarecki, director of Sport and Touring Cars at the FIA.

'We have different phases from different types of cars, and allow them to have dynamic differences we have to identify, and then put them as close as possible together in order to not allow significant advantages from one car to another.

'There are some effects from the rear hybrid that we have to identify the possible advantages, and the same for the front hybrid motor. The convergence looks to identify the process, the gap of functions and operations of the system to allow different types of cars to compete, and win.'

The FIA, ACO and IMSA-agreed process takes into account many aspects of car performance to balance the different concepts

Majority rules

The United Autosport team has won twice this season and comes to Le Mans as reigning LMP2 champion

Racecar *talks to John Manchester, operations director at British engine manufacturer, Gibson Technology, about the company's hopes for an overall win at this year's 24 Hours of Le Mans*

By ANDREW COTTON

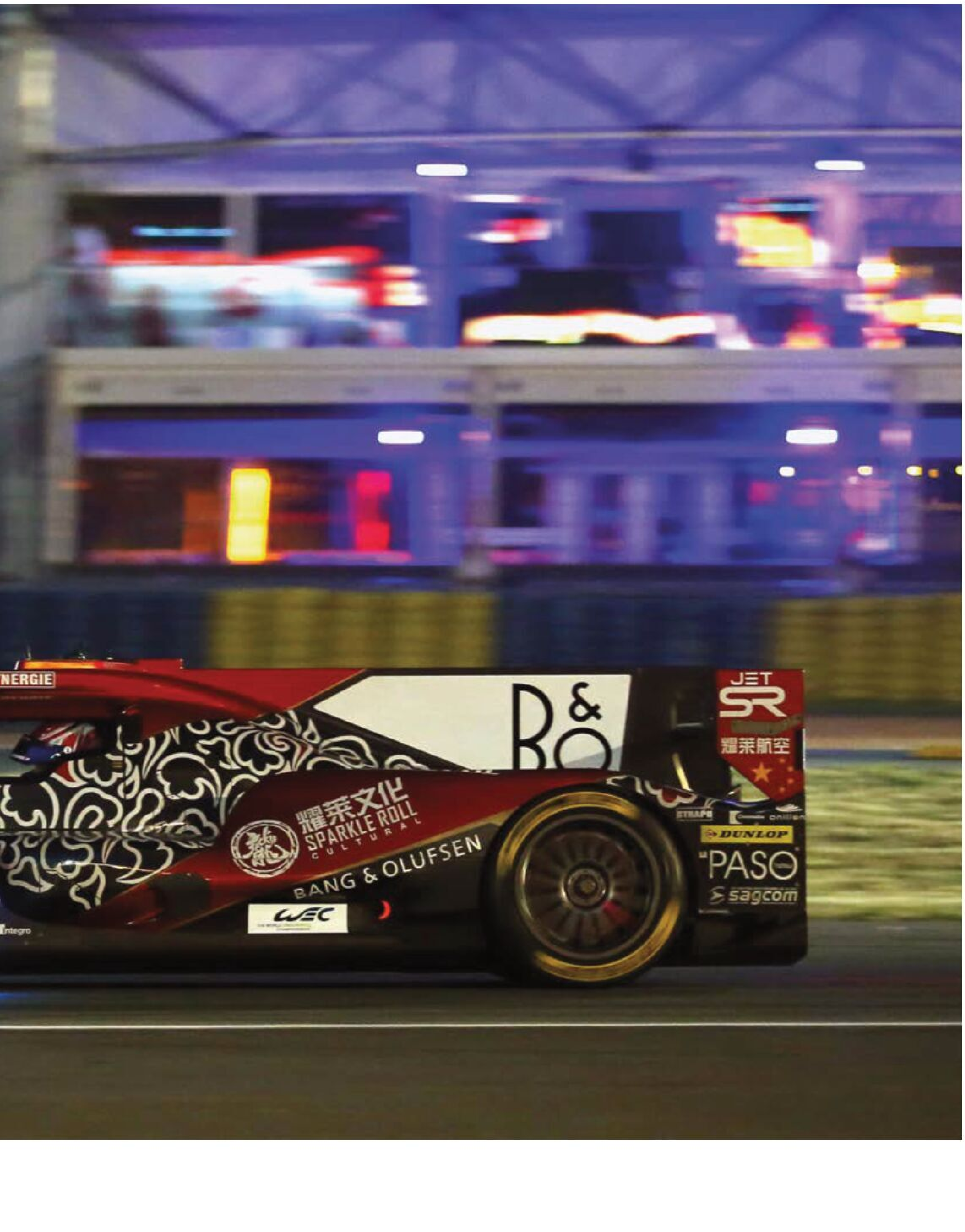
Gibson won the contract to be the sole supplier to LMP2 worldwide, including IMSA, the Asian and European Le Mans Series and the WEC

To provide power for almost half the grid competing at Le Mans this year is an achievement in itself but, judging by the opening few races of the 2021 FIA WEC season, this year is engine manufacturer Gibson's best chance of securing overall victory for the first time.

The British company landed the contract to supply the LMP2 cars, for customer teams and drivers, when the new category was launched in 2017, and almost immediately come close to winning endurance racing's greatest prize in its first year as the Prototypes from Toyota and Porsche hit trouble. The Jackie Chan Racing ORECA Gibson LMP2 led the race for much of Sunday, only ceding the lead in the final 90 minutes to a fast-recovering Porsche LMP1 car.

Despite Brexit, which has added complications for international supply for British companies, meaning all engines from Gibson now have to travel on a carnet, and Covid, which has complicated travel for all racing teams and personnel this year, Gibson's supply of engines to teams competing in IMSA, the European Le Mans Series, the Asian Le Mans Series and the World Endurance Championship has been uninterrupted, both in terms of supplying hardware and support at each of the key races.

Gibson came close to winning the race overall in 2017 with Jackie Chan Racing's LMP2 car run by Jota, but a fast-recovering Porsche LMP1 hybrid pipped them to the post with 90 minutes to go



LMP2 is not Gibson's only chance of winning overall, or even its best one

Much has been made of the class stratification in the World Endurance Championship, the separation of the new Hypercar and LMP2 cars, this season with the Hypercar manufacturers complaining that the LMP2 cars were too close. Not only does a fast LMP2 car challenge the Hypercars in qualifying, should there be a reliability issue with the top-class cars, as there was in 2017, the chance of recovery is much slimmer with the reduced gap in lap time.

Not that LMP2 is Gibson's only chance of winning overall, or even its best one. The Signatech Alpine, last year's Rebellion now in French hands, is also powered by the Gibson engine. The team ran the Toyotas close in the opening couple of races, finishing second at Monza, and has had no major reliability issues this year.

Top flight

One of the season-long protagonists in the FIA WEC Hypercar category, Signatech Alpine is keeping its hand in ahead of Renault's anticipated return to Le Mans, when it hopes it will be selected to run the car. In order to maintain a racing programme in the WEC, the team secured the former Rebellion R13 chassis, powered by Gibson's GL458 engine, a 4.5-litre, normally-aspirated V8.

However, the car is based on ORECA's current LMP2 chassis and, as such, is unable to accommodate a larger fuel tank with sufficient volume to complete a full stint. The team is aiming to be able to do 11 laps on a full fill, compared to 12 allowed in the Balance of Performance table issued by the FIA and the ACO.

'It is effectively a P2 chassis that has been heavily modified and developed,' says Gibson Technology's operations director, John Manchester. 'That's why the car has to do an extra fuel stop. We are also restricted on the power of the engine compared to last season, but then so are the Hypercars.'

The team will have to do an extra stop after every 11 stints, which will cost more than a minute in the pits if it is for fuel and tyres. If the weather is hot – and hot weather has been a feature at Le Mans for the last few years – that will have a further detrimental effect on performance, the N/A engines being affected more than the turbocharged ones.

'Obviously when air inlet temperature increases it has an effect on the density of the air, and that has an effect on engine performance,' says Manchester. 'From our perspective, and I am sure all the teams, it would be better to have a cooler Le Mans as hot temperatures can create reliability issues.

'As an example, look what happened in the top class [in 2017]. Some of those issues were probably down to heat because everything on the car gets extremely hot, and that puts excessive demands on components.

'It is obviously difficult to compete with an OEM such as Toyota, especially with its vast resources, but hopefully we can give them a good fight.'

Judging by the first two races, at Spa and Monza, reliability is an issue for the top-class cars. The Toyotas have suffered electrical problems, plus at Monza a fuel pressure issue, while the Glickenhaus 007C has yet to sort out its traction control and front brake overheating ahead of the race.

Alpine is the sole Gibson entry in Hypercar, grandfathered from the old LMP1 era and performance balanced against the new cars

Restrictive practice

When the Hypercar regulations were introduced, there was an immediate problem in that the target lap time for the cars was 3m30s in race conditions, already slower than the LMP2 cars from 2020, which therefore needed to have their performance curtailed. The LMP2 pole position time was 3m24.5s, set by Paul di Resta in the United Autosport ORECA Gibson, and the majority of cars had their fastest laps during the race around the 3m29s mark.

It was clear the LMP2 cars had to be slowed in order to prevent them challenging, or even beating, the new Hypercars. Consequently, the FIA and ACO mandated a series of measures, including permitting them to run with a single, low downforce aero kit, tasked Goodyear with producing slower tyres, and then removed substantial power from the engine.

'The performance levels have been restricted for the Hypercars, and so obviously the LMP2 class had to be restricted, too. The LMP2 cars are now racing with minus 50kW,' confirms Manchester. 'This was achieved through the intake system and throttle opening. Teams can clearly feel the difference, as it is quite a significant reduction in power.

'We completed a large amount of development work over the winter last year on the new spec engine. That was then followed by an on-track testing programme, and the FIA then evaluated the result.

'The decision was originally taken to go -30kW, but that was then reduced to -50kW in both the WEC and European Le Mans Series.'

Mandating such a change this year has been challenging, not only for Gibson but also for the teams. The company has more than 50 engines leased to LMP2 teams around the world, so any hardware fixes was going to add pressure onto the company.

'We focused on reducing the power in the most economical and effective way we could,' says Manchester. 'We have more than 50 engines [currently running with teams] and they all had to be updated accordingly. And, as with any hardware changes, there is additional design and manufacturing work that has to be undertaken.'

Part of the contract between Gibson and the FIA is that there is on-track support and, while that continues unabated, the British company has restricted the number of personnel at the track to only essential engineers. Part of their role is to monitor engine performance from each of the cars and report any discrepancies to the FIA.

'It would not really be possible for a team to change the performance of the engine as all the engine maps etc. are access protected,' says Manchester. 'Even if that did happen, and it never has, we would know because we analyse every log from every engine after each session and would see any discrepancy.

'Obviously, if that ever did happen, then we would have to report it.'

With the performance loop closed off on the engine side, teams are looking at the finer details of the chassis, set-up and aerodynamics to improve lap time.

Future proof

One of the main topics of conversation at Monza was the future of the LMP2 category. At the FIA World Motorsport Council meeting in July, it was confirmed that the current LMP2 cars would be carried over to 2024 without change, giving the teams maximum time with the existing machinery.

By extending the homologation period, it means the LMDh cars, which were supposed to be based on the LMP2 chassis but which, instead, will have to be adapted to LMP2 spec afterwards, will have a year of competition before being handed to customers until the end of 2023.

The key areas of any spec series are about reliability, service and providing a good product that performs at a consistent level, which has always been our aim

John Manchester, operations director, Gibson Technology

The FIA and ACO have confirmed they have not even started to think about the new regulations, other than that the 'spine' of the car, the chassis, will be LMDh specification. They have also not yet issued the invitation to tender for the engine.

'We would obviously look to submit a tender,' confirms Manchester. 'I think when people look at LMP2 for what it is now, they would say that it is a really good class. It's a great car, an excellent, cost-effective package and, of course, it is reliable. I think the key areas of any spec series are about reliability, service and providing a good product that performs at a consistent level, which has always been our aim.'

Le Mans is always a challenging race for all suppliers but in Covid times, with reduced staffing levels and a record number of cars supplied, Gibson's engineers will be under even greater pressure, but they know this year's race is their best chance yet of a dream result for the company.

Blended learning

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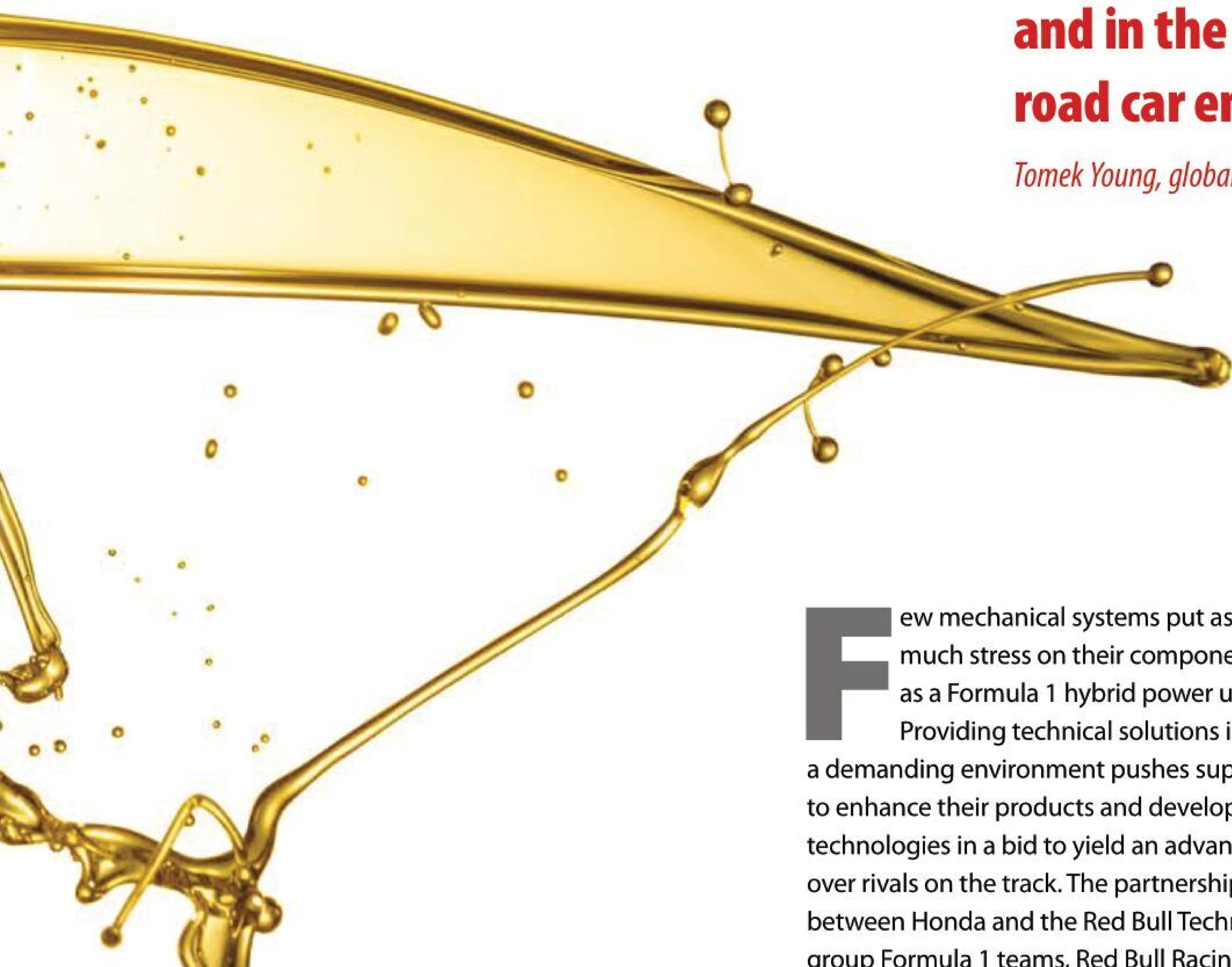
Racecar investigates how Mobil 1's engine oil is offering a performance advantage for Honda-powered Formula 1 teams

By STEWART MITCHELL

Photos: XPB

'I think the results will bring advantages both to the racing world in Formula 1… and in the consumer car world and with road car engines in general'

Tomek Young, global motorsport technology manager at Mobil 1



Few mechanical systems put as much stress on their components as a Formula 1 hybrid power unit. Providing technical solutions in such a demanding environment pushes suppliers to enhance their products and develop new technologies in a bid to yield an advantage over rivals on the track. The partnership between Honda and the Red Bull Technology group Formula 1 teams, Red Bull Racing and Alpha Tauri, has provided a key learning platform and a proving ground for the fuels and lubricants brand, Mobil 1.

The partnership provides Mobil 1 with the opportunity to improve its engine fluid technologies, raising the standard of lubricant and fuel performance for its customers, while at the same time delivering higher resilience to contamination and longer service intervals.

Mobil 1 and Honda's engineers have worked closely with Red Bull Technology since changing from a power unit supplier to a partnership with Toro Rosso in 2018.

'That shift in the relationship has made a significant difference,' highlights Honda F1 technical director, Toyoharu Tanabe.

'We had many meetings to develop our relationship, which is not only technical but also personal. We have very open communication between Mobil 1 engineers and Honda engineers.

'Reviewing the test data, we looked at the direction for development and a new lubrication solution for the 2021 Honda power unit, and this provides us with higher performance for the Red Bull Racing and Scuderia Alpha Tauri Formula 1 teams.'

Blend development

Mobil 1's new lubricant formulation for the Honda-powered Red Bull Technology group F1 teams was led by Tomek Young, Mobil 1's global motorsport technology manager.

'The engine oil interacts with many parts, and we're careful when changing its chemistry,' highlights Young. 'When we have a proven formula, moving to a new generation poses potential risks. Before we change anything, we must be confident that the performance gains are worth the risk of potential reliability issues, which carry a heavy penalty.'

Mobil 1 begin with computer modelling and simulating the lubrication regime in the digital world. Once the company is confident with the oil's performance in simulation, it tests it in a laboratory environment before moving to single-cylinder test rigs with some small batches of the new blend. Following that, the formulation is further refined where needed and goes on to Honda for its engineers to put in their complete power unit test stands. Only after passing all these tests does it go into the racecar.

'We use much more fuel with Honda off track than we use on the track,' explains Young of the process. 'We have done a lot of testing to push the boundaries of what's possible with the race engine oil and have a unique molecular composition of products for this Honda Formula 1 power unit engine oil not seen anywhere else.

'There are traditional elements used in race engine oil such as those that offer anti-wear properties, including boron, zinc, phosphorus and sulphur. Some base stocks are also traditional.

'We asked the question: can we change the composition completely? We started to look in some unusual places for components and compounds that would improve the oil in a Formula 1 application and make it even more effective. We searched for the characteristics we wanted in many different applications, including the cosmetics industry, and we brought in some new components to our race oil formulation.

'Specifically, we were able to eliminate some of the metals that were previously used, and we've been able to limit the content of others, making this oil stand out in sustainability as well as performance.'

Honda F1 technical director, Toyoharu Tanabe

The latest Mobil 1 oil poured into the Honda-powered Formula 1 teams' cars at the Baku round in 2021 brought together years of work on multiple iterations, as Young explains: 'This latest blend culminates our last eight years of lubrication research and development. It gives the Honda-powered race teams a performance advantage on track, and helps us improve our product for our commercial customers, too.'

Performance act

That's all well and good coming from the supplier, but how do you quantify a performance advantage from a lubricant? The primary driver for oil in the Formula 1 engine environment is the power unit's performance, and to maximise that is to minimise friction losses. Internal combustion engines are energy conversion devices – they convert chemical energy in the fuel at the injectors into mechanical energy at the engine output shaft.

A significant percentage of the chemical energy delivered to the combustion chamber is lost to mechanical friction between components, the most significant of which are the piston and cylinder interface, and the con rod and big end bearing assemblies.

Developing an oil to provide a higher-performing lubrication regime with less friction in these areas offers a considerable contribution to engine performance.

Reducing friction also has a knock-on effect in other areas of engine efficiency, such as lessening the amount of energy required to carry out the non-firing strokes, known as pumping losses.

Additionally, wear on the engine is reduced, giving it the ability to run at a higher-performing mode for more miles.

Paul Monaghan, Red Bull Racing Honda chief engineer of car engineering

'Our relationship… is not only technical but also personal. We have very open communication between Mobil 1 engineers and Honda engineers'

Toyoharu Tanabe, technical director at Honda F1

Since the introduction of Technical Directive 37, teams want to be able to run at the highest performance mode possible at all times

Since Technical Directive 37 was introduced at the Monza, Italy round of the 2020 championship, restricting the number of engine modes teams can use, the ability to change into different performance modes to manage energy and race strategy is gone. As such, teams want to run in the most performant mode for the entire weekend, provided the powertrain can handle it. Reliability is therefore key here, and can be aided by a higher-performing oil, making it easier for teams to observe the three power units per year regulation.

'Friction reduction improves the engine considerably,' says Young. 'Efficiency improvements form an effective route to enhance our challenge for this season's championship, and forthcoming seasons championship battles.'

Thermal conductivity

The ability to carry heat is one of the critical functions of engine oil, and that function is one that Mobil 1 has been investigating in great detail with Honda and carefully optimising for the Formula 1 application.

'We try to maximise the heat capacity per molecule of the lubricant,' notes Young. 'However, the oil must not only have heat capacity, but also a high thermal conductivity, releasing the heat as it passes through the heat exchanging device quickly and efficiently. Improving the conductivity of the oil is an effective route to lowering the running temperature of the engine.'

The 2021 engine oil can withstand significantly higher temperatures than its predecessor, and that has potentially huge knock-on effects for the design of other components on the car. For example, the Honda-powered cars now have scope to design a smaller, more efficient engine and consequently improve the car's aerodynamics, the most performance-dependent factor in current Formula 1.

'We're not yet taking full advantage of that ability, but we have done some work,' notes Paul Monaghan, Red Bull Racing Honda chief engineer of car engineering. 'Mobil 1 made the oil performance so high that we could potentially run the power unit even harder down the road, and much more optimisation of the power unit, aerodynamics and car operation will be possible.

'When we do optimise the car, we will know how much of a difference the oil can make, and we are confident it can make a tangible difference in terms of the overall performance of the car, primarily in the cooling configuration.

'The new oil may affect the decisions made for next year's car as well. For now though, it is fair to say these are early days in terms of establishing just how high we could push the oil on the car.

Improving the oil's heat capacity and thermal conductivity has knock-on effects on many other areas of the racecar, including cooling, packaging, bodywork and, ultimately, aerodynamics, too

'The limits are dependent not only on the oil's ability to take heat out of the engine and exchange it through a cooler but, thanks to the work Mobil 1 has done with the oil's ability to withstand high temperatures, we can also keep the turbo running temperatures down to a level where Honda can design an engine that has effectively moved the temperature targets without consequence.

'Having said that, we could also lift the operating temperature of the engine, but that does not mean it's going to run as we would want. We have a range of cooling solutions on the car with bodywork to test using different inlet and exit configurations, which is quite common practice.

'With the new oil, we can tune the engine not only for an operating condition but push whatever Mobil 1 and Honda allow us to run.

'We can also split the cooling system to treat cooling circuits independently, allowing for more tuneability. Sometimes, they might ask for a bit more cooling, or less. If they want a little bit less, we will be able to close the bodywork up a bit and run the car generally hotter but with more aerodynamic efficiency.

'It is impossible to treat a set of operating parameters and car set-up in isolation as one, typically, will influence in the other. Whether we can take greater steps through this season, we do not know just yet. We are on the learning curve right now, and the more we learn, the more we will exploit it.

'It's still early stages so it's not a considerable effect on the car performance *yet*. Whether it becomes that is very much down to cleverer people than I.

'The new oil formulation enables huge potential and a steep development curve for our 2021 campaign. The next iteration of the Red Bull Technology group cars could be quite a big step up in performance once we have built up more real-world experience with the new oil.'

Fighting LSPI

Even in the most efficient performance operating regions of the latest Formula 1 engines, the most efficient race power units on the planet, not all the fuel injected into the combustion chamber burns to generate power thanks to crevice losses around the spark plug, valve seats and piston top land. Formula 1 engines typically have very low crevice volumes, but still roughly two per cent of the injected fuel escapes combustion by residing in them.

From a mass standpoint, the most significant single crevice is the area around the top piston ring land. If exacerbated by high cylinder pressures (high charge density, combustion can occur in that region.

'Thanks to the work Mobil 1 has done with the oil's ability to withstand high temperatures… Honda can do an engine that has effectively moved the temperature targets without consequence'

Paul Monaghan, chief engineer of car engineering at Red Bull Racing Honda

Over recent history, it has been discovered that even a minuscule amount of engine oil that enters the combustion chamber can affect this type of combustion and the performance of the engine in a dramatic way.

A phenomenon called low-speed pre-ignition (LSPI) can be catastrophic, potentially even destroying the engine, and it is particularly bad in small displacement, turbocharged, direct-injection engines.

While the fuel that goes in the tank is a liquid, the engine must convert that liquid into a vapour to burn it. If the fuel does not

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turn into a vapour, the engine cannot burn it. Because direct-injection engines spray the fuel directly into the combustion chambers, some unburnt fuel mixes with the oil that lubricates the cylinder walls. This mixing of liquid fuel and oil is where things begin to go bad, chemically speaking.

Engine oil is a mixture of base oil and additives. The additives used in the oil influence how well the oil and fuel will (or will not) mix. If fuel in the top ring land crevice and oil mix, it creates a volatile mixture that can lead to LSPI - a combustion event prior to the spark event. This causes abnormally high pressures within the cylinders, which can potentially damage pistons.

Engine lubricant research indicates the engine oil formula directly links to the frequency and severity of LSPI.

Said research has found that reducing the amount of calcium detergent and eliminating sodium detergent in the oil reduces the frequency and severity of LSPI and other abnormal combustion events caused by mixing of the oil and fuel.

Calcium-based detergents are widely used in off-the-shelf engine oils, typically in high concentrations. Mobil 1's Formula 1 engine oil reduces these and is explicitly formulated for direct-injection engines, designed to avoid potentially catastrophic LSPI events, and ensure long-term engine durability.

'We've been playing with the concentrations of various constituents to reduce the risk of LSPI and notice that as we change some of these oil elements, it can affect regular combustion in some ways as well,' explains Young.

'So, even though the oil is not viewed as part of the combustion process, it actually is, and this is just one example of areas we explored. I think the results will bring advantages both to the racing world in Formula 1 with the Red Bull Technology group teams, and in the consumer car world with road car engines in general.'

Bio-based content

In terms of the sustainability of Mobil 1's engine lubricant products, when the technology is moved out of the Formula 1 environment into the road car environment, there is strict legislation in place for emissions.

'When we talk specifically about oil consumption, it is a minuscule number of particles entering the combustion chamber, so you would not even see the oil level decreasing over a regular drain interval,' explains Young. 'The lubricants industry is governed by environmental legislation in countries and regions, but mostly it is limited by regulations that engine manufacturers and the automotive sector imposes on itself. Specifically, several tests are carried out that measure the volatility and emissions of oil in the combustion chamber that oil manufacturers must pass, proving that the oil does not negatively affect combustion.

'It is not often thought that environmental formulations coincide with high performance, but it does'

Tomek Young, global motorsport technology manager at Mobil 1

'To improve the sustainability of our lubricant products, we have adjusted the chemistry of our base stocks. The base stocks are the largest percentage of an engine oil, and we challenged ourselves to see if we can use something that is environmentally friendlier at the pinnacle of motorsports.

'We use base stock with a high percentage of bio-based content. It is over 25 per cent right now in the oil used in the Honda-powered Formula 1 cars on track this season. It is not often thought that environmental formulations coincide with high performance, but it does. In fact, in the case of the engine oil that Mobil 1 developed for the Honda-powered Formula 1 teams on the grid in 2021, it enhances it. The use of bio-based components helps Honda-powered teams win races, which is tremendous for us. We are so excited about its influence and potential for Honda power going forward.'

Recent developments haven't just been about performance, by eliminating some of the metals used and increasing its bio-based content, Mobil 1's new oil is also more environmentally friendly

18 wheelers

Formula 1 is finally joining the rest of the motorsport world in embracing low profile tyres. Racecar *investigates the process of bringing 18in rubber to the track*

By DIETER RENCKEN

F1 has used 13in wheels and tyres since the 1980s, so the step up to 18in versions of both is a major technological development, both for the series' tyre manufacturer and the teams

Ryan Davis

For irrefutable proof that Formula 1 places road relevance at the very heart of its future technical regulations, look no further than the big black roundels that adorn each corner of a grand prix car. Where for 30 years the aspect ratios of F1's front and rear tyres had been unchanged at around 75 and 65 respectively, from next season the ratios will reduce dramatically to around half that, give or take a digit or two at each end.

The history of F1 tyre sizes and aspect ratios – the relationship between sidewall height and contact patch width expressed as a percentage – is as complex as it is convoluted. While road car tyres gradually grew in width and reduced in sidewall height, for political and economic reasons F1 doggedly stuck to the 13in wheel sizes originally introduced during the 1980s. Indeed, a case could be made that the F1 trucks that ferry cars and kit have more contemporary tyre ratios.

Rewind to 1985. With Goodyear enjoying an effective monopoly that ran through to 1996, sporadic competition rarely got a look in. The US tyre brand saw no reason to follow road car trends simply to beat itself. When Bridgestone entered F1 in 1997, the Japanese manufacturer suggested lower aspect ratios, only to be rebuffed after Goodyear, afraid of losing its competitive advantage, threatened to leave should the dimensions be changed.

When Goodyear did depart, two seasons later, Bridgestone, now by implication the sole supplier, applied the same arguments, reiterating them when Michelin announced its entry a year later.

After the French company left in 2007, Bridgestone was awarded the first of the FIA's sole supplier tenders, and simply carried over its rubber through to the end of 2010. Meanwhile, various other series across the globe embraced low profile tyres.

'New era' package

Pirelli replaced the Japanese company in 2011, but so hurried was the process that F1 had no choice but to stick with 13s until finally, with the 2021-'23 tender, both Pirelli and Hankook submitted documents – the former being successful – specifying 18in rims with reduced tyre aspect ratios. At last.

The new wheel sizes form an integral part of F1's 'new era' regulation package, which was planned for introduction in 2021, but delays caused by the Covid pandemic pushed the target season out a year. This, in turn, gave Pirelli additional development time, although track testing was temporarily placed on the back burner due to costs and the punishing 2020 schedule after racing resumed last July with 17 rounds in 160 days.

To compensate for Covid delays, Pirelli's contract was extended by a year. The irony of the latest delay, after so many lost seasons, is not lost on F1's decision makers. After decades of internal resistance to low-profile tyres, their introduction was disrupted by factors outside the control of the sport.

However, according to a source with knowledge of FIA processes, the decision to switch to low profiles is not as recent as we might think. '[It was taken] around five or six years ago in the interests of modernity and a bit more relevance,' our source says.

Due to the massive implications of the change on car design, it was delayed until a revised technical package was introduced, particularly as teams had (then) been promised regulatory stability on all major components until the end of the 2020 season.

Crucial to the decision was experience of low-profile tyres gained by the FIA

Crucial to the decision was experience of low-profile tyres gained by the FIA from Formula E and World Endurance Championship tyre suppliers

from Formula E and World Endurance Championship tyre suppliers, in turn enabling the governing body to formulate a comprehensive specification list. Once the tender had been awarded, discussions with the Italian tyre company opened at FIA Technical Advisory Committee level.

Advantage 18s

Apart from aesthetics, the advantages of larger rims and lower sidewall heights include more direct response to steering and braking input, greater control over spring rates as the 'jounce' of high sidewalls is reduced, and increased brake disc area, therefore potentially improving stopping power. This latter point could potentially see F1 adopt ceramic (or other) braking technologies as it strives to phase out carbon friction materials.

'Based on Brembo's strategy and new vision, we are already working on new materials and evolutionary processes in terms of consumption and emissions,' a spokesperson for the brake company told *Racecar Engineering*.

'This is our philosophy, not only because Formula 1 is asking all suppliers to adapt to this new sustainable approach, but because our corporate strategy is to produce materials

Antoine Truchet

So great is the impact of the new tyres on car design that their introduction was delayed to coincide with the 2021 'new era' technical regulations, though Covid delayed those by a further year

XPB

The increased diameter of the new 18in tyres (up from 660mm to 720mm) has broad design implications, as does the increased distance between the brakes and the rim of the larger wheels

that are sustainable for the environment. In Formula 1 this process has started.'

During initial Technical Advisory Committee (TAC) discussions, attended by all teams, FIA, F1 and Pirelli, it was agreed that tyre diameter would increase marginally (from 660mm to 720mm) with rims incorporating (fixed) wheel covers and finger recesses for ease of grip during carry and pitstop activities. Covers displaying graphic information were also considered, but these were pushed out, possibly to 2023.

'Obviously, [at that stage] there was an idea for F1 to completely change the cars for 2021, but that was postponed to 2022 [due to Covid],' notes Mario Isola, Pirelli's head of car racing. 'The discussion flow started with understanding some parameters in the technical regulations.'

Although these had not at that early stage been finalised, and would not be for another year, Isola says they requested information on expected levels of downforce [and resultant *g* forces], details on engine torque and power outputs and anticipated maximum speeds.

'Heat transfer is another important parameter because the spacing between the brakes and the rim is much higher,' Isola adds. 'Therefore, we predict there will a lot less heat transfer from the brakes.'

Only once these details had been verified – Isola smiles as he recalls some of the 'crazy figures' teams provided during a similar exercise in 2016 ahead of developing a range of wider tyres for 2017 – could Pirelli embark on preparing initial finite element models to design the first 'virtual' 18in tyres.

'We supplied to the teams two different models,' says Isola. 'One is a finite element model [FEM], the other is a thermal mechanical model of the tyre, which is what teams use in their simulators, including driver-in-the-loop simulators.'

He adds that Pirelli's FEM data is encrypted. 'We are the owner of the model and only we know what's inside, but we update it periodically depending on the feedback we get from the teams,' he stresses. 'Sometimes you get feedback from individual teams that is quite different.

'Then we ask for clarifications. Sometimes they realise that [with their simulations] not everything is perfect, so they adjust their simulations, or we can adjust our model.'

Parallel engineering

According to Pirelli's R&D chief, Pierangelo Misani, the various processes, from design through prototyping to testing and manufacture, were developed via its F1 engagement, and then adopted by the road car tyre and other divisions. Indeed, he says these techniques enabled the company to remotely develop three different road car tyre ranges during the height of the pandemic, all of which have since been launched.

'[F1] has enabled us to develop new techniques. If you need a tyre that is so light with less material than the standard one you have to reduce the tolerances. So, I can say the experience in Formula 1 is not purely related to materials, or geometry, or performance, but also to development tools and methods and manufacturing processes.

'Heat transfer is another important parameter because the spacing between the brakes and the rim is much higher'

Mario Isola, head of car racing at Pirelli

'There is not much difference between the development steps to develop Formula 1 tyres and street tyres simply because we use the experience and modelling tools from Formula 1 for both,' he says.

'The first step is virtual, then we go to physical [laboratory] testing, but there is a sequence of activities inside both steps.'

However, Misani stresses the profile of the tyre is fundamental. 'It determines how the tyre will generate forces, both because it's how you put the contact patch on the ground, but also how the forces generated are then transmitted to the rim, and then to the car, by what we call the 'ply line'.

'According to the geometry of this carcass, you have a quite different behaviour. When you move to 18in, you will typically realise a faster response [due primarily to less sidewall flex] than with 13in.'

The final profile is also crucial to the entire process as it dictates the moulds that are required for batch production of the prototype tyres used for both laboratory and

track testing. Get the shape wrong and it's back to square one, whereas the materials used for actual carcass construction and compound ingredients can be fine tuned later on in the process.

Validation process

'We started to design a couple of different profiles, then the next step was to validate the profile,' explains Isola, adding that the selected profile is squarer than on current tyres due to the smaller, stiffer sidewall.

'We start from the models, then we prepare some physical prototypes, which are tested indoors [on high-speed rigs]. We have several different tests for integrity and for performance. The final validation is on track.

'To validate the profile we asked, and [FIA, F1 and the teams] agreed, to start testing [on the so-called 'mule' cars, adapted from 2018 cars to replicate ride height, downforce and car mass] in September 2019. That way we had the possibility to freeze the profile, and then start 2020 focussing our attention on construction and compounds.'

All was running to schedule at that point. Four teams had completed 'dry' tests, but then along came Covid, which brought the entire process to an immediate and inconvenient halt for around two months as all the teams went on a total, FIA-enforced shut down during April and May 2020.

In the interim, Pirelli continued with its indoor test programme at its Milan R&D base using tyres produced in batches of 10 by its F1 plant in Slatina, Romania and trucked overland to Italy. As an aside, Pirelli has replicated the F1 tyre production line at its Izmit, Turkey facility, just in case the Romanian plant is hit by a natural, or other, disaster.

Once the worst of the pandemic had blown over and F1 operations returned closer to normal in the early part of 2021, track testing resumed, with nine of 10 teams having committed to 2021 after expressions of interest were called for in August last year. Williams is still considering its options after being unable to confirm participation during its sale process to Dorilton Capital, which occurred just as the deadline loomed.

Even record-setting World Champion, Lewis Hamilton, who usually shuns testing, offered his services during his Mercedes team's programme at Imola after the Emilia Romagna Grand Prix in April.

'It's probably one of the first [test days] I have ever volunteered for,' he said afterwards. 'So I immediately regretted it when I woke up in the morning on the day!

'It was a really great track to test at, though, and the weather was good, so I enjoyed it. I plan to be [in F1] next year and want to be a part of it, so I want to help Pirelli towards having a better product. It's important for me to gauge what the starting point is, and what differences I can help with, so that from a driver point of view we have more mechanical grip from the tyres and less degradation. It was a good test, and though obviously it was only the first step with the new tyres, it definitely wasn't a bad place to start.'

Isola was equally upbeat after the Imola test. 'It provided us [Pirelli] with a result that was coherent across different cars and across different circuits,' he said. 'We had the possibility to validate different constructions, starting from Jerez to Bahrain, Imola and we are now in a situation where I would say the construction is almost finalised. [Next] we start a test campaign on compounds.'

As part of the programme, all tyre-specific data is shared with all teams, and then updated on an as-and-when basis.

Weight watchers

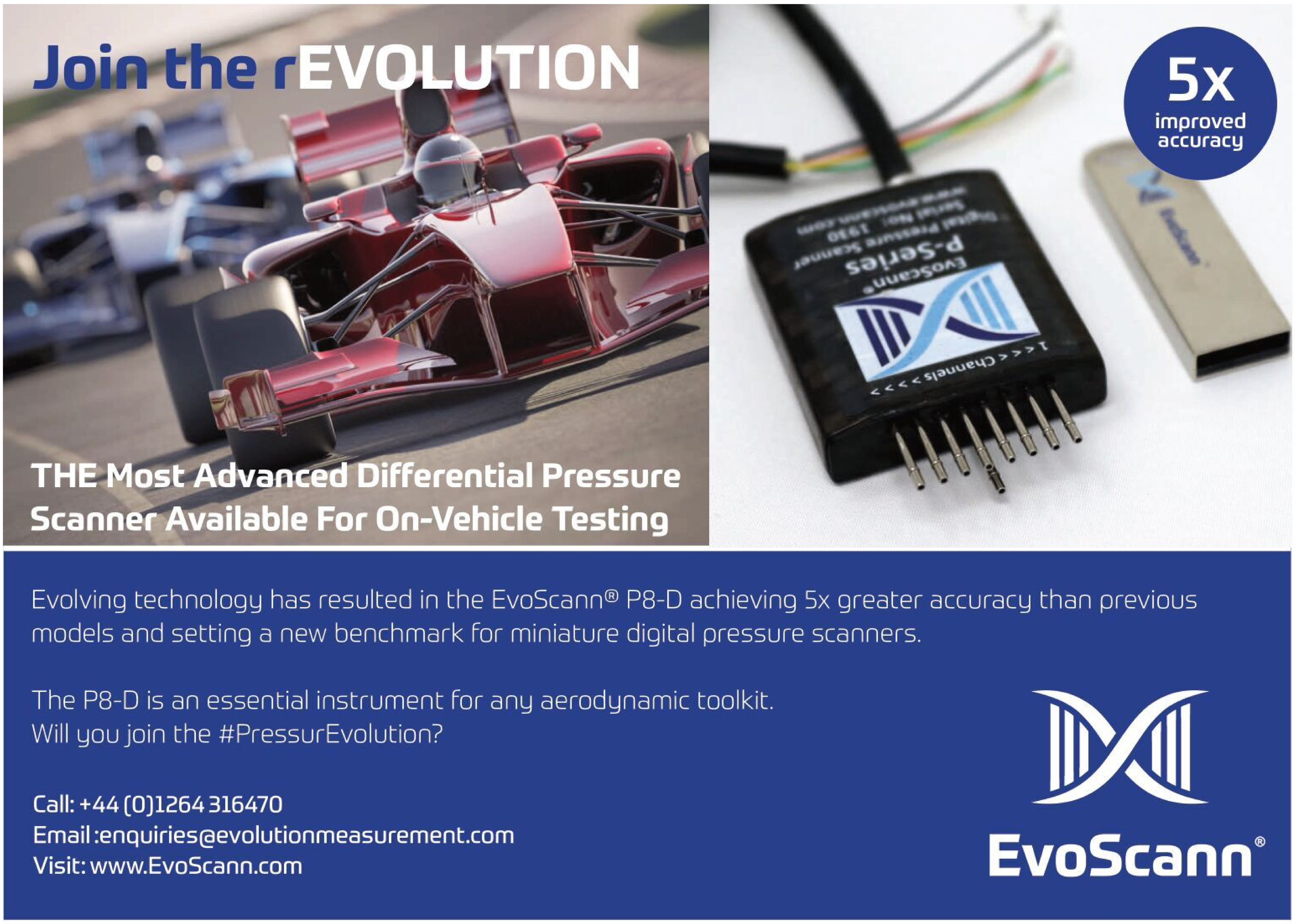
'We've had feedback lap times and basic information from each test, with technical bulletins coming through from Pirelli,' confirms Alpha Tauri technical director, Jody Egginton. 'We've done a lot of simulation work with the model [of] the tyre, so we

Pirelli

The new tyres started as finite element models and, only when approved by the FIA and the teams, did they become physical tyres

Pirelli

These were then tested under laboratory conditions for integrity and performance, and also on track on the so-called 'mule' cars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Pirelli

Although Covid delayed track testing, Pirelli continued its indoor test programme at its R&D facility in Milan, Italy, focusing on fine tuning the compounds that will eventually be used

understand what it's going to do, and we've got a good grip in vehicle dynamics terms.'

He also makes a point about a rather hefty elephant in the F1 paddock: 'We've got a big increase in tyre and wheel mass, plus we're not allowed to run inerters [from next year].'

The latest calculations suggest car mass will rise by 14kg, due to heavier wheel / rim assemblies, split approximately 3kg per front wheel and 4kg for each rear wheel. The reason is simple: for a given circumference, with low profile tyres, alloy largely displaces air and lightweight rubber.

At time of writing, seven of the 10 scheduled 2021 tests, comprising a mix of dry, intermediate and wet running, had been completed, with two further dry tests planned for after the British and Hungarian Grands Prix respectively, with a final wet fling listed for Paul Ricard in France mid-September. After that, all 10 teams are expected to attend a composite test in Abu Dhabi after the final race of the season.

By then, teams will be in the thick of manufacturing their new era car designs, having based concepts on a combination of data obtained from wind tunnel studies, simulations and CFD calculations. In each instance, input from Pirelli is crucial to the process, in particular tyre modelling data and 60 per cent scale wind tunnel tyres, which accurately simulate tyre behaviour at speed.

The latter, produced in a dedicated Pirelli studio in Rome, are a particular challenge as tyres make up approximately a third of frontal area while spinning at enormous speeds. The resultant wake affects airflow across the car, while steered tyres deform in compression, yaw and pitch, causing changes in sidewall and contact patch shape. An aerodynamicist's nightmare, in other words, unless the mini tyres are spot on.

The 2022 challenge

For teams, however, the biggest challenge is yet to come – translating the tyre test data into sustainable on-track performance, as Ferrari racing director, Laurent Mekies, notes. 'Twenty twenty-two will bring three massive pillars that are entirely new: completely different aerodynamic regulations, different ways to operate the car [due to revised sporting regulations] and mechanical suspension, which nobody has had for 10 or 15 years. So, a lot of different limitations and, in the middle of those, how to 'switch on' the completely new tyres. I think that's going to be the big challenge.

'There will be a huge amount of discovery with the 18in [wheels and tyres]. It's a great challenge as a team to make sure we have the base to get the core understanding we need.

'It will be a steep learning curve, but in two years we will look back at the starting point and wonder what we were doing at the time.'

Although Mekies does not foresee the switch to 18in wheels alone resulting in major changes to the competitive order, he does see it as a contributory factor, when taken in conjunction with the 'pillars' listed above. 'I think it will be a combination of the concepts, the new regulations, how they interact with the tyres and how you make everything work,' he says. 'I think we have the potential to see a surprise also from the midfield teams. It's risk and opportunity for everybody.'

'We are now in a situation where I would say the construction is almost finalised. [Next] we start a test campaign on compounds'

Mario Isola, head of car racing at Pirelli

All parties agree that the amount of research that has gone into the 2022 regulations by far exceeds what has gone before, whether at FIA, F1 or team level, while Pirelli has been afforded a longer timeframe than at any previous stage in its 10-year F1 history. Indeed, longer than any tyre supplier has *ever* been given, with the pandemic only widening that development window.

Come the 2022 season opener – probably in Bahrain, after even more warm weather tests on the desert island – the big black roundels that adorn each corner of a grand prix car will not only represent arguably the single biggest visual indicator of F1's 'new era', but the biggest advance in F1 tyre technology since the sport adopted radial ply tyres in the 1970s. That is how radical the 18in tyres are in F1 terms.


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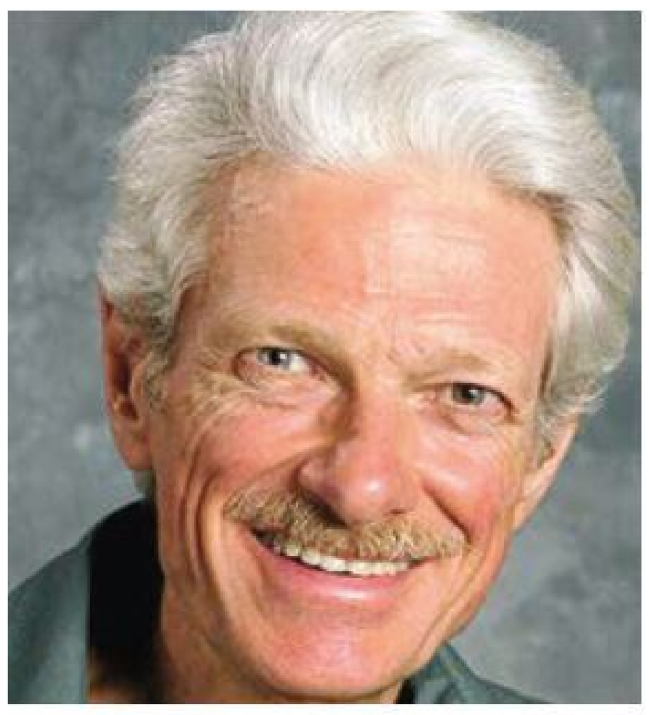


Link awry

Understanding three-link rear suspension with lower links at different heights

By MARK ORTIZ

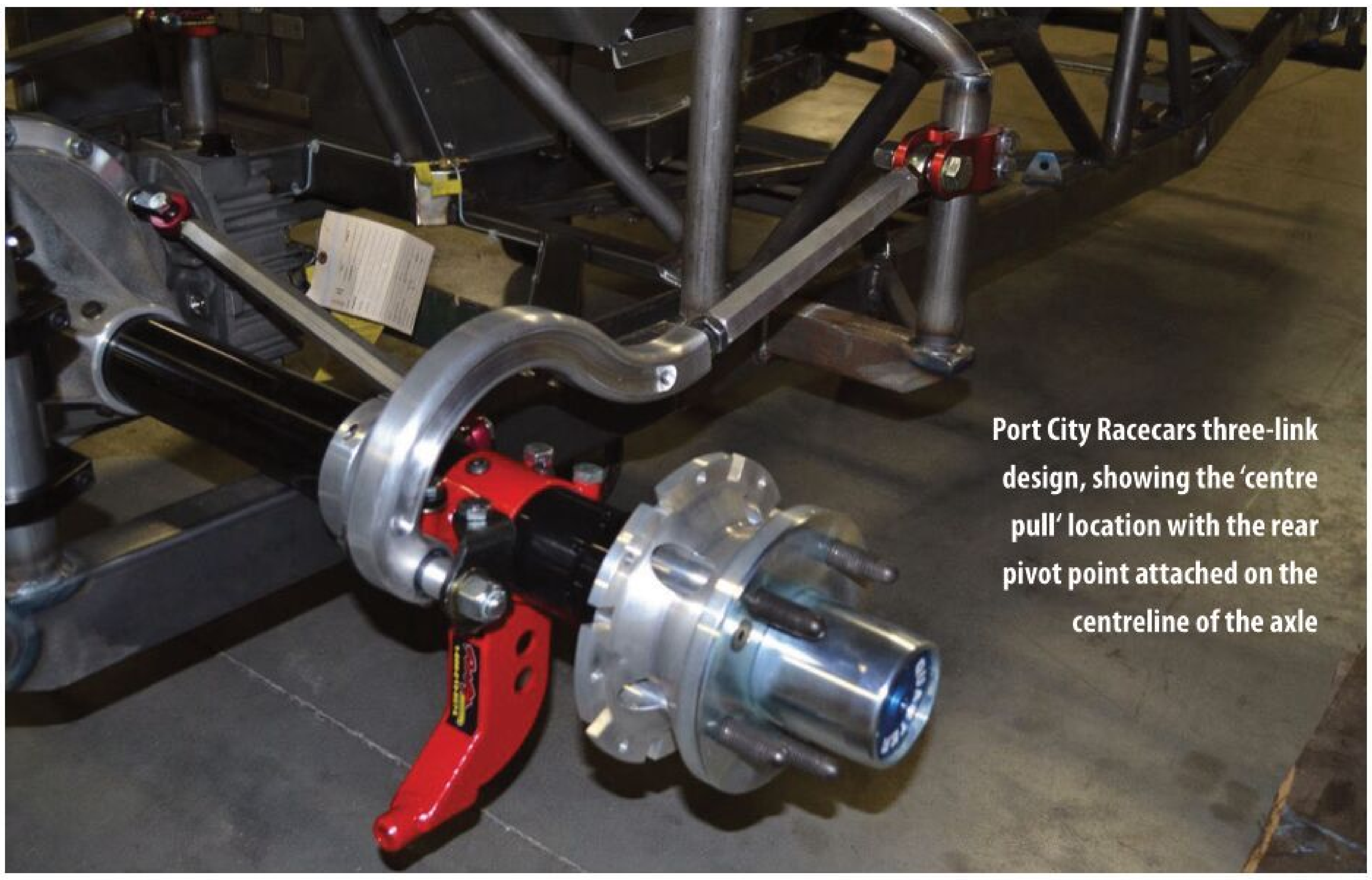
Q I need help on a Template Super Late Model. Like most chassis manufacturers, ours is built to accommodate both a standard three-link rear suspension and a centre pull design, with the lower trailing arms at the centreline of the axle. Some set ups call for both the outer trailing arms to be mounted in the 'centre pull' location, with the pivot in the rear (though in some cases the pivots are in front of the axle), while others use the standard three-link location on the left side and the centre pull location on the right side.

Typically, the third link is run fairly level, but much lower. I have seen it run uphill and downhill to the front, but only by a few degrees. As I understand it, the upper link is the sole link that absorbs the torque, while the lower links take care of the drive.

There seems to be just speculation as to why one set up works better than the other, and doesn't seem to be a lot of information available on the centre pull design. I am not sure how to calculate anti-squat, especially if one link is standard and one is centre pull. Generally speaking, the response is more bite but not tight; right trailing arm up at 3-5 degrees.

I have attached a pic of the Port City Racecars design, and they say the springs must be positioned in front of the rear axle as they are the only things keeping the rear end from wrapping up. Well, they might be closer together, but the pivot points are still on a plane not a line. And what would stop it moving during decceleration? In our set up, we run the springs behind the rear end.

Am I missing something here? Can you explain how the full centre pull works, and how it compares to the other two set ups?



Port City Racecars three-link design, showing the 'centre pull' location with the rear pivot point attached on the centreline of the axle

Photo: by questioner

THE CONSULTANT

A First, the 'centre pull' thing is just a gimmick. It's a fairly harmless one as long as it doesn't break, but it's not an advancement. Having a hook in a trailing link and having the rear pivot on the back of the axle tube hardly changes anything geometrically, compared to using a birdcage around the tube or attaching the rear pivot to the front of the axle tube.

The hooked link in the picture above looks different, but it doesn't do anything significant to the behaviour of the link. The ears on the axle tube or clamped bracket that the rear pivot attaches to are in tension under power, rather than compression, but the link is still under compression. If the whole thing is made beefy enough, it can be made to stay together, but it is structurally inefficient to put a bend in a link unnecessarily, and it is bad engineering practice to put a threaded adjustment near the middle of a link that sees compression loads and therefore has to resist buckling.

It is correct that the springs do not react axle torque in a three-link. The loads on the links do change a bit, depending on where the springs are, but the trailing links locate the axle both rotationally and longitudinally, not the springs.

Wherever a trailing link's rear pivot is, what counts is where the link's centreline intersects the yz (transverse, vertical) axle plane. The pivot point's x (longitudinal) location influences how that intersection migrates as the suspension moves, but that effect is small when the pivot point's distance from the axle plane is small compared to the link's length.

Now, what is the effect of raising or lowering the lower links, all else unchanged?

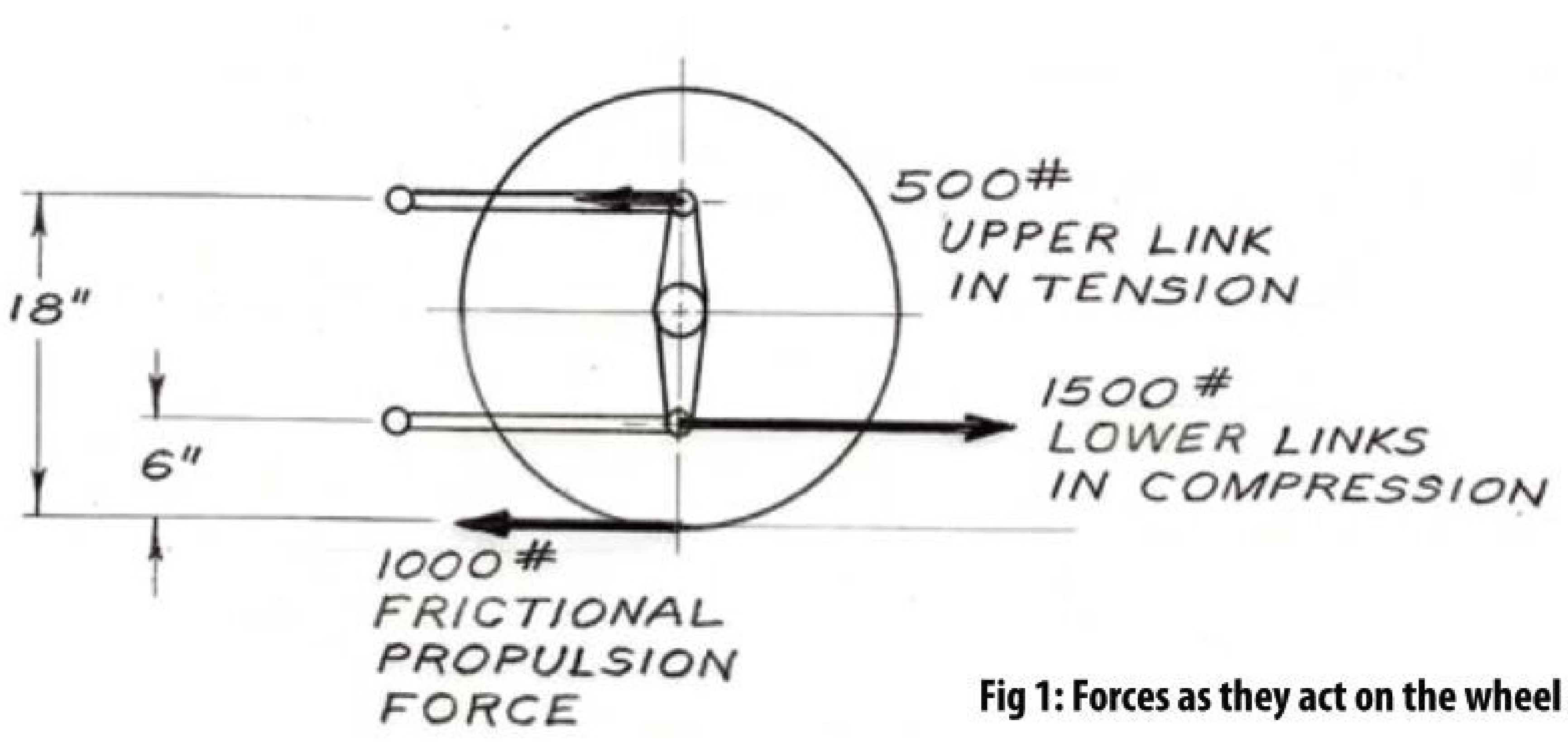
It is not true that the load on the two lower links is equal to the thrust, or that the lower links react the thrust and the upper reacts the torque. In somewhat simplified terms, what actually happens is the lower links see a combined compression load considerably greater than the total thrust, and the top link sees a tension load equal to the difference between the total thrust and the total lower link force. The total lower link force, minus the upper link force, equals the total thrust.

The magnitudes of the lower and upper link forces depend on their heights above the ground plane and how far apart they are in side view. The total lower link force equals the total thrust force, times the upper link height above the ground, divided by the upper link height above the lowers. The upper link force is equal to the total thrust force, times the lower link height above ground, divided by the upper link height above the lowers.

Thrust forces

To explain with an example, if the total thrust is 1000lb, the lower links are six inches high and the upper is 18in above ground (12in above the lowers), the total lower link force is 1500lb compression, the upper is 500lb tension.

The 'centre pull' thing is just a gimmick. It's a fairly harmless one as long as it doesn't break, but it's not an advancement



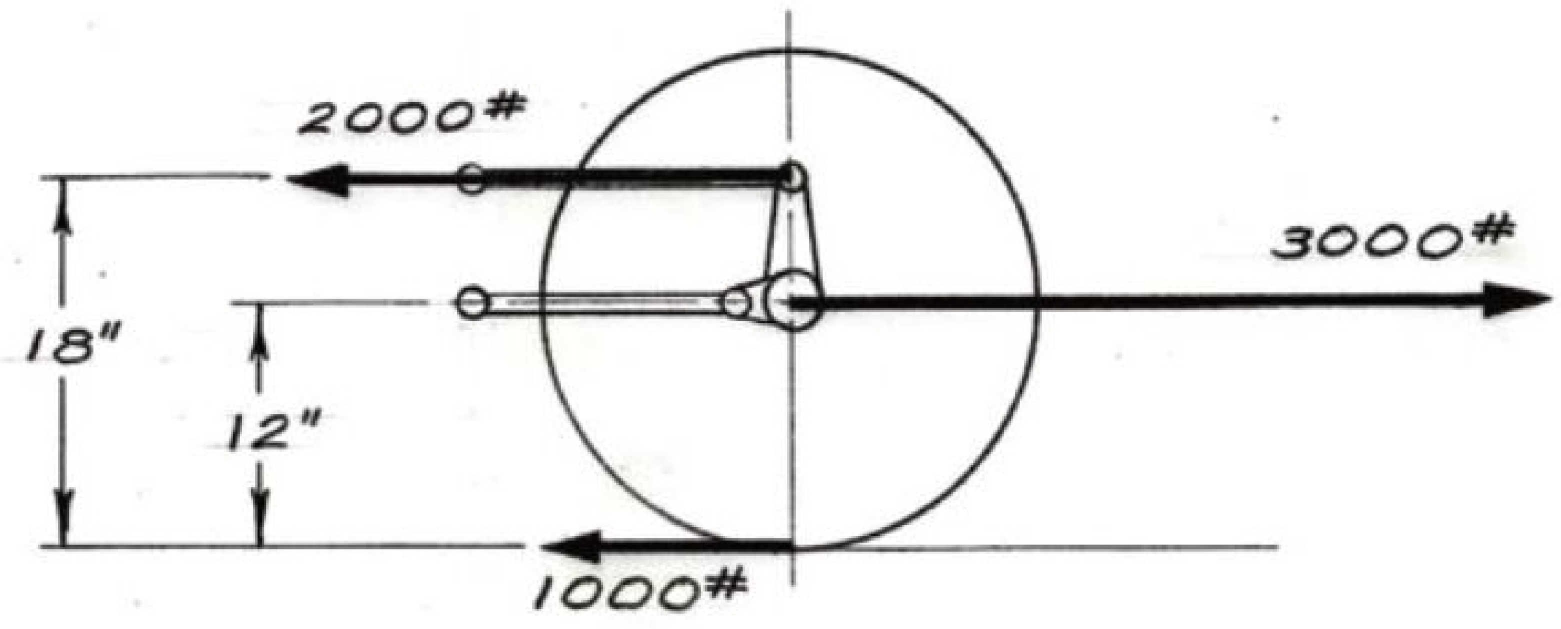


Fig 1: Forces as they act on the wheel and axle assembly with horizontal links

If we then raise the lowers to 12in from the ground and leave all else unchanged, the lowers now see 3000lb compression and the upper sees 2000lb tension.

In either case, the difference between upper and lower forces equals the 1000lb thrust, but all the link forces increase dramatically when we raise the lowers.

Or, we could have the same link forces as in the first instance, with the lowers at 12in, if we raised the upper by the same percentage, meaning to 36in above ground.

In **Figure 1**, the forces are shown as they act on the wheel and axle assembly (front of the car is to the left). For example, a tension force exerted on the axle by the top link acts leftward upon the axle. The equal and opposite rightward force exerted by the axle upon the link, and by the link upon the frame, is not shown.

Yes, this is a very simplified way of looking at these things. What I'm trying to do is conversationally explain what changes we get to the link forces when we vary the link heights.

When we angle the links in side view, as in **Figure 2**, the x components of the forces remain as above, but we induce z axis forces that will jack the car up or down under power.

The slope of the force line, tan β, is also known as the jacking coefficient, the ratio of jacking force to ground plane force. It is also the instantaneous rate of contact patch x translation with respect to suspension movement (dx / dz). This is often easier to measure on an existing car than it is to measure the coordinates of all the pivot points. Just jack the car straight up and down with the wheels on slip plates and measure how much the slip plates move per inch of ride height change.

The jacking coefficient, times the wheelbase, divided by the sprung mass c of g height, expressed customarily as a percentage, is the anti-squat.

Anti-squat

In the cases illustrated by **Figure 1**, the force line is horizontal, the side view instant centre is undefined and there is zero anti-squat. The heights of the links don't change that. If the links were still parallel but sloped up toward the front, there would be anti-squat, but it still would not depend on the link heights. The force line slope, the link slope and the jacking coefficient would all be equal to each other. And since the lower links control roll steer, there would be roll oversteer. The outside wheel in a turn would move back as the car rolls, the inside one would move forward and the rear wheels would steer toward the outside of the turn.

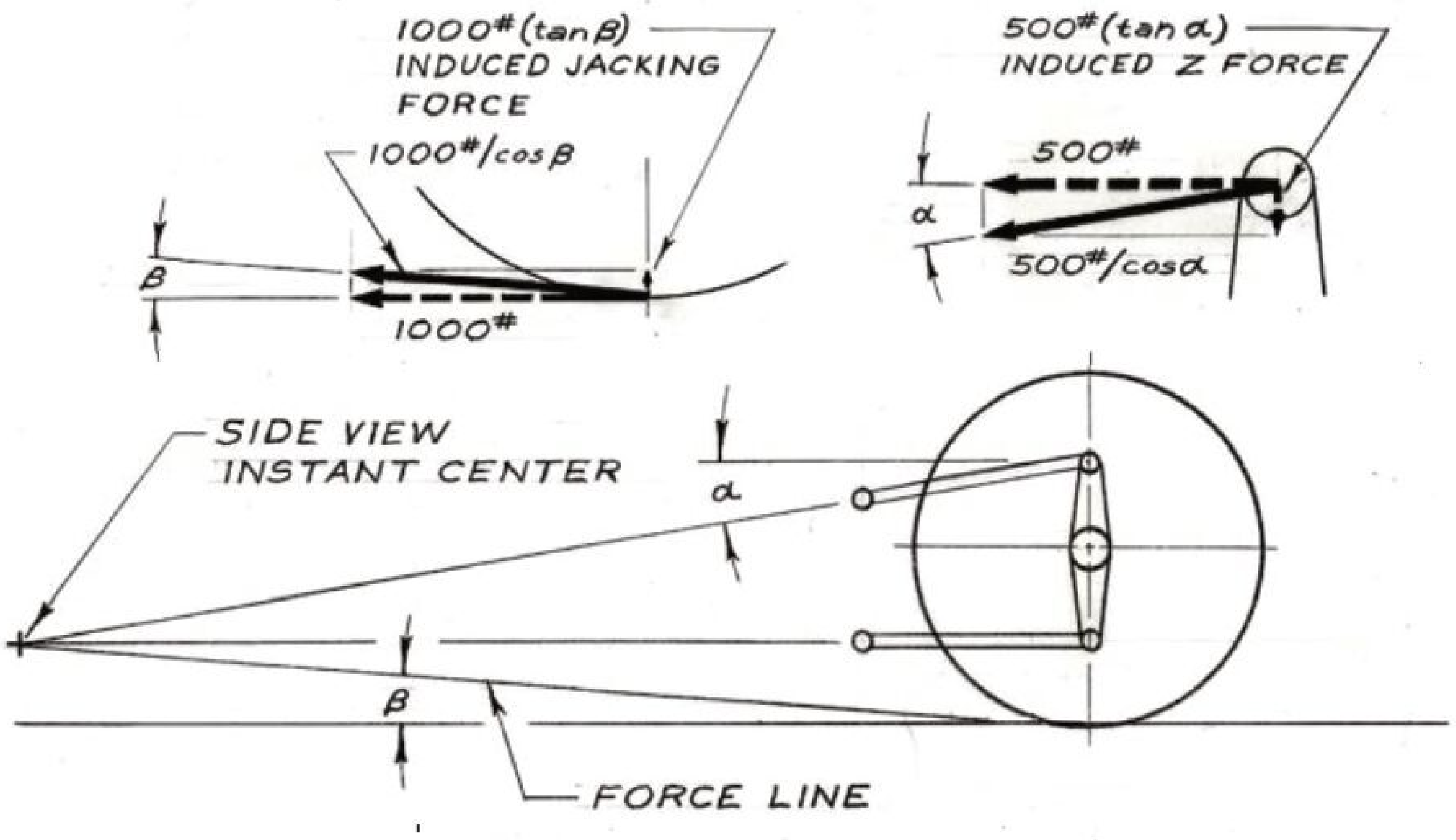
However, when the links have some side view convergence, their heights *do* affect anti-squat. In **Figure 2** when we move the lower links up to axle height, leaving all the link angles unchanged, α is unchanged, and the lower links are still level, but β increased enormously. The upper link is still the only one with any induced z force, and the induced z force is still equal to the upper link x force times tan α, but the upper link x force is four times as great. It will also be true that the jacking coefficient, tan β, is four times as great, and the contact patch will move longitudinally in the test described above at four times the rate.

So far, we've been looking at side view geometry of cases where the suspension is laterally symmetrical. Now comes the $64,000 question; what happens when one lower link is high and the other is low? The answer is the same as the answer to incontinence: depends.

When all the links have the same inclination, it doesn't matter. When the side view instant centre is ahead of the axle, the wheel with the higher bottom link will have more anti-squat. If that's the right wheel, the effect will tend to de-wedge the car under power. If it's the left wheel, the effect will add wedge (add RF + LR wheel load percentage) under power.

In braking, there will be a reverse effect. Braking will tend to add wedge if the right lower link is higher and will tend to de-wedge the car if the left lower link is higher.

If the top link slopes up at the front more than the lowers, so that the SVIC is behind the axle, all these effects reverse.



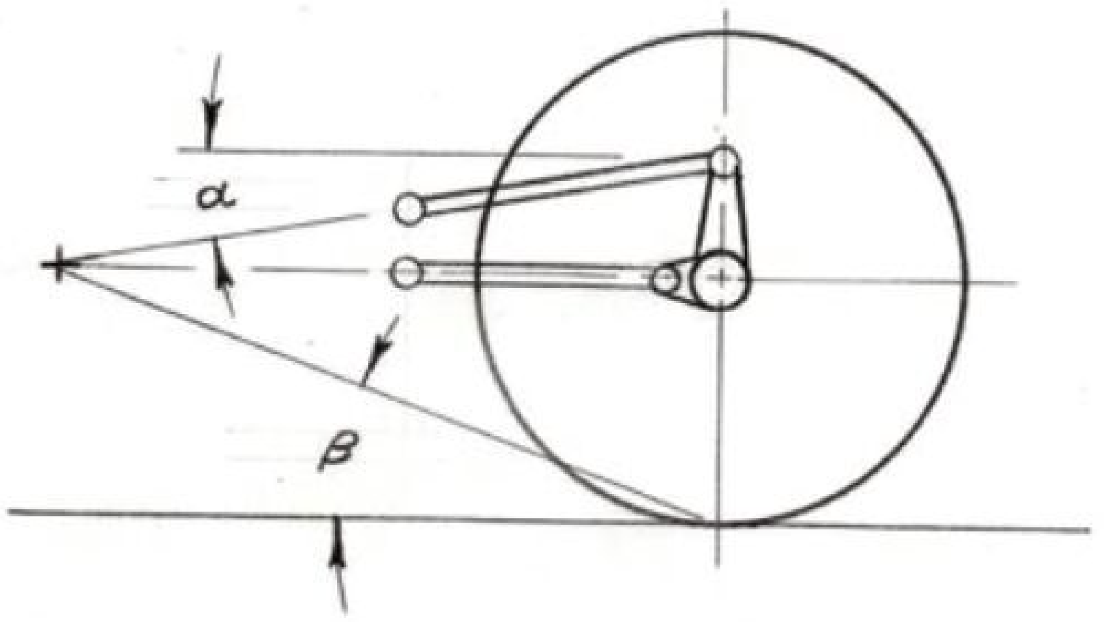


Fig 2: Forces as they act on the wheel and axle assembly with converging (in side view) links

CONTACT
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The no way transfer part 2

The difference between suspended mass geometric and elastic load transfer, and the influence of kinematics

BY CLAUDE ROUELLE

In this follow on from last month's article, we will explain the difference between the suspended mass geometric and elastic load transfers, and why kinematics has a considerable influence on car behaviour at the corner entrance.

In part one of this article, we divided the total lateral load transfer in a non-suspended mass load transfer and a suspended mass load transfer. A reminder is shown in **Figure 1**, as well as in part (a) of **Figure 2**.

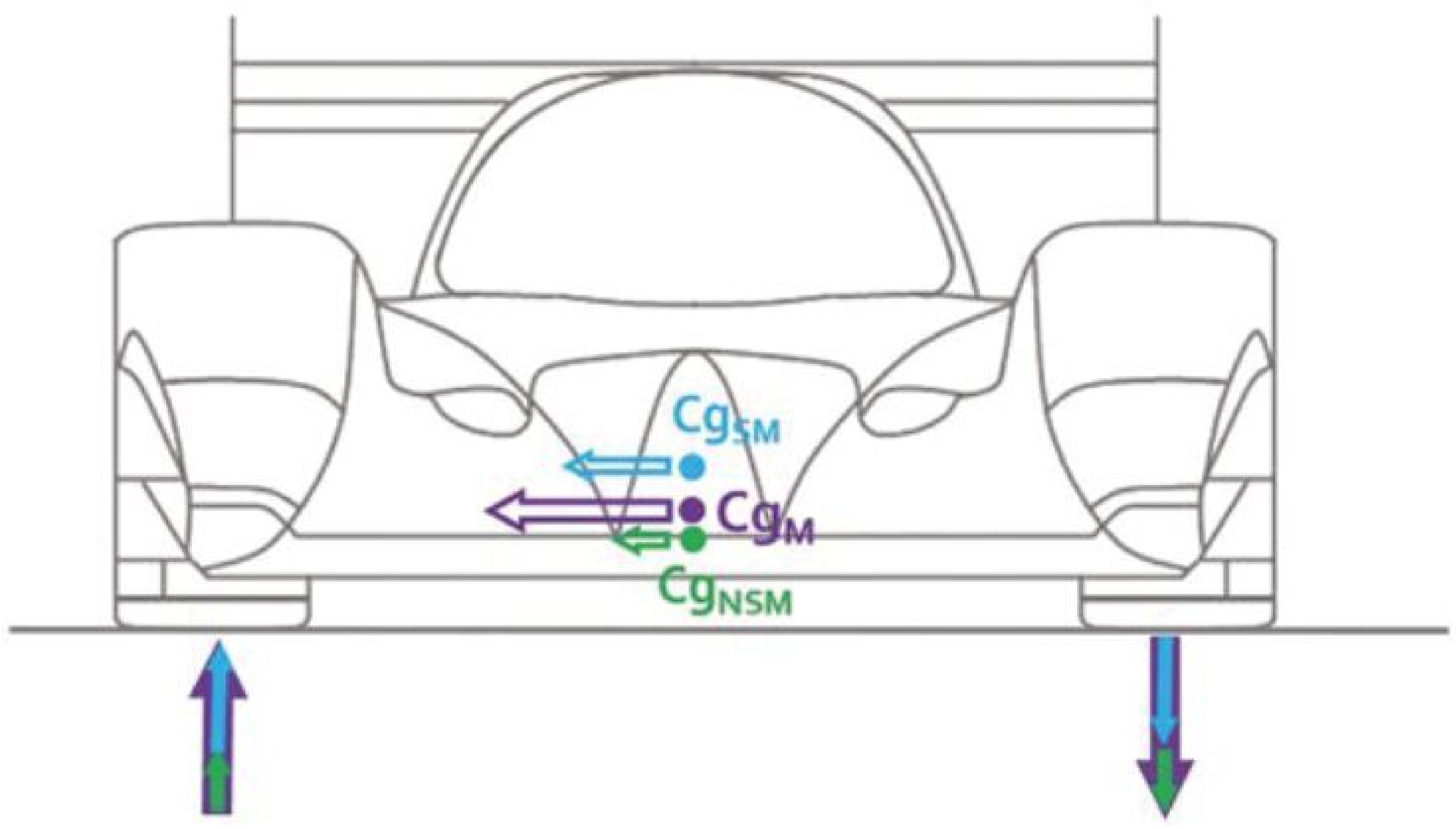
We will now split the suspended mass lateral load transfer in a geometric and an elastic load transfer as indicated in part (b) of **Figure 2**.

Based on the principle that a force applied at one point of a body is equal to the same force applied at another point of the same body force and a torque, as shown in **Figure 3**, we will now replace the lateral force applied at the suspended mass c of g (in blue in **Figure 4**) in an equal force applied at the kinematic roll centre (in red in **Figure 4**) and a suspended mass roll moment (in yellow in **Figure 4**).

There are many considerations to be made here:

1. The roll moment that creates the suspended mass elastic load transfer is a function of the vertical distance between the suspended mass c of g and the kinematic roll centre. The higher the roll centre, the less roll moment and elastic load transfer, but the more geometric load transfer.
2. The figures shown are a simplified 2D view (here, the front) in steady state. We will soon make considerations on transient load transfers and, later, in 3D (four wheels, the whole car) load transfers.
3. As I insisted in a previous article, there are flaws in this simplified explanation. The suspended mass does *not* rotate about the kinematic roll centre. You will notice that, so far, we have only looked at the effect the lateral acceleration has on the variation of the tyres' vertical load.

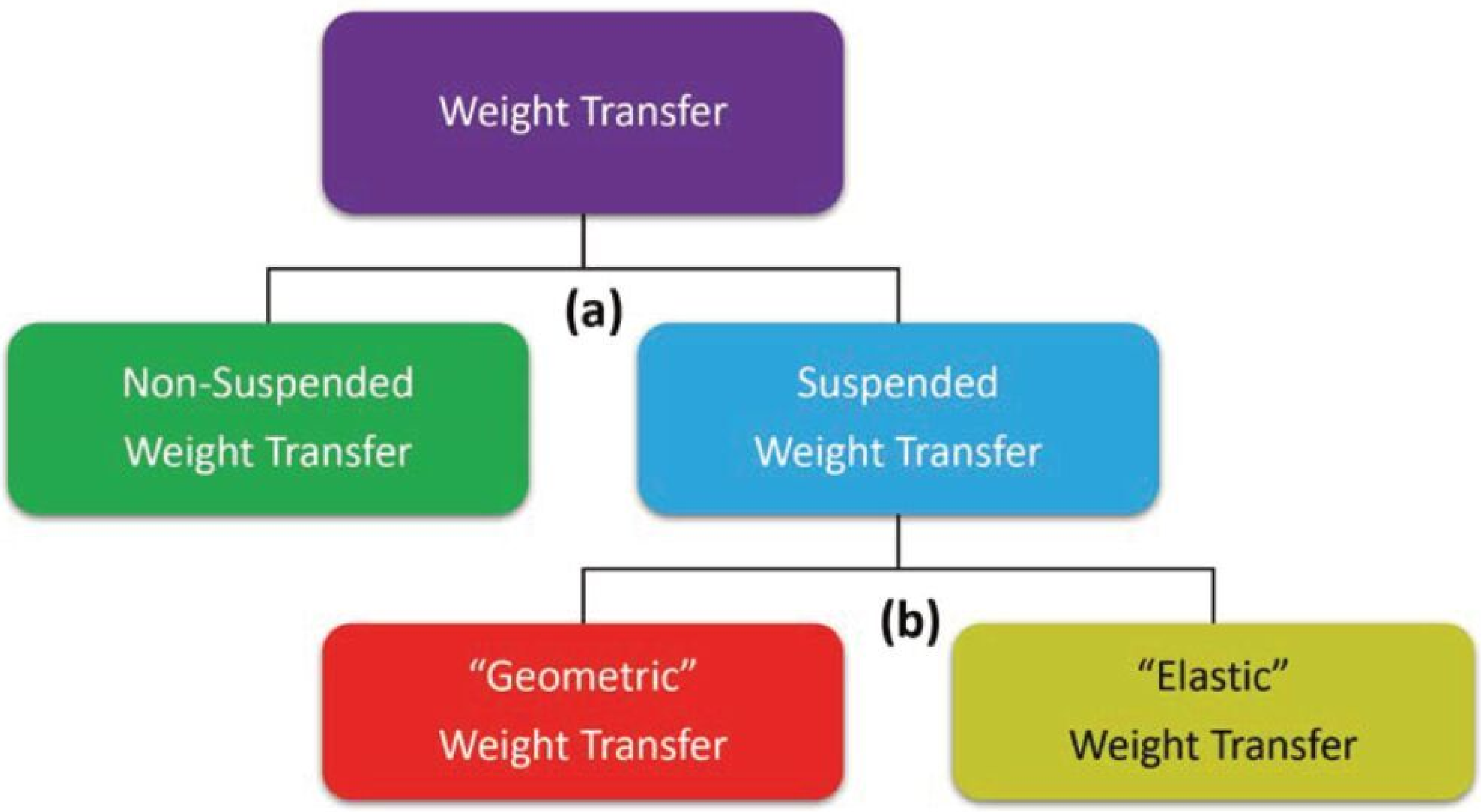
Fig 1: Simplified 2D suspended mass and non-suspended mass load transfer equations



Lateral SM Load Transfer = SM × V²/R × SM CG height /Track

Lateral NSM Load Transfer =NSM v V²/ R x NSM CG height / Track

Fig2: Simplified 2D view equations of the decomposition of load transfer situations

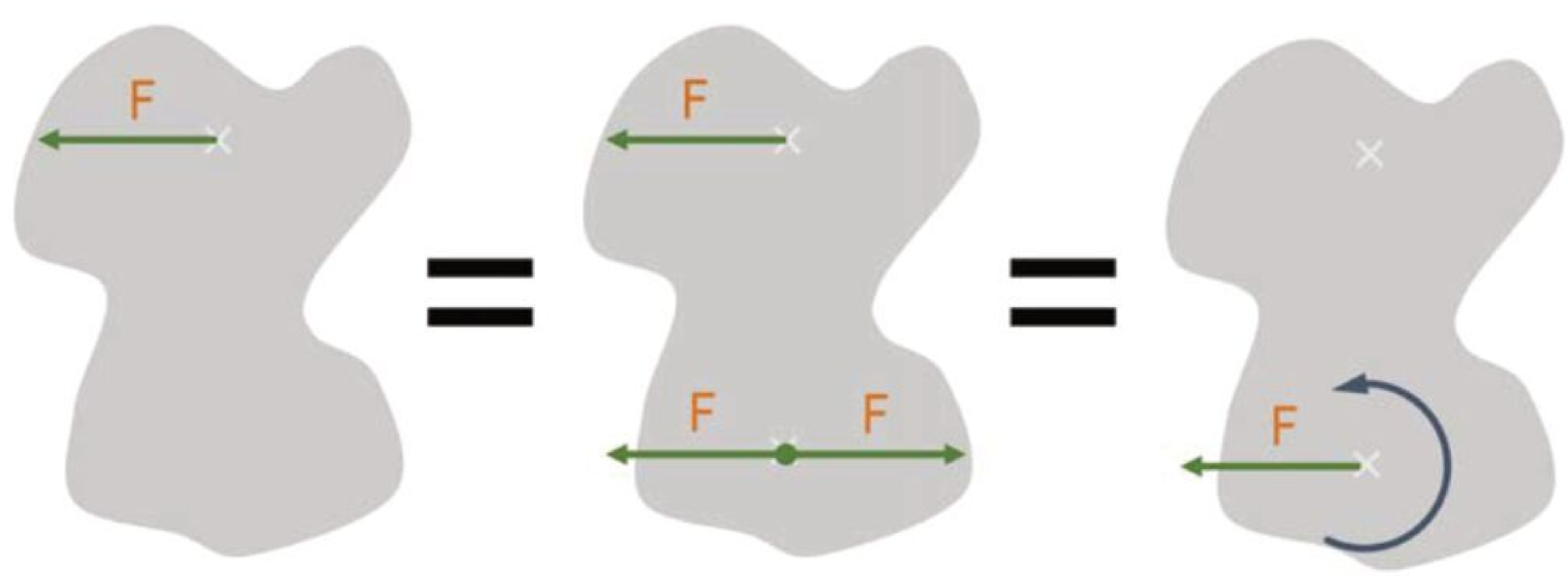


(a): decomposition of the total lateral load transfer in a non-suspended and a suspended mass load transfer

(b): decomposition of the suspended mass load transfer in a geometric load and an elastic load transfer

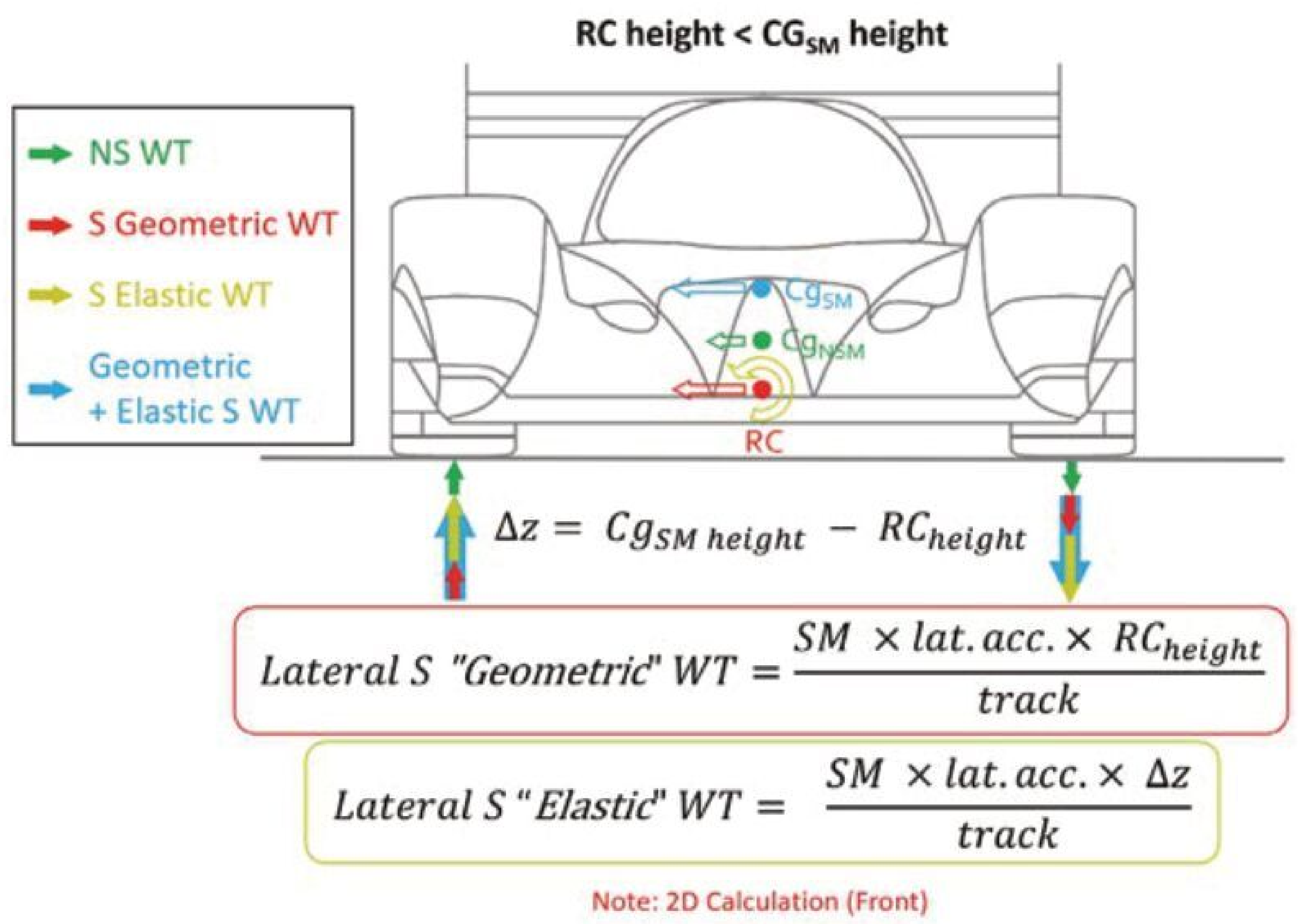
The higher the roll centre, the less roll moment and elastic roll transfer, but the more geometric load transfer

Fig 3: The basic principle of force



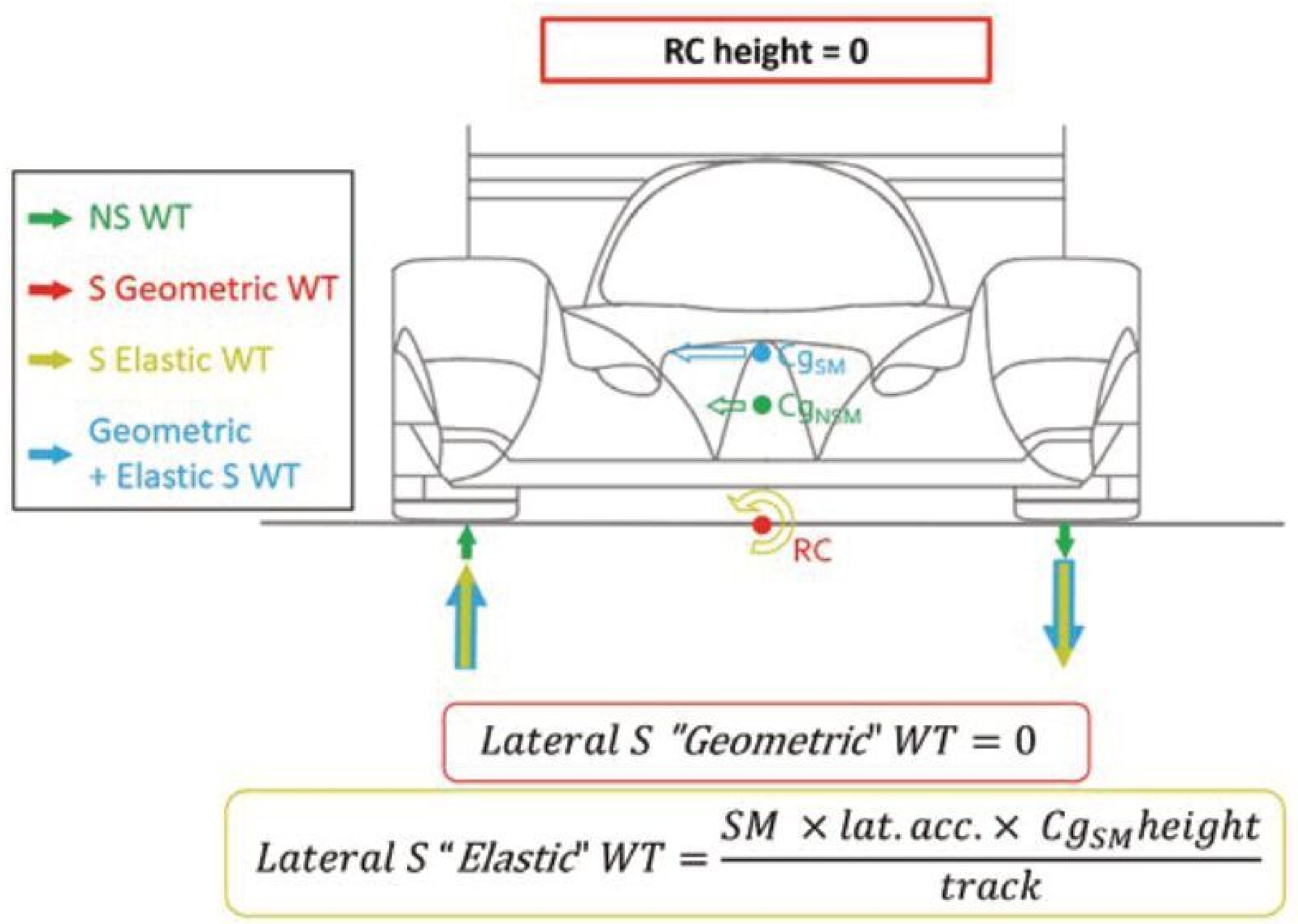
A force applied at one point of a body is equal to the same force applied at another point of that body and a torque

Fig 4: Simplified 2D equation of suspended mass load transfer in geometric and elastic load cases



Decomposition of the suspended mass load transfer in geometric (red), and in elastic (yellow) conditions

Fig 5: Simplified 2D equation of load transfer with the roll centre at ground height



In this condition, the suspended mass load transfer (blue) is elastic (yellow) and there is no geometric load transfer (red)

The fact is the kinematic roll centre is not a real, physical point of the body. But there are still a few useful perspectives to be shared

Once we take the tyres' lateral force, as well as the concepts of force-based roll centre and jacking forces (a topic for a future article), we will have a more exact appreciation of the load transfer principles.

But my experience is that for novices, this simplified explanation is a good, necessary (but insufficient) first step to better understand load transfers.

4. One of these simplifications is shown in **Figures 3** and **4**. These say that a force applied at one point of a body (the suspended mass c of g) is the same as the equal force applied at another point of the body (the kinematic roll centre) and a torque. The fact is the kinematic roll centre is not a real, physical point of the body. But, there are still a few useful perspectives to be shared.
5. If we look at the equations, and the vertical force vectors at each tyre base, we realise that if the roll centre is on the ground (**Figure 5**) the totality of the suspended mass load transfer is elastic. 100 per cent of suspended mass load transfer (blue) is in fact an elastic load transfer (yellow) and there isn't any geometric load transfer (red).
6. In the (very hypothetical) case of a roll centre at the same height as the suspended mass c of g (**Figure 6**), there isn't any roll moment because the distance between the suspended mass c of g and the roll centre is zero. There won't *be* any roll angle.

Of course, there will still be a roll angle due to the tyres' deflection and the chassis and suspension elements compliance. But whether the spring and anti-roll bars are stiff or not, it does not make any difference. If there isn't any roll moment (action), there isn't any kinematic roll angle (reaction).

And here is an important concept: if there isn't any roll moment and

So far we have been looking at the 'picture' (steady state), but once we look at the 'movie' (transient) things are quite different

any roll angle, there are no spring compression (outside) or extension (inside) nor any anti-roll bar twisting. A strain gauge on a pushrod would not record any force variation.

But how then is the load transferred from the inside to the outside wheel? Answer: through the wishbones.

8. That is why we speak about geometric load transfer. What determines the amount of geometric load transfer? The roll centre altitude. What determines the roll centre position? The geometry of the suspension.

   Similarly, we speak about elastic load transfer because the roll moment will be reacted by the elastic component of the suspension: springs, anti-roll bars, maybe bump stops (if they are engaged) and, in transient, dampers.
9. If the roll centre was at half the distance between the ground and the suspended mass c of g, 50 per cent of the suspended load transfer would also be, and 50 per cent geometric, and the other 50 per cent would be elastic.
10. Last illustration of the distribution of geometric and elastic suspended mass load transfers the roll centre under the ground (**Figure 7**). In this case, the whole suspended mass load transfer (blue) is divided in a negative geometric (red) load transfer and a bigger, positive elastic load transfer (yellow). But the total remains the same, because the load transfer (at least in this simplified 2D, one-track example) is essentially depending on the mass, car speed and the corner radius, thus lateral acceleration (A = V2/R), the c of g height and the track width.

So, why do we care about splitting the load transfer in a non-suspended and suspended load transfer, and then the suspended one in a geometric and an elastic load transfer, if at the end the total of these load transfers remains the same? Because they do not grow at the same rate, that's why. So far, we have been looking at the 'picture' (steady state), but once we look at the 'movie' (transient), things are quite different.

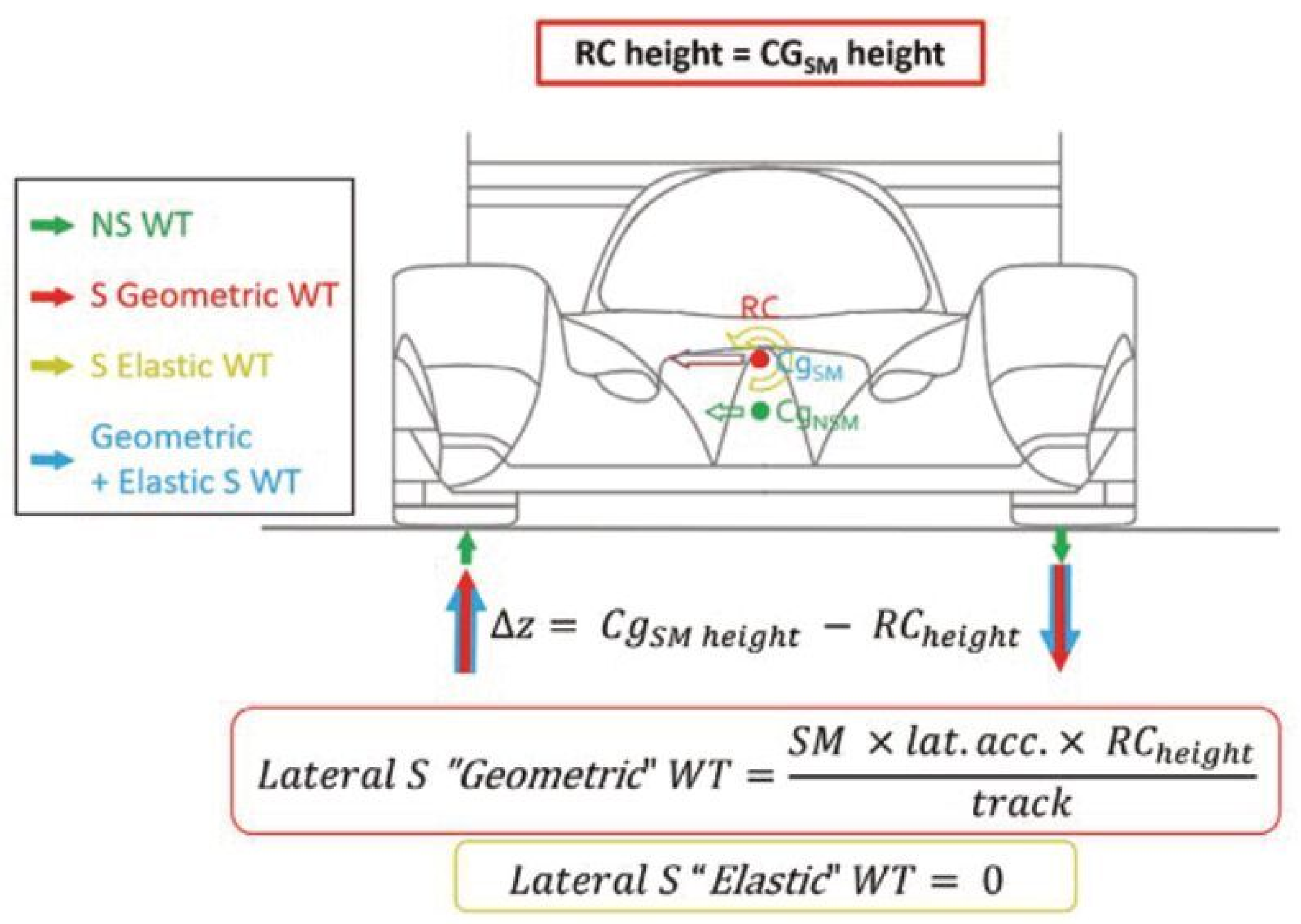
In **Figure 8** we can see the evolution of the different parts of the suspended mass load transfer vs time by observing the variation of the left front tyre load in a right-hand corner under a simplified open loop input of an increasing, and then decreasing lateral acceleration (light brown) from 0.5 to 2.5 seconds with a peak at 2*g*.

Geometric is shown in red, and the three components of the elastic load transfer: anti-roll bar in blue, spring in green and damper in purple, with a roll centre above the ground.

Some interesting observations here:

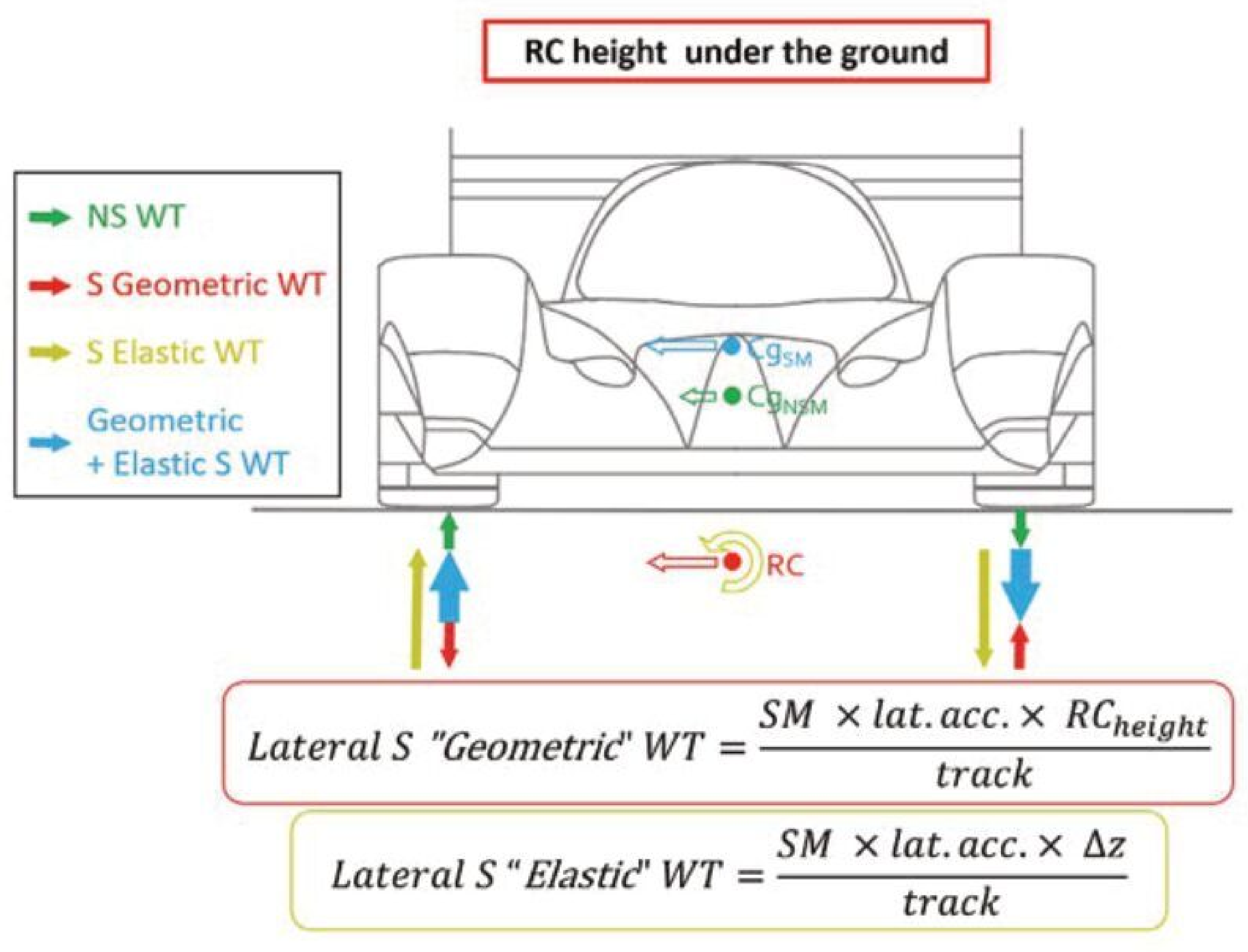
1. The shape of this lateral acceleration is roughly what we see in a corner with a peak around the corner apex.
2. This is a simplified open loop. Simple then complicated, not the other way! In the real world, the lateral acceleration depends, in a closed loop, on the tyre lateral forces, which in turn depend in part on the tyres' vertical load, which depend on the load transfers, which depend on the lateral acceleration.
3. The non-suspended load transfer is not displayed here.
4. We see the geometric load transfer (red) has the same shape as the lateral acceleration. It starts and ends at the same time. There is no delay or sluggishness, unless there would be

Figure 6: Simplified 2D equation of load transfer with the roll centre at the same height as the c of g

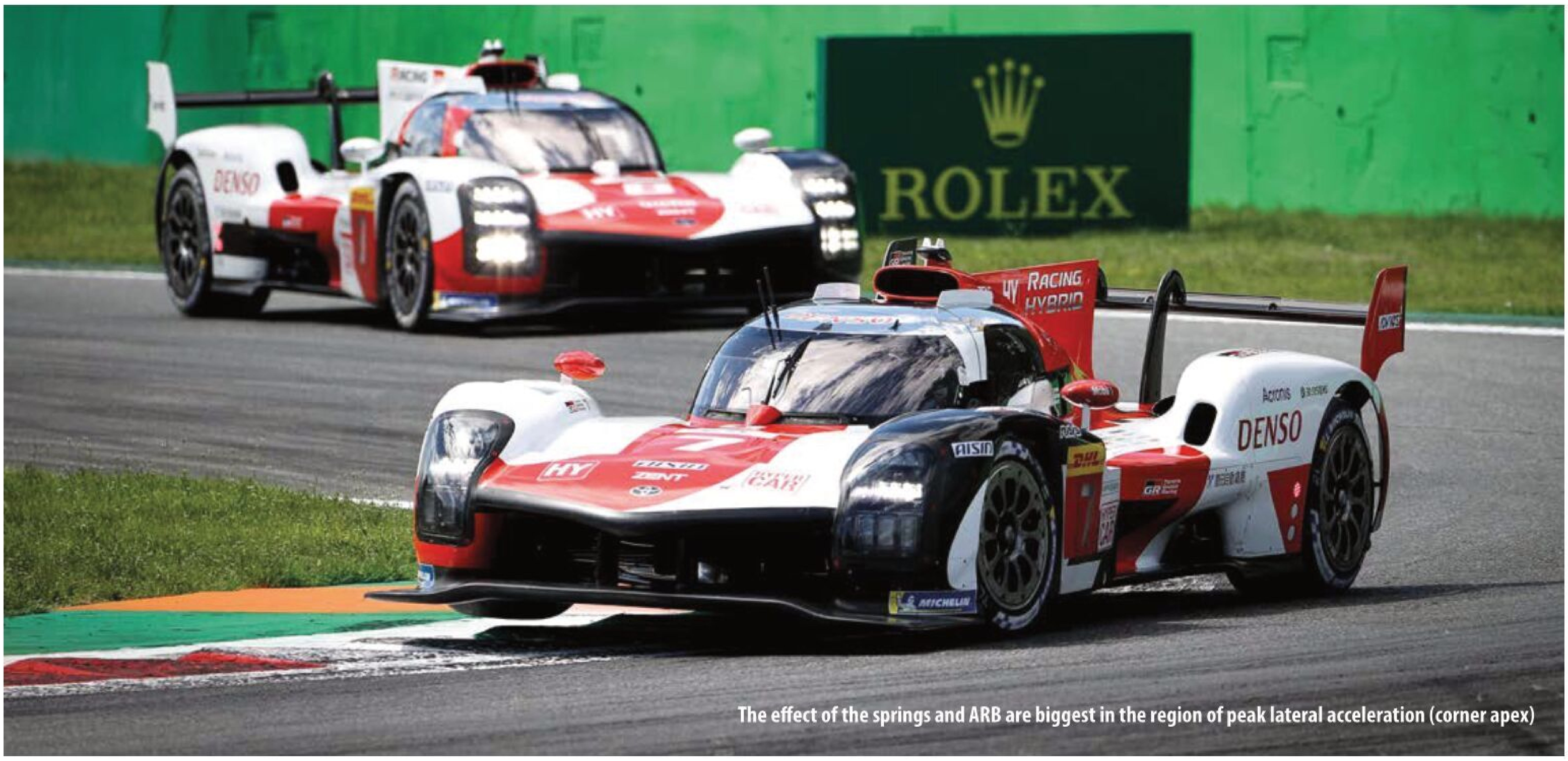


In this highly unlikely, hypothetical case, the whole suspended mass load transfer (blue) is geometric (red) and there is no elastic load transfer (yellow)

Fig 7: Simplified 2D equation of load transfer with the roll centre beneath the ground



Here, the whole suspended mass load transfer (blue) is divided in a negative geometric (red) load transfer and a bigger, positive elastic load transfer (yellow)



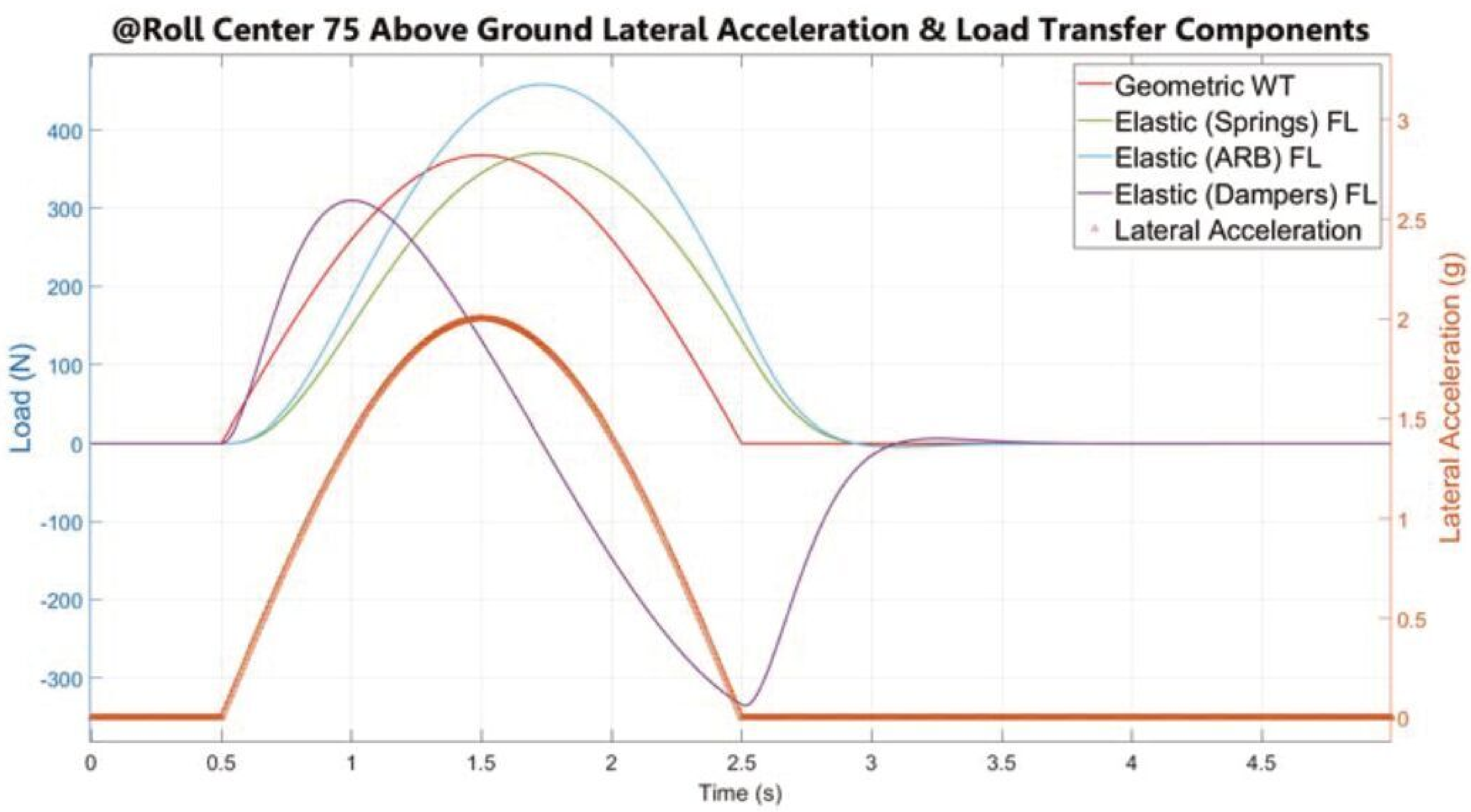
The effect of the springs and ARB are biggest in the region of peak lateral acceleration (corner apex)

some elasticity on the suspension elements, which is the case on a passenger car with suspension bushings.

5. If we look at the peaks, there is more load transfer from the ARB (blue) than the springs (green). That is usually the case in rear-wheel drive racecars.
6. Suspended mass elastic load transfers that go through springs, ARB and the dampers do not stop when the lateral acceleration does. In fact, it takes about one second for the system to stabilise. That is all due to the suspended mass roll inertia.
7. The peaks of the suspended mass elastic load transfers that go through the ARB (blue) and springs (green) occur later (about 0.25 second in this case) than the peak of the lateral acceleration. Again, due to the suspended mass inertia.
8. While the effect of the springs and ARB are biggest in the region of peak lateral acceleration (corner apex), they are negligible at corner entry and exit. At corner entry, there is low lateral acceleration, small roll angle and small deformation of springs and the ARB.
9. However, that is the contrary for the dampers. At peak lateral acceleration (in fact, a touch later due to the suspended mass roll inertia), the roll angle is the biggest, but the roll speed changes sign and goes from zero. No roll speed, no damper speed, no damper effect.
10. If the effect of the dampers is close to negligible in the region of the peak lateral acceleration, it is considerable at corner entry and exit. In the first 0.5 second the dampers do, for better or worse, much more than the springs and the ARB.
11. If you pay attention to the first one or two tenths of a second, in the very first metres of corner entry, you'll see the geometric load transfer (red) does much more than the springs (green), the ARB (blue) and even the dampers (purple). We then realise how suspension kinematics will have a considerable effect on car behaviour.

We will go into detail on this next month.

Fig 8: Evolution of the different parts of the suspended mass load transfer vs time



Decomposition of the geometric (red) load transfer and the different parts of the suspended mass elastic load transfers due to spring (green), anti-roll bar (blue) and damper (purple) vs time with a simplified open loop lateral acceleration input (brown)

Slip Angle is a summary of Claude Rouelle's OptimumG seminars, which are held worldwide throughout the year.

Public, onsite, and online OptimumG seminars are held worldwide throughout the year. The Advanced Vehicle Dynamics and the Data Driven Performance Engineering seminars present several theories and best practices that can be used by engineers when making decisions on how to improve vehicle performance. OptimumG engineers can also be found around the world working as consultants for top level teams.

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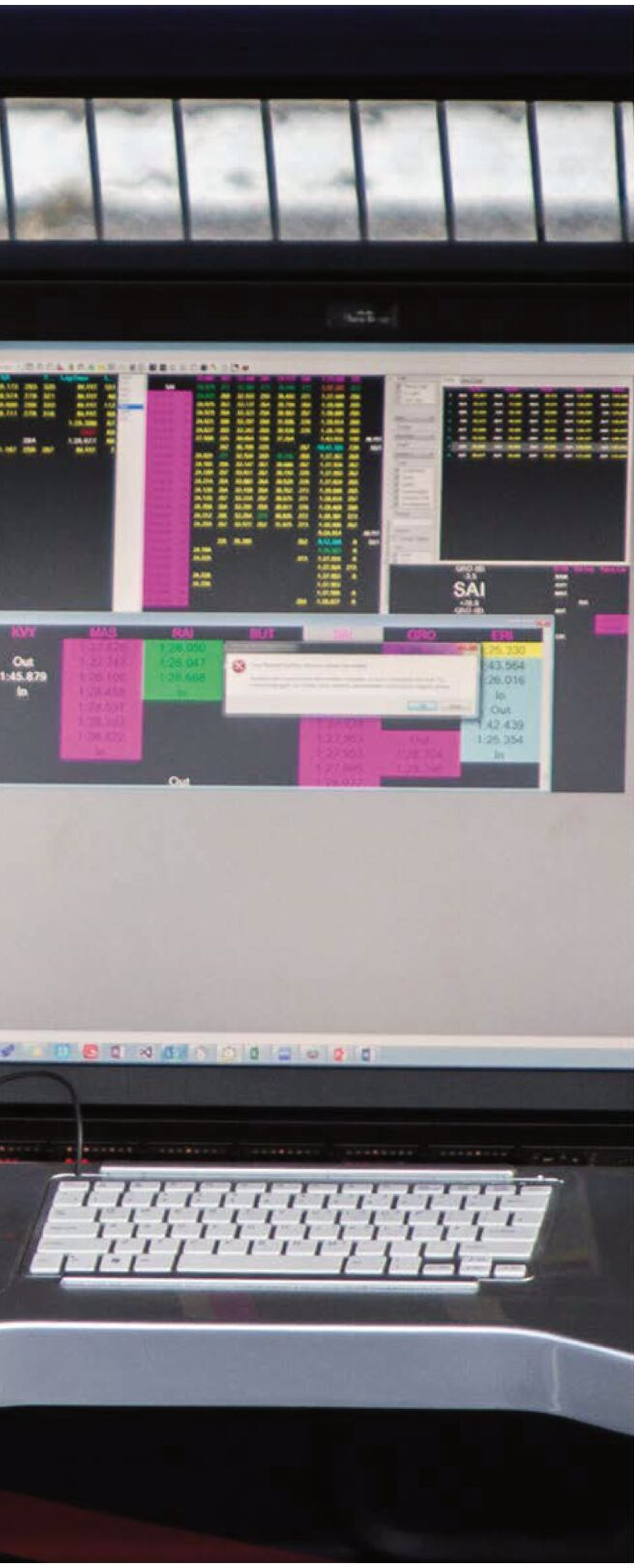
The virtual garage

Racecar *investigates the latest advances in the ultra-hi-tech data and communications systems in Formula 1*

By LAWRENCE BUTCHER



Formula 1 runs on data, and every element of each team's operation is monitored and analysed to the n'th degree. The reason outfits such as Mercedes are so successful is because, among other factors, they have the best grasp of the data available to them and are able to process and understand it rapidly.

This is only possible thanks to a constantly evolving array of tools used to record, store, transmit and analyse that data. And, most importantly of all, filter out that which is most significant. The ideal situation is for every department to access whichever data it needs, at any time, and interrogate it to achieve a competitive advantage.

This data-driven approach to racing has seen the pit wall steadily extended. It now encompasses the garage, paddock and the factory the racecars are built in, creating a virtual garage environment where dedicated teams of engineers can analyse car performance and race strategy away from the high-pressure atmosphere of the track.

To achieve seamless data flow across the globe, teams need an IT and communications system that is both efficient and resilient, and it should come as no surprise that many teams' current sponsorship deals with relevant technology companies go hand in hand with technical partnerships.

Moving data

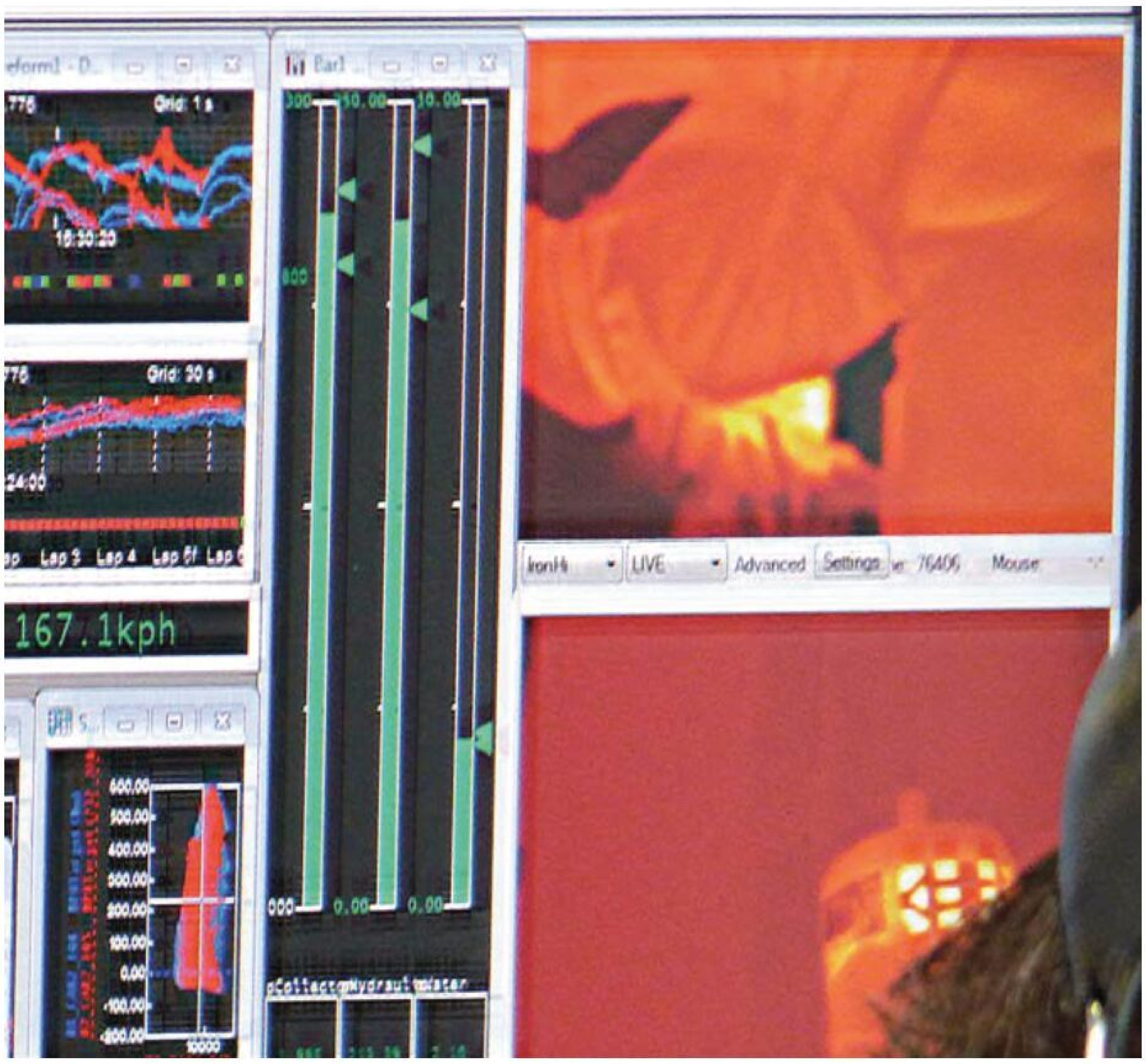
With approximately 300 sensors installed on a car during a race weekend collecting gigabytes of data, simply moving the information harvested through practice, qualifying and race sessions is an onerous task. It needs to be moved quickly, so that both real-time and offline simulations can be conducted to refine set-ups, strategy calls calculated and preventative maintenance issues dealt with in good time.

Whereas a decade ago, most sensors only recorded parameters such as position, speed, load and temperature, in recent years the use of video-based data collection has increased exponentially. For example, thermal cameras, in addition to infrared thermal sensors, are used to record tyre data, while other cameras can be deployed across the vehicle and in the pit lane for pit stop and performance analysis. And teams are not only looking at their own cars, but also the competition, trying to work out their strengths and weaknesses.

Core operating data from the car will be transmitted via the telemetry system to the pits over the course of a lap, though the bandwidth of this is relatively narrow and so is limited to important readings related to powertrain and chassis performance. More detailed data will be downloaded when the car comes into pit, traditionally through a hard cable connection, though some teams have deployed sophisticated systems to dump data either each lap, or before the car enters the garage after a stint.

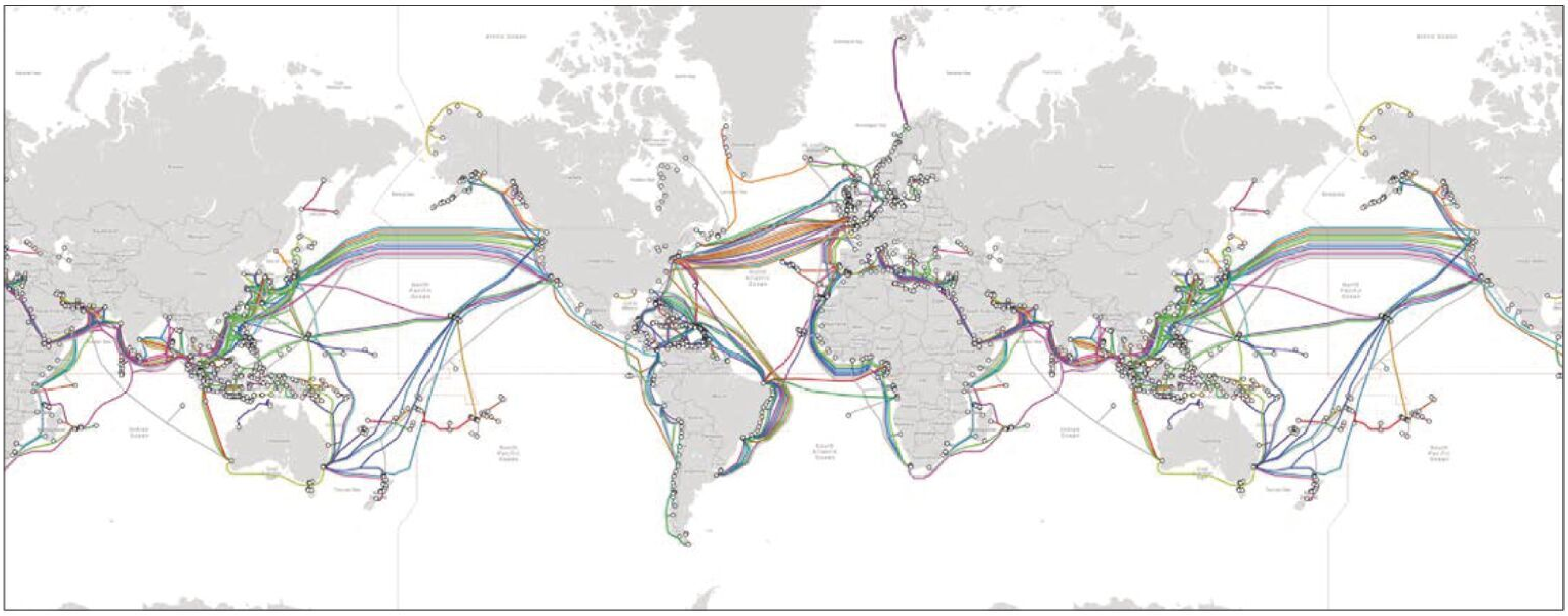
For example, since 2017, working with technology partner Qualcomm, the Mercedes Formula 1 team has been using a high-speed Wi-Fi system located at the pit entry to dump thermal camera data from its cars as they pass by, making it available to engineers to analyse before the car even enters the garage.

The ideal situation is for every department to access whichever data it needs, at any time, and interrogate it to achieve a competitive advantage



Downloading thermal data on the fly can help powertrain engineers monitor how a car is running before the car pits

Red Bull AT&T ops room



Fibre optic connections are not limited to land, this map shows some of the under-sea network that links the globe. F1 partner, Tata Communications, owns over 500,000kms of sub-sea network

At the time of its introduction, the system relied on a 60GHz, 802.11ad Wi-Fi connection, albeit highly uprated by Qualcomm, capable of data transfer at a rate of 200-600Mbit/s, about three times faster than a standard 802.11ac system. Since then, the team and partner have been working on moving other data beyond tyres, and also transmitting each time the car passes the pits, while also investigating 5G-based C-V2X (Cellular Vehicle to Infrastructure) transmission, but so far remain tight lipped about the results.

Hard networks

Once the data is grabbed from the car, it then needs to be distributed around the garage and paddock and on to teams' facilities back at their factories, in addition to F1 and the FIA's race control networks. On a race weekend, a team's IT staff will install a high-speed ethernet connection between the pit wall, garage and paddock, providing a real-time connection across all elements of their operation. The use of a hard network is vital for two reasons: first, Wi-Fi is too susceptible to disruption in the 'noisy' environment of a pit lane and second, wired connections are far more secure, reducing the chance of another team pilfering critical data.

From the track, teams need a secure and very high-speed data link back to their bases, in order to fully utilise the 'Mission Control' concept, allowing engineers at the factory to augment those at the track in real time. This connection will be provided by a third-party supplier and invariably use fibre optic links capable of data transmission speed in excess of 100Mbit/s. On top of this, there can also be back-up systems relying on satellite and cellular connections.

Fibre optic cable networks span the globe (there is even a fibre link between the islands of French Polynesia), and are capable of providing low latency, high speed data flow. Technical partners come in very useful here, as setting up a dedicated connection from a new location every week is far from cheap.

Tata Communications, for example, which until 2020 was heavily invested in F1 as an official partner and of several teams, owns over 500,000km of sub-sea and 210,000km of terrestrial fibre cable network. This means it can provide customers with dedicated fibre links, even in remote corners of the globe.

In the case of Red Bull, partner, AT&T, handles its communications needs and has staff trackside at every race to set up and break down the required infrastructure, even going so far as to lay cables to local exchanges from the garage if necessary.

Mercedes F1's technical partnership with Hewlett Packard sees it use the company's Edgeline 4000 chassis for high speed trackside data crunching

The technical detail of these network set-ups is beyond the scope of this article, but there are a number of different approaches to creating a resilient international link. Traditionally, if you wanted to establish a reliable data connection between two remote locations, the go-to solution would be an MPLS (Multi-Protocol Label Switching). MPLS is a routing technique for telecommunications networks that directs data from one node to the next based on short path labels rather than long network addresses. This avoids complex lookups in a routing table, which can restrict traffic flow. MPLS's main advantage is that a very reliable (in data terms) link can be created. However, when it comes to high demand for bandwidth, it can be very costly, and also potentially vulnerable to data breaches.

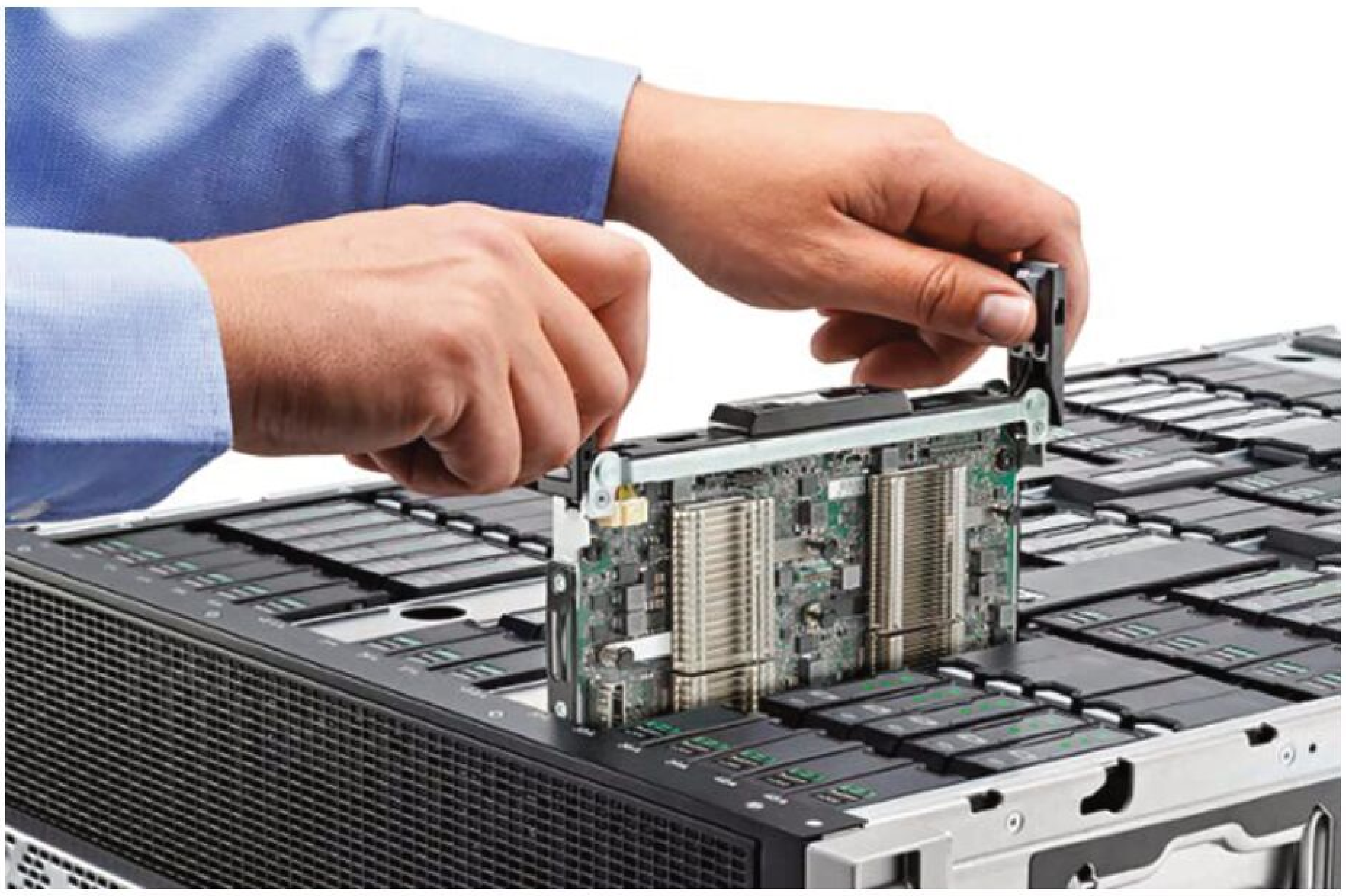
For these reasons, some teams have started to utilise SD-WANs (Software Defined Wide Area Networks). These virtualise network functions so they can run as software on commodity hardware, whereas MPLS technology must run on proprietary hardware. SD-WAN connections can also utilise dedicated lines or public networks, while MPLS can only use the former.

In certain cases, an SD-WAN can also integrate MPLS as one of the SD-WAN connections. McLaren is one team that leverages an SD-WAN via its partner, NTT Communications, the Woking, UK-based outfit having moved to the system in 2018 to help it better handle the bandwidth-hungry video data it was harvesting at races.

Crunching the data

The computational power needed to process the reams of data gathered over a weekend is considerable, and the F1 pit lane is a great display of edge computing. This term refers to putting computation and data storage at the edge of a network where data is gathered, so it can be used for tasks such as simulation and data analysis, without having to rely on centralised HPC (high performance computing) resources. This is not to say teams do not make use of their factory data centres as well as cloud computing facilities, but having considerable computing firepower trackside is vital when making split second strategy decisions.

To this end, every team has a data centre in its support trucks. The power of these has increased considerably in recent years, even as their physical size has decreased. Not only has this broadened the range of tasks that can be undertaken at the track, but also, somewhat surprisingly, reduced costs. For example, when Williams updated its trackside servers, it was able to move from four-rack units to two, which reduced the overall weight of the system. With air freight coming in at $300/kg, the savings on shipping the kit from round to round meant the upgrade paid for itself in nine months.



While back in the factory, HPE Moonshot bladed CPUs are used in their thousands for CFD simulation work

Williams also found greater performance. The increasingly large data sets produced by the car's telemetry system, plus the proliferation of high-definition video, meant that the input / output of storage was causing bottlenecks in the transfer of information around the team. It could take the trackside engineers up to three minutes to open up a data set for analysis, which is an age in the short gaps between track sessions.

The team consolidated its computer resources and storage into a single chassis (the racks of computers one sees in a server room). The resulting system allowed more efficient assigning of resources to various tasks and faster processing of those tasks, thanks to the storage being on board each chassis, rather than relying on a centralised network storage system. According to the team, this gained up to 11 times the throughput it had been getting from its network-attached storage. The real-world impact of this improvement meant engineers could access full data sets from the car in around six seconds, rather than the two to three minutes it had previously taken.

Technical partners come in very useful here, as setting up a dedicated connection from a new location every week is far from cheap

In the case of Mercedes, which has a technical partnership with Hewlett Packard Enterprise, it uses the company's latest HPC kit trackside. In its factory, the team relies on HPE's Moonshot, a converged, bladed (where CPUs are mounted on blades that slot into racks) HPC system, originally developed for the financial services industry and renowned for its high performance and energy efficiency. It uses several thousand of these processors for its CFD simulation work.

In 2019, it moved the same technology to the edge, consolidating its trackside infrastructure of 16 units into a single, rugged HPE Edgeline 4000 chassis, designed for edge applications. The simplified system had greater resilience and performance, allowing for faster data crunching during the crucial seconds of qualifying sessions.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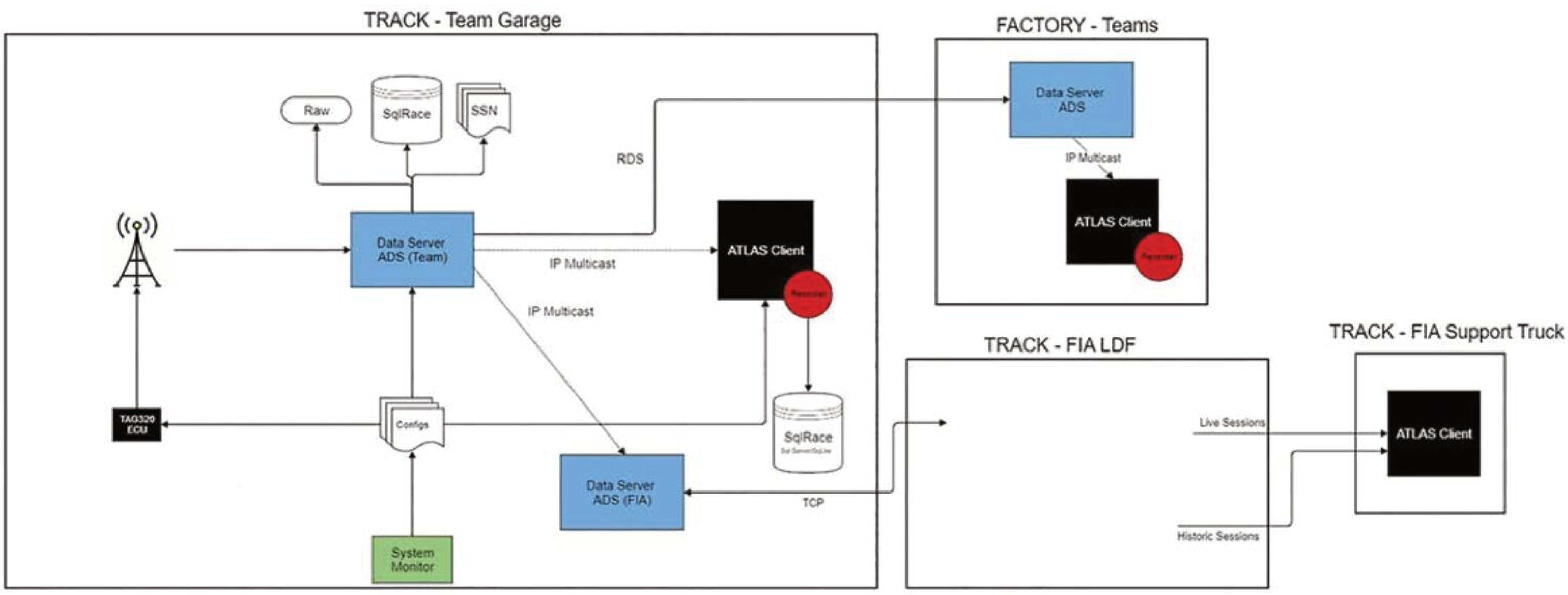


McLaren Applied's ATLAS (Advanced Telemetry Linked Acquisition System) is used by almost all F1 teams and is the engineers' main point of contact with data at the track and in the factory

Mercedes also takes full advantage of is its partnership with specialist Pure Storage, which has supplied solid-state flash storage across all of the team's infrastructure. As anyone who has switched from a traditional HDD to a flash drive will know, these are far faster and, for Mercedes, the shift saw a cut in response times for key database queries of 95 per cent. Similarly, the time needed to open data files reduced by two thirds and it saw a near 70 per cent reduction in the space occupied by its data centre racks.

In this Internet of Everything age, teams are not limited to the computing power they physically possess, and many now also turn to cloud resources for rapid scaling to meet complex computational tasks. Big players such as Amazon Web Services (AWS) and Microsoft feature prominently, alongside others such as Aston Martin Racing's tie up with Cognizant and Red Bull's with Oracle. The most evident to the viewing public is, of course, F1's deal with AWS, which is used to generate in-race insights, and was deployed for development of the 2022 regulations.

These partnerships do not just bring access to computing power in the cloud, but also expertise in areas such as machine learning and data management. For example, Ferrari has recently signed an agreement with AWS and will use its Elastic Compute Cloud (Amazon EC2) system, and is set to build a data lake with Amazon Simple Storage Service (Amazon S3) and AWS Lake Formation to gather, catalogue and clean petabytes of data. Having all of this data centralised allow it to 'scrape' for patterns that might affect car performance.

Data sorting

It is one thing being able to move data around the globe in real time, but it's what teams do with it that counts. It has to be sifted and relevant portions dished out to those that need it, while being presented in such a way that engineers can quickly see important changes or trends.

Almost universal across the grid when it comes to monitoring car operating parameters is McLaren Applied's ATLAS (Advanced Telemetry Linked Acquisition System). Glance at any garage on a race weekend and various ATLAS displays will be apparent, each team having its own data workbooks incorporating various displays and pages. The system is most engineer's main point of contact with vehicle data, and is used both trackside and at the factory.

It should come as little surprise that, as one of the originators of the mission control systems that are now commonplace, McLaren Applied ensured global networking capabilities are incorporated into ATLAS. The Atlas Data Server (ADS) features a Remote Data Server (RDS) function allowing the daisy chaining of two or more ADS, and simultaneous broadcasting to two ADS for multicasting to other network clients.

However, there are many other systems teams use to interpret their myriad data streams. Pit stops, safety cars – both physical and virtual – as well as the actions of the other teams all dictate the split-second tactical calls teams make, and many have developed tools to aid in this. For example, UK-based SBG Sports Software, which specialises in performance analysis software, has worked with Mercedes since the last days of Brawn, refining its Race Strategy software system to provide up-to-the-second analysis of these tactical situations, incorporating the video feeds from the various cameras recording the race.

Via a series of customisable worksheets, engineers can quickly access and overlay the data they need to make decisions from the pit wall, including not only that provided by the FIA, such as GPS and sector times, but also inputs from a team's sources, predicting tyre degradation, pit stop windows and the like.

In this Internet of Everything age, teams are not limited to the computing power they physically possess

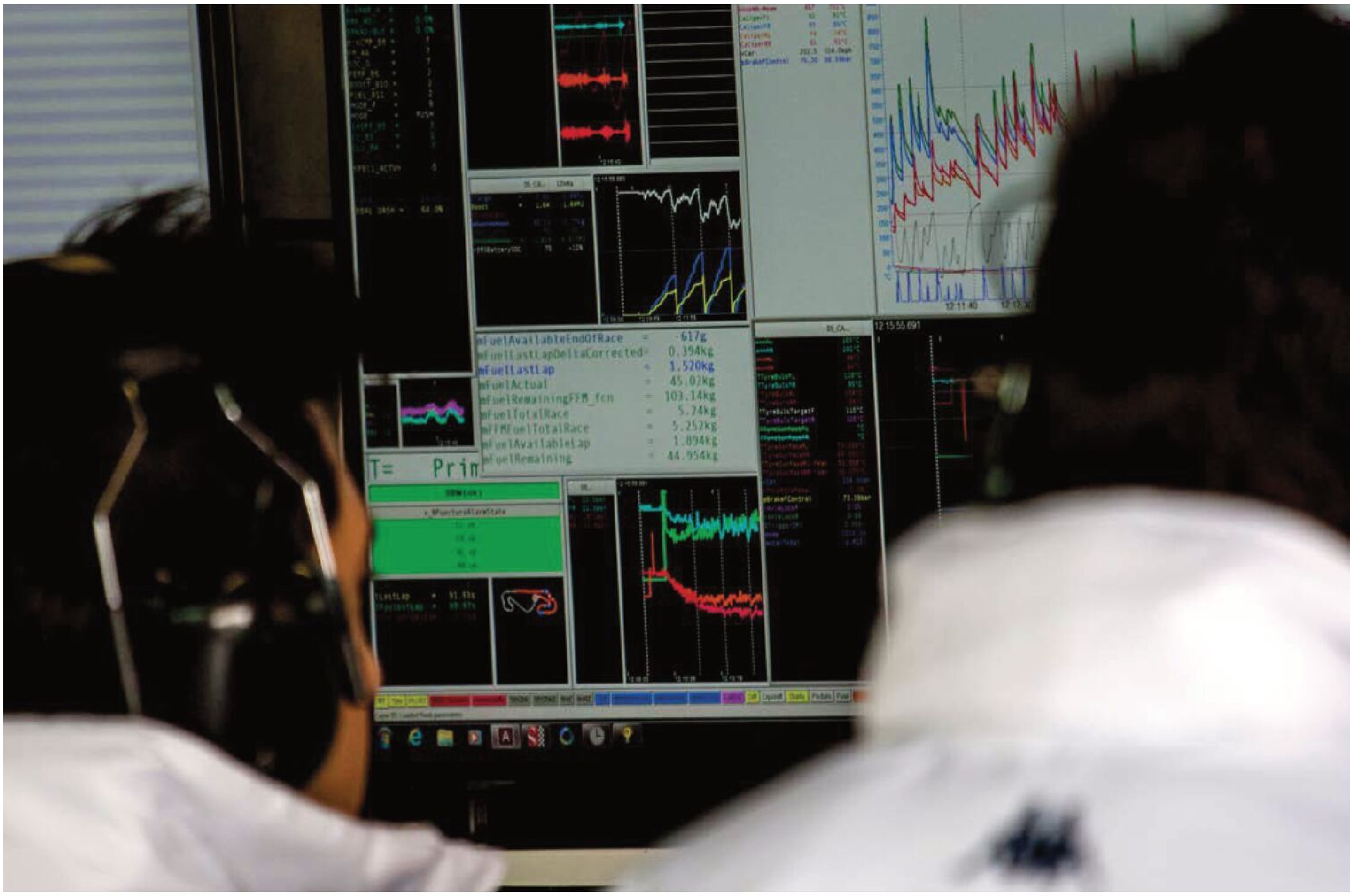
As well as making in-race calls, the system can also be used for pre- and post-race planning. The team will feed data into the system and run through a multitude of scenarios to work out the impact of various events on its tactical calls, even going so far as to run full race simulations with engineers operating in real time. Similarly, it will also use the system for post-race analysis and debriefing, with every channel of video, radio data and relevant telemetry recorded.

Trend spotting

It is not just race strategy where teams such as Mercedes have benefited from having well-developed tools. Given the huge amount of data produced by the team's modelling and simulation programs, spotting trends that highlight fruitful development directions can be challenging.

The Brackley, UK-based team deploys a data analytics suite from technical partner, Tibco, called Spotfire. This allows it to review and amalgamate various data streams for visualisation, making it easier to spot trends over time periods from a single race session to an entire season. By being able to identify automatically what is 'normal' in data sets, analysts can better focus their efforts on investigating areas that may be of concern, filtering out the 'noise' of regular data.

One of the first applications for Tibco's technology was in the development of improved gearbox control systems, and finding new avenues for development of the power unit. In the past, teams such as



Security is an increasingly important part of a team's data strategy, and some now use highly secure virtual machines held on a team's data centre, so individual laptops hold no significant data

Mercedes would use relatively crude methods such as Excel spreadsheets for this type of analysis. Mercedes is, of course, not the only team exploiting the latest advances in data analytics and management from outside sources. Nearly every team has at least one technical partner that specialises in data analysis or other IT-dependent activities.

Data security

In just the same way that everyone now takes steps to prevent some ne'er-do-well pilfering their personal information online and taking out a mortgage on a house in Majorca, F1 teams must also take data security seriously. Teams are regularly subject to hacking attempts, ranging from regular malware attacks through to extreme ransomware cases. Again, many teams turn to technical partners to implement a multi-layered approach to security, covering both day-to-day IT operations and the more F1-specific cases such as sensitive data transfer from car to pits to factory.

Looking again to Williams, which has a long-standing partnership with data security and management specialist Acronis, it works on the principle of protecting its data, rather than necessarily ensuring every laptop and desktop computer is 'secure'. This is achieved by team members accessing virtual machines, which reside on the team's data centre and are protected by many layers of security. This means individual machines do not actually contain any data, it all stays within the network and Acronis' Cyber Protect package monitors usage to automatically flag any unusual behaviour.

The same system also ensures that data is always backed up, removing the onus from the individual team member. Implementing such a system is no small task. In the case of Williams, its IT system incorporates approximately 600 individual servers, 1500 workstations (known as end points) and some 1200 email inboxes, with around 0.5 petabytes of data.

Williams has it relatively easy in that its engineers are either at the track *or* the factory. For a team such as Haas, which has bases in the UK, United States and staff in Italy, the data security problem is even more complex. One tool the American team uses to mitigate threats is the Nominet DNS platform, which monitors Domain Name System traffic to automatically detect threats, be they malware, phishing or data theft. Thanks to the automated process, the team says it is able to achieve far greater coverage than human IT operators could and react faster.

Of course, no system is entirely foolproof, and it is still possible for a 'trusted insider' – someone within a team who might be leaving to work for a competitor, for example – to walk off with valuable intellectual property (IP) on a flash drive. Or, in the case of Williams, for the back end of its marketing-led, augmented reality app to be easily accessed, releasing accurate 3D models of its current car out into the wild.

The IT and communications specialists are the unsung heroes of modern F1 teams, managing phenomenally capable systems that push the boundaries of modern connectivity

However, with the increasing sophistication of automated data security systems, such incidences are far more likely to be flagged up and nipped in the bud before any real damage is done.

Overall, it is fair to say that the IT and communications specialists are the unsung heroes of contemporary F1 teams, managing phenomenally capable systems that push the boundaries of modern connectivity in order to gain that elusive competitive edge.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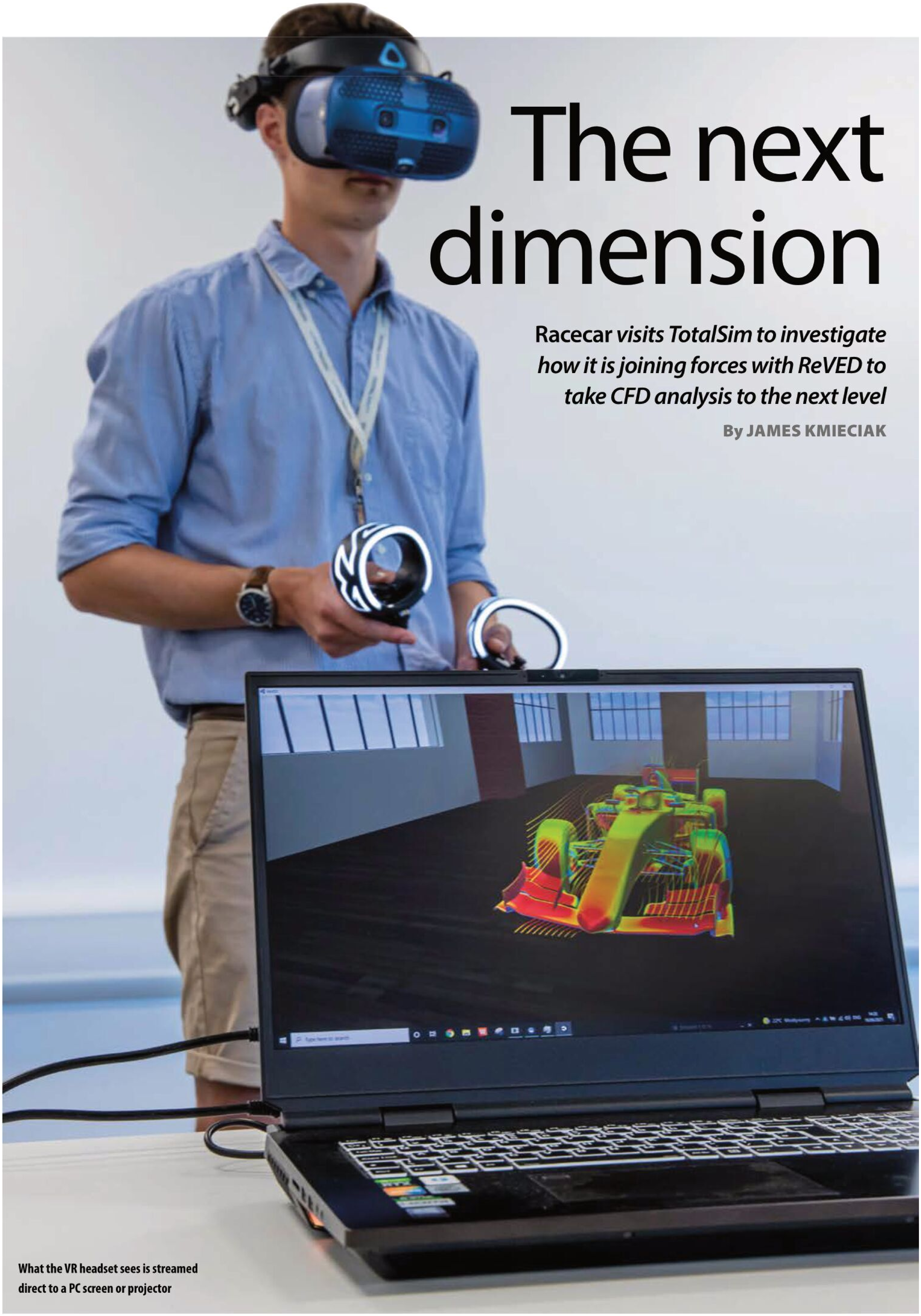


The next dimension

Racecar *visits TotalSim to investigate how it is joining forces with ReVED to take CFD analysis to the next level*

By JAMES KMIECIAK

What the VR headset sees is streamed direct to a PC screen or projector

Images: TotalSim

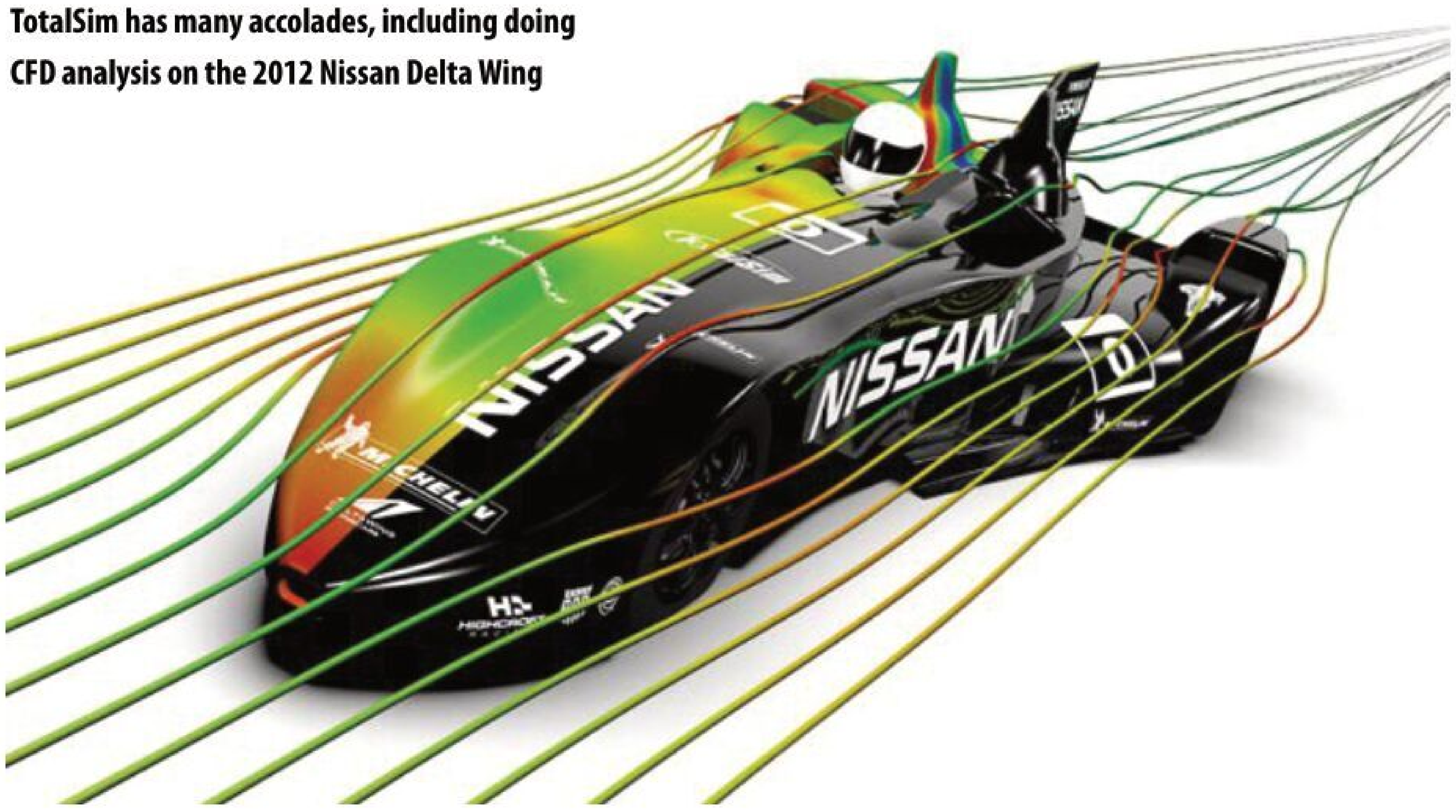
FHTC Vive Cosmos headset and the two hand controllers, which are used for navigation of menus and the manipulation of the virtual domain

TotalSim has long been associated with the successful application of computational fluid dynamics (CFD), primarily for automotive, motorsport and other elite level sport. In fact, the company's managing director, Dr. Rob Lewis, received an OBE in 2017 for his contribution to the performance of the British Olympic and Paralympic teams, while in motorsport the company has taken the aerodynamic design lead on projects ranging from the Bentley Continental GT3, through the beautifully sculpted lines of the Lola Aston Martin V12 LMP1 to one of the most innovative cars ever to compete at Le Mans, the Nissan DeltaWing.

Now, using its in-house modified version of OpenFOAM CFD software, TotalSim has teamed up with US father and son developers at Immersive Visualization Inc. to combine ReVED virtual reality software with post-processed CFD data to give clients a fully immersive aerodynamic experience.

ReVED is an acronym for Realtime Virtual Engineering Design, and has been

TotalSim has many accolades, including doing CFD analysis on the 2012 Nissan Delta Wing



Being able to view 100mph streamlines, oil flows and pressure plots under the floor of a full-size racecar while it floats above your head is a fantastic experience

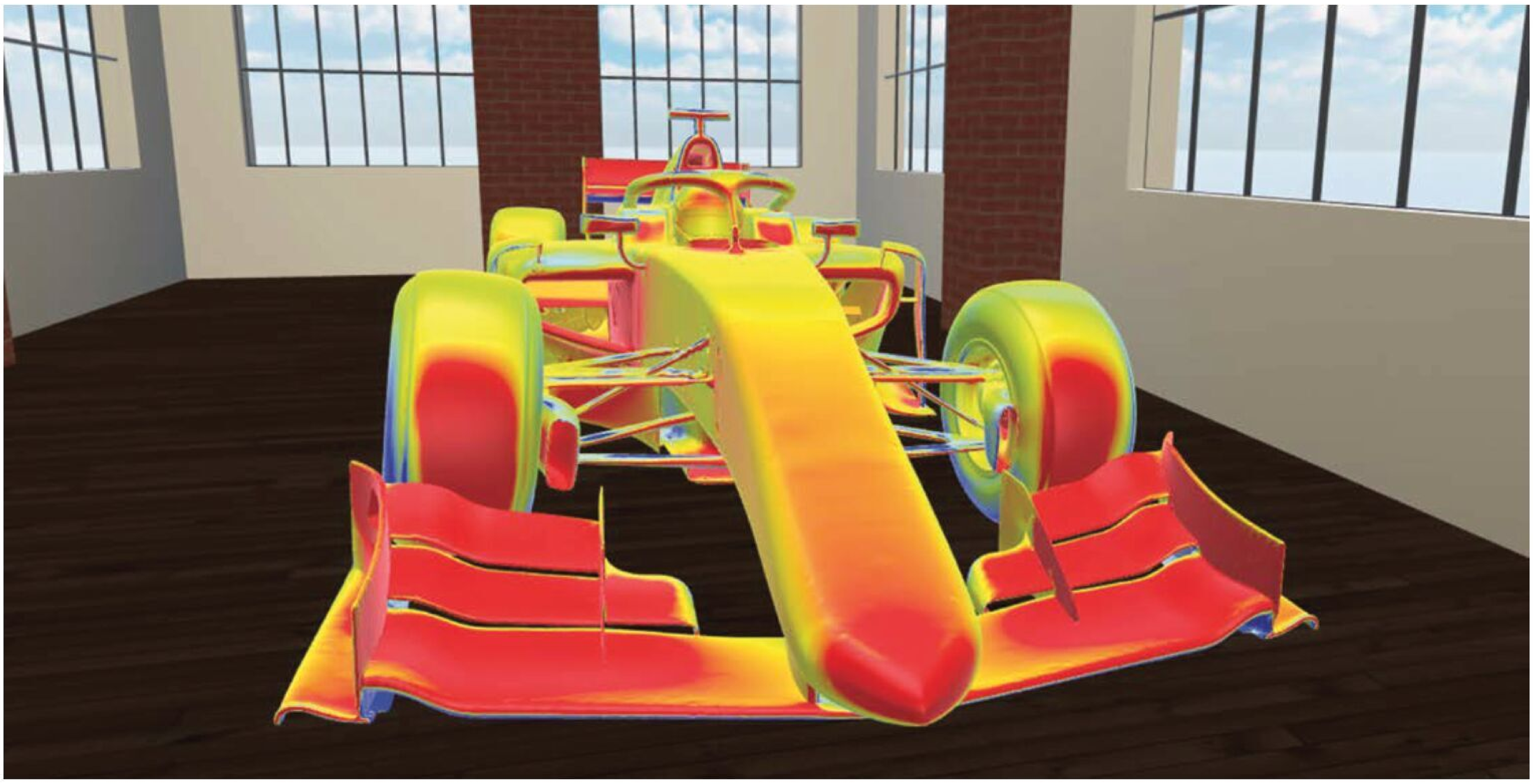


Fig 1: Surface pressure plots on the current Dallara Formula 2 model are not wildly different to a desktop CFD package. The major advance is in the way the screen image can be manipulated

developed to be compatible with all major commercially available VR headsets.

Having spent the past 10 years looking at CFD images on a flat, 27in screen, and trying to show clients what their new bumper modification does to airflow using a mixture of screenshots and screen sharing applications, it was intriguing to find out what TotalSim had in store at its home in the Silverstone Sports Engineering Hub.

Airplay introduction

George Maxted and Henry Pang were my guides through the virtual wind tunnel for the day. George is an experienced CFD and VR test engineer, Henry has been with TotalSim for over a decade and is a team leader.

Standing in the large industrial warehouse space, we walk through the headset and controller operations. The headset we are using is an HTC Vive Cosmos that uses two 1440 x 1700 pixel displays, one for each eye, giving suitably high definition for the task at hand. It comes with two hand controllers that are used for navigation of menus and the manipulation of the virtual domain itself.

The model we are going to look at is a current FIA Formula 2 car built by Dallara, with two different aero packages comprising front and rear wing modifications. This is typical of a comparative aerodynamic analysis that would usually be undertaken using either a wind tunnel or CFD, depending on client budget and accessibility.

The model itself consists of around 126 million cells and has already been analysed in OpenFOAM prior to all of the data being uploaded to TotalSim's online cloud CFD platform client, Bramble.

At this point, a client would normally be sat down in a meeting room in front of a laptop or projector screen to be shown the various surface plots, cut plots and streamlines across their CAD model but now, with headset on and controllers in hand, they find themselves stood in a serenely lit studio with a full-size F2 car parked neatly in the middle.

A virtual boundary is set up to allow you to walk around the car without having to worry about real-world obstructions. If a boundary is crossed, the lenses clear to show your actual surroundings, making it extremely safe to use.

It should be noted the system doesn't require a warehouse to operate, it can be used in any size room or even sat down at a desk if so required.

Optimum view

After a few minutes' tutorial, it is possible to not only walk around the model, but to lift the car up and hold it at head height, rotating it in your hands to view it from the optimum position without moving from where you're standing.

Up to this point, there is nothing we haven't already seen in architectural and automotive design studios, but this is where it all starts to step up a level.

Having quickly got to grips with the VR motion controls, it was time to overlay the CFD data. Using buttons on the left-hand controller, a menu slate appears in front of you and you scroll through this using the virtual laser pointer in your right hand, selecting your preferred option with the trigger button.

The model consists of around 126 million cells and has already been analysed in OpenFOAM prior to all of the data being uploaded to TotalSim's online cloud CFD platform

To begin with, we viewed the standard model with surface pressures applied, as shown in **Figure 1**. Looking at the overview of the car, it's not dissimilar to a desktop CFD package except, instead of manipulating the image on screen, you pick up the entire car and put your head in the region of where you want to view. We see a practical benefit immediately here when viewing the surface pressures inside the engine bay, for example, as this does not require an extra period of post-processing to hide external surfaces and only show the internal ones. Instead, you simply put your head through the engine cover and have a quick look around.

Admittedly, if you wanted to review this in more detail it would still be easier to remove the engine cover, as you would on a desktop, but you still don't need to rotate your screen and zoom in and out to capture that perfect, unobscured screenshot. All this is made better still by the fact the headset is constantly streaming what we're seeing direct to the PC screen or projector.

By selecting the comparison option and using the 'switcher' mode on the controller, wing changes happen instantaneously

Next up, we viewed section pressure plots, as shown in **Figures 2** and **3**. These show pressures acting on a virtual planar surface as if the car had been cut into slices along that plane. They provide a useful 2D guide that complement surface pressure plots when overlaid.

Starting the cut plane at the car centreline, it was easily moved side to side while the car remained stationary. Likewise, vertical and fore / aft cut plots were easy to use but, with the need to stand back to view the whole car and plane, it felt the same as viewing it on a flat screen.

Smoke and flows

With cut plots and surface pressures explored, it was time to look at the streamlines over the front and rear wing versions we were going to compare. This is where the VR system really started to come into its own. Instead of setting planes, boundaries or selecting surfaces for the streamlines to flow over, via the menu the right-hand controller allows points in free space to be created precisely where they are needed to produce streamlines to flow over the components you are looking at. One click gives you one streamline, more clicks, more streamlines.

As we were reviewing the front and rear wings, a batch of streamlines were produced at the car's nose that should cover both of these modifications, along with a batch to highlight barge board and floor flows.

We also changed the surface pressure plots to normalised Uw plots. These are basically comparison of near wall velocity to free stream velocity (velocity ratio) plots that generate similar lines on the surface of the model as would be visible using flow visualisation fluid in the wind tunnel or on track.

By selecting the comparison option and using the 'switcher' mode on the controller, wing changes happen instantaneously, allowing us to look at comparisons between the front and rear wings. As shown in **Figures 4** and **5**, the flow into the front brake ducts and over the front tyres changed significantly enough to cause us to walk the length of the car and closely study where the flows and pressures are changing along the body.

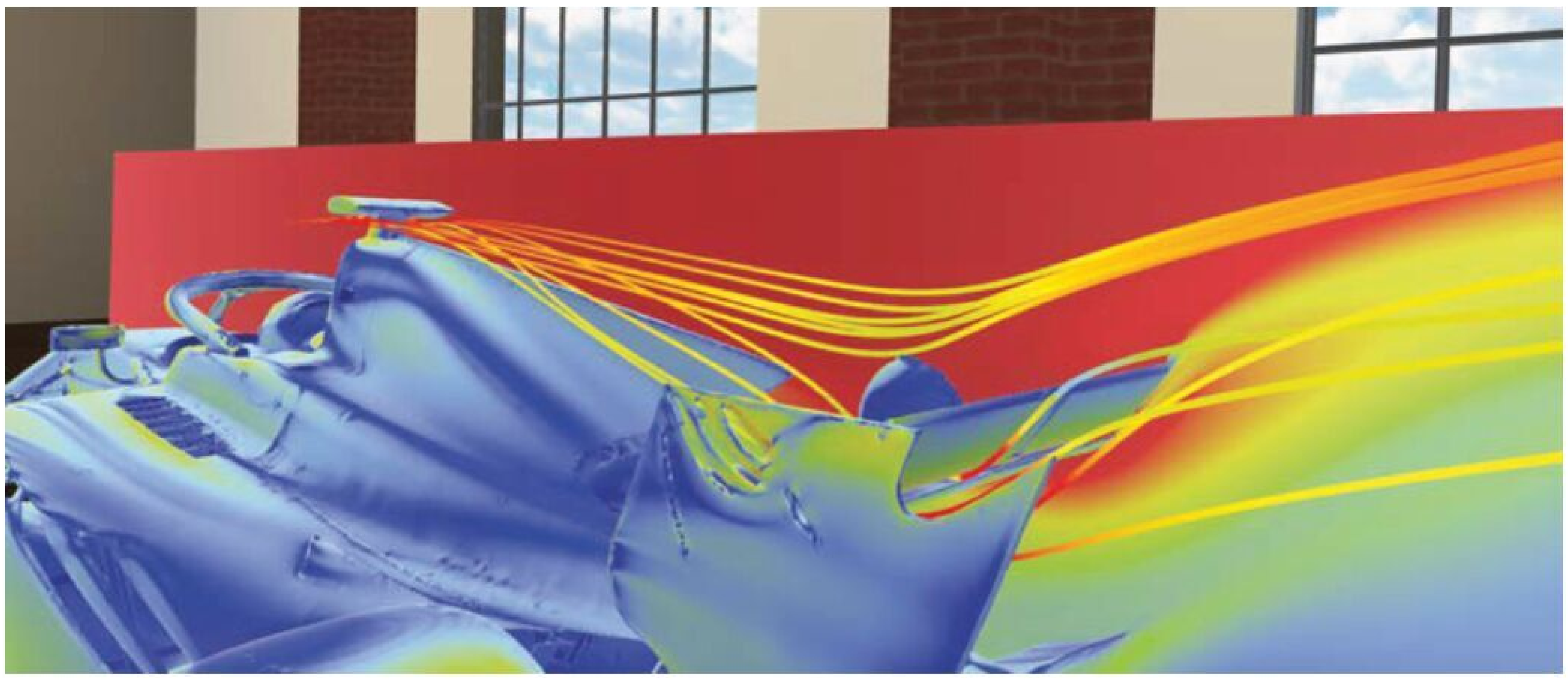


Figure 2: Section pressure plots and streamlines around the rear wing area. This was our baseline plot

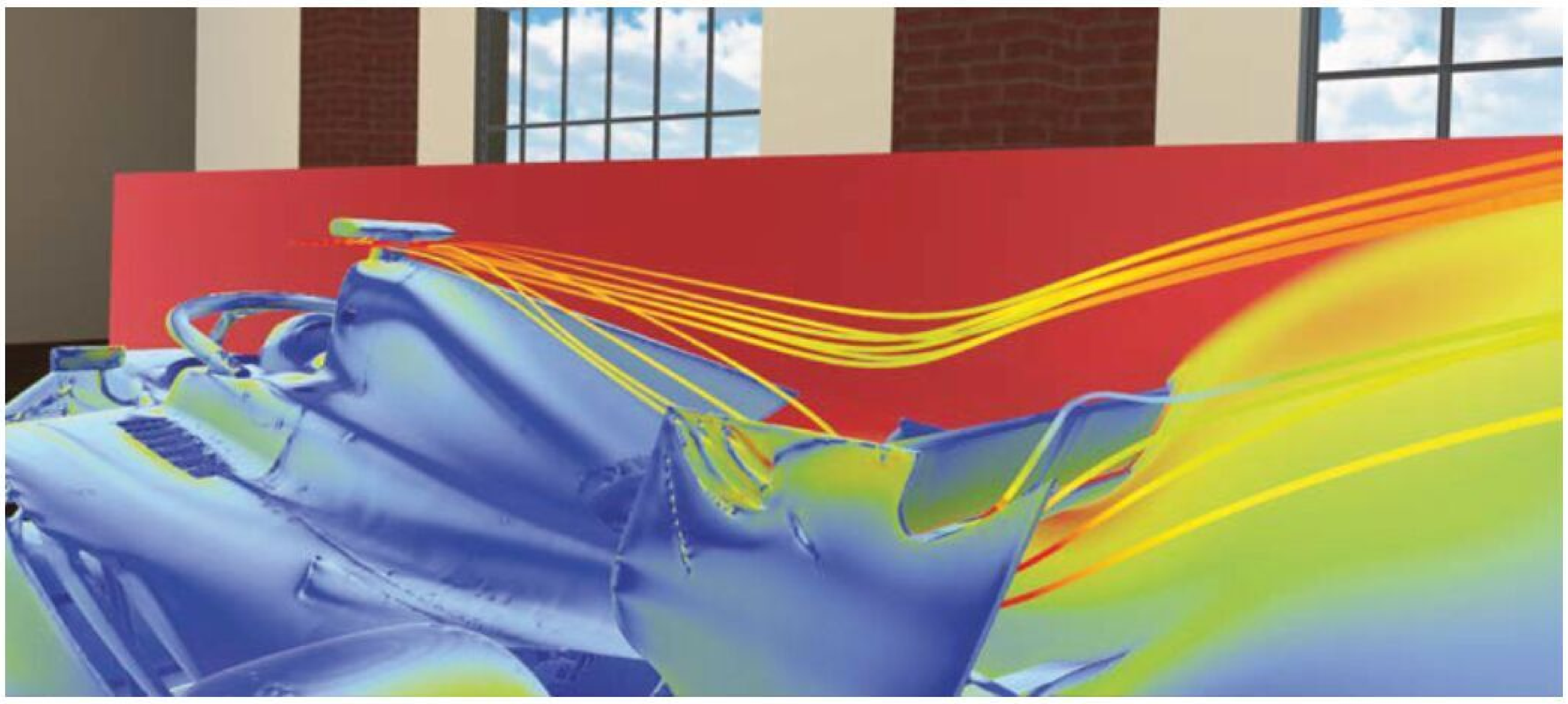


Figure 3: And the same pressure plots and streamlines viewed with a different wing configuration

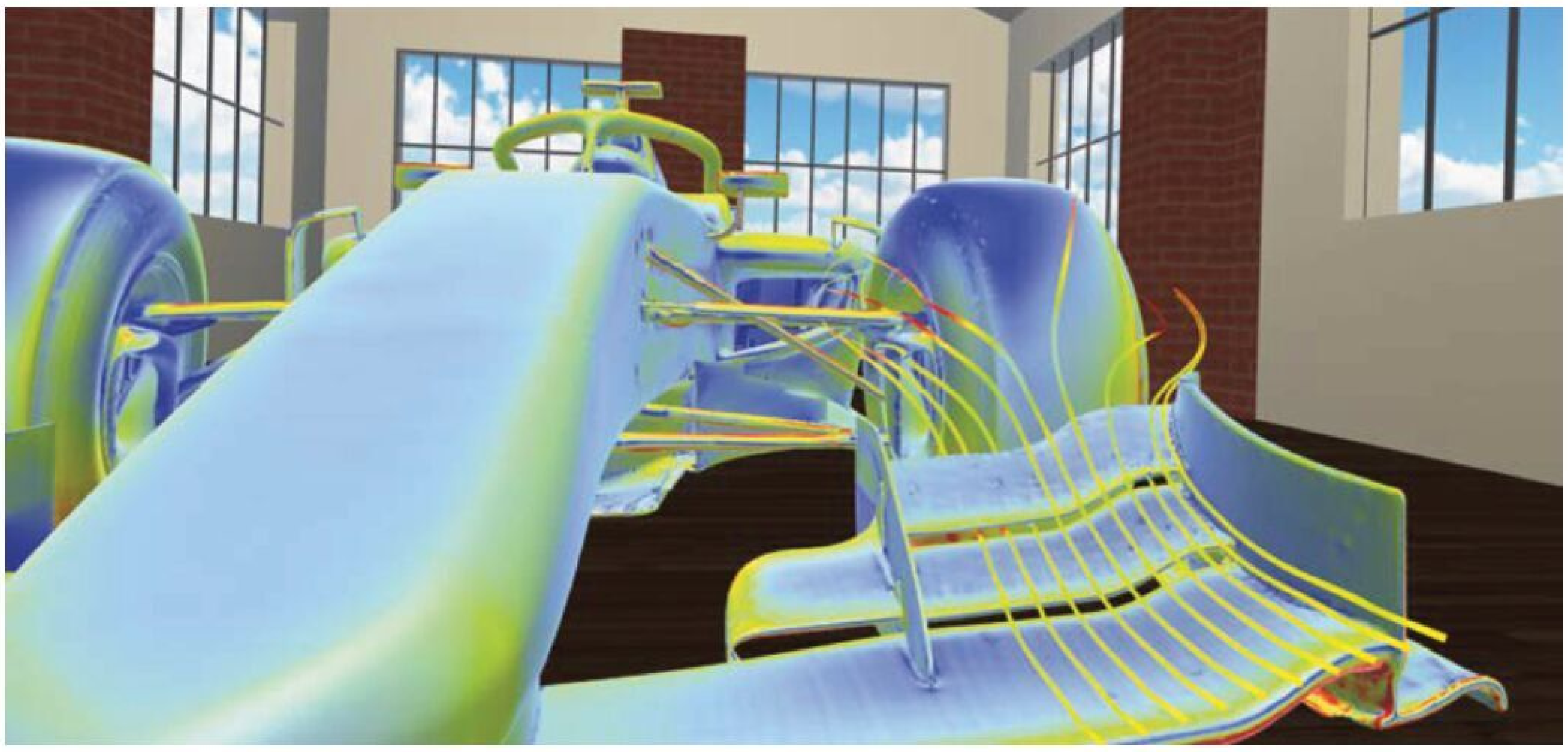


Figure 4: Baseline front wing streamlines, showing flow into the brake ducts and over the front tyres

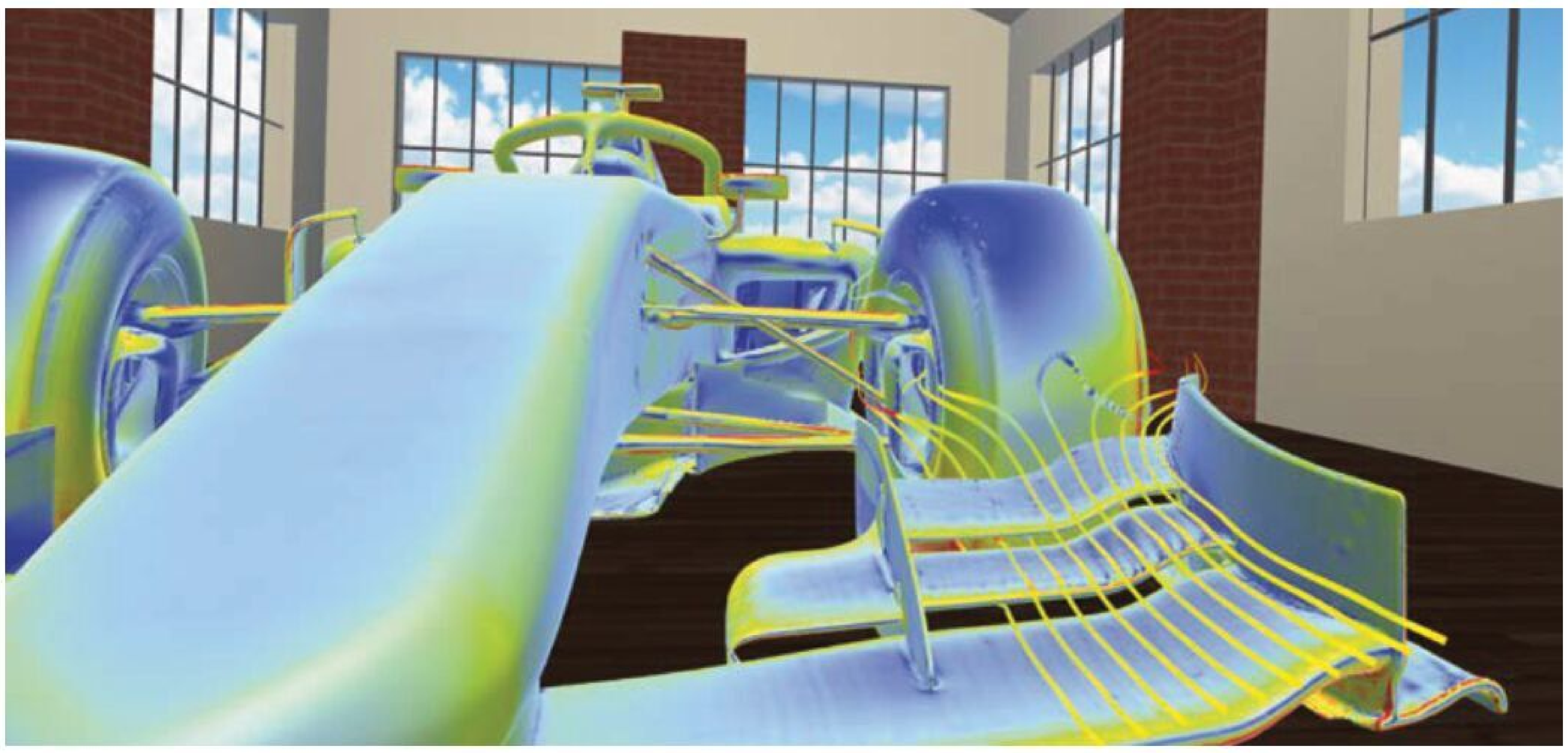
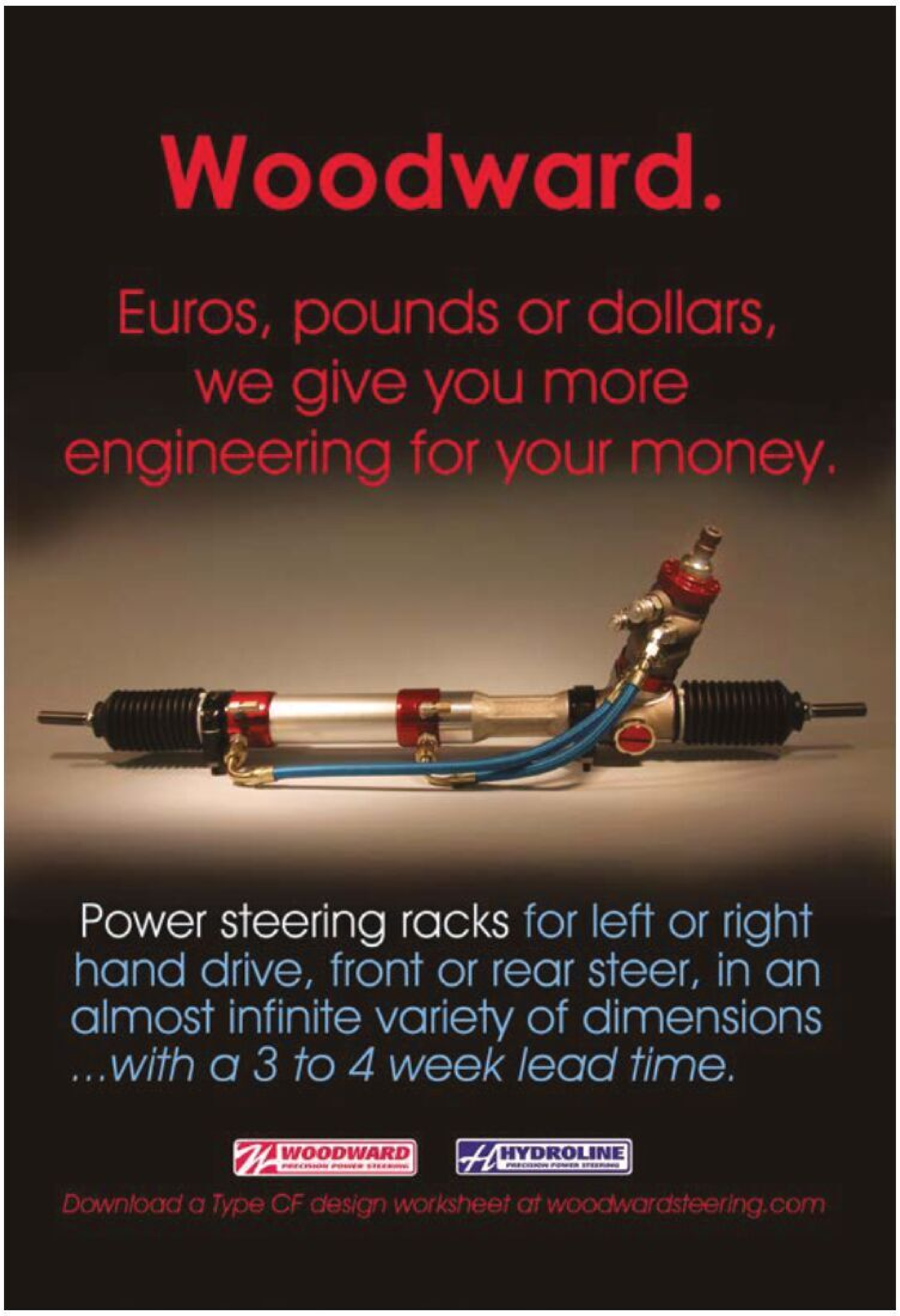


Figure 5: The same front wing streamlines but with a swap to a different wing design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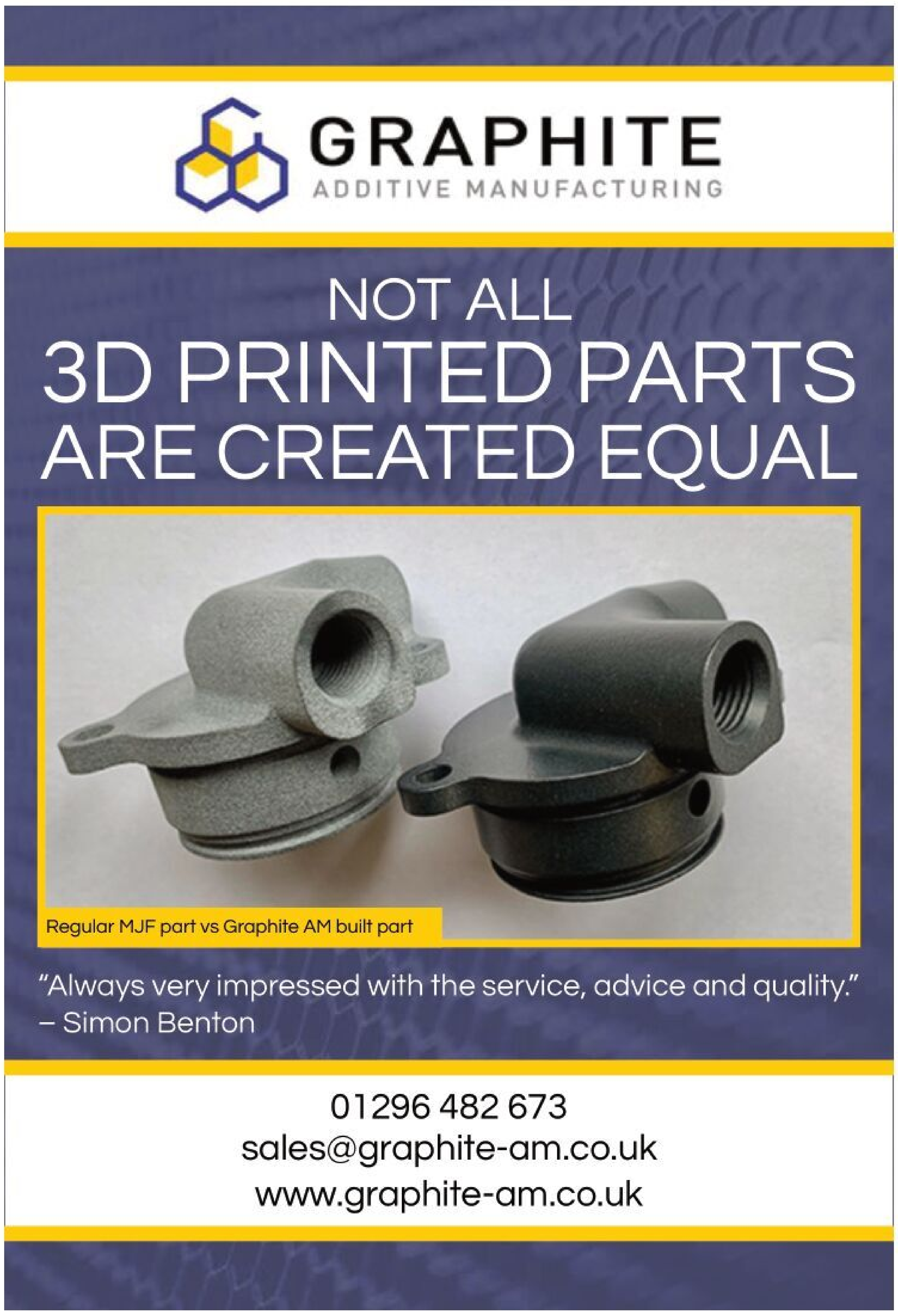
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The immersive nature of a set of VR goggles seems to help the brain clearly capture the flow interactions, and assist the mind's ability to process them

This is where VR starts to pull ahead of how we view CFD data on a regular desktop.

Just like eyeing up alignment of body panels in a workshop, you find yourself walking around the car, squatting down between imaginary suspension wishbones and hovering over non-existent tyres to get just the right angle to see what you want. In this case, looking at how a set of streamlines is interacting with your latest modification to the car's body, and all from the optimum viewing angle.

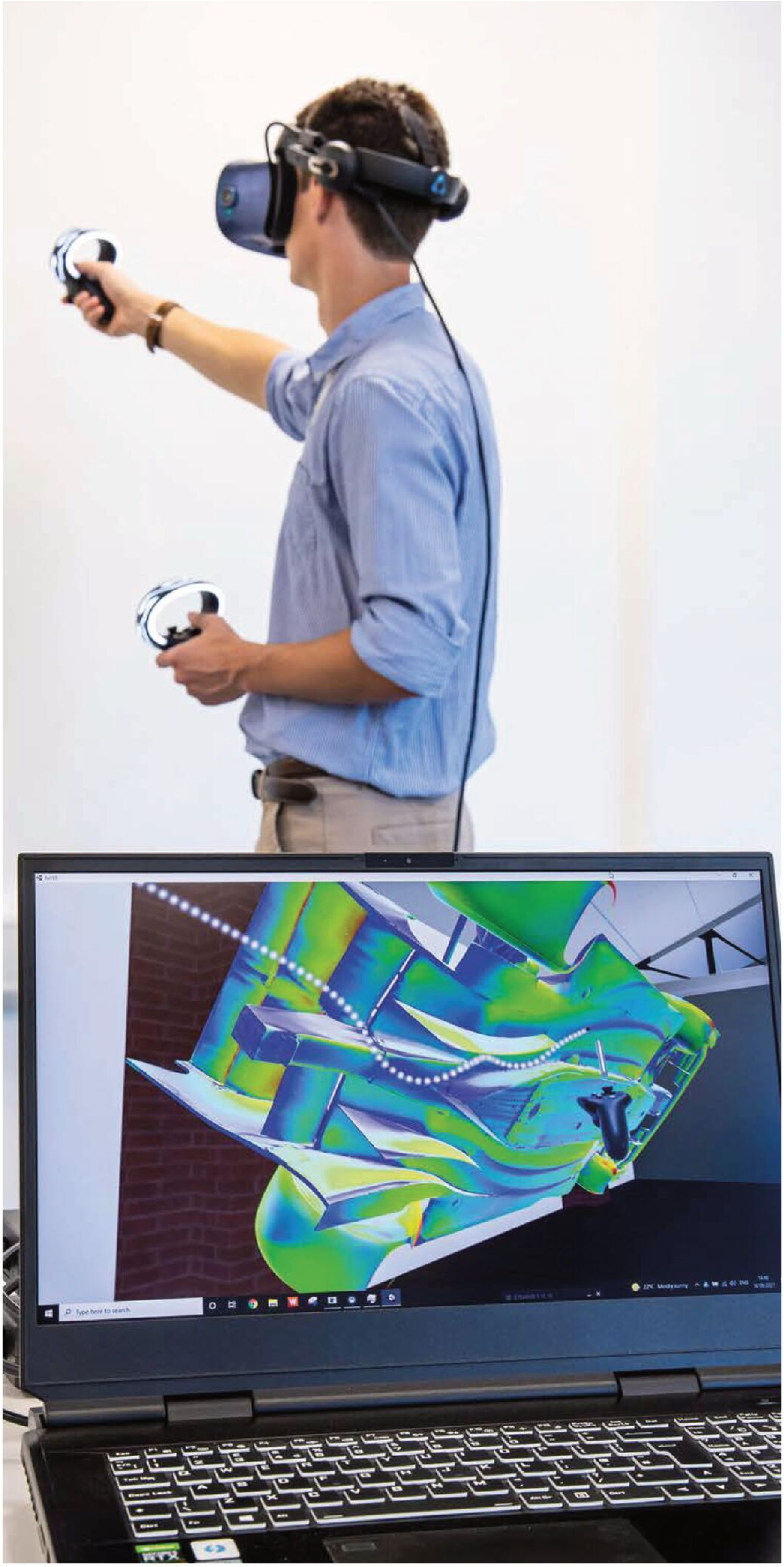
It should be noted, although the Vive Cosmos headset only has a 110-degree field of view, the immersive nature of a set of VR goggles seems to help the brain clearly capture the upstream and downstream flow interactions, and assist the mind's ability to process them. This is something a 2D screen will never quite achieve, no matter what graphics card or number of screens are being used.

Crossing the divide

Finally, we fully cross the divide between the real and virtual worlds with the use of the smoke wand. In a wind tunnel, the use of smoke is essential to capture flow attachment and direction over the downforce producing surfaces, the biggest of which on most racecars tends to be the floor. But due to the low ground clearance of many racecars, when viewing flows in a wind tunnel we either have to use a camera to look underneath, all the while being careful not to disrupt the flow, or get on our hands and knees trying to view the flows first hand. Now, though, we have a third way, the ReVED way.

Just as we set a streamline up in free space earlier, we can do the same with a virtual smoke wand, and then pick the whole car up and see exactly how it travels along the floor from barge board to exit of the diffuser, as shown in **Figures 6** and **7**. With the car 'floating' in space, you can then scroll back through the menu and switch the various options on or off, or start new smoke trails and streamlines wherever you see fit.

It has to be said that being able to view 100mph streamlines, oil flows and pressure



Turning on the virtual smoke machine, we can see flows along the underside of the car, with the model hovering above our head

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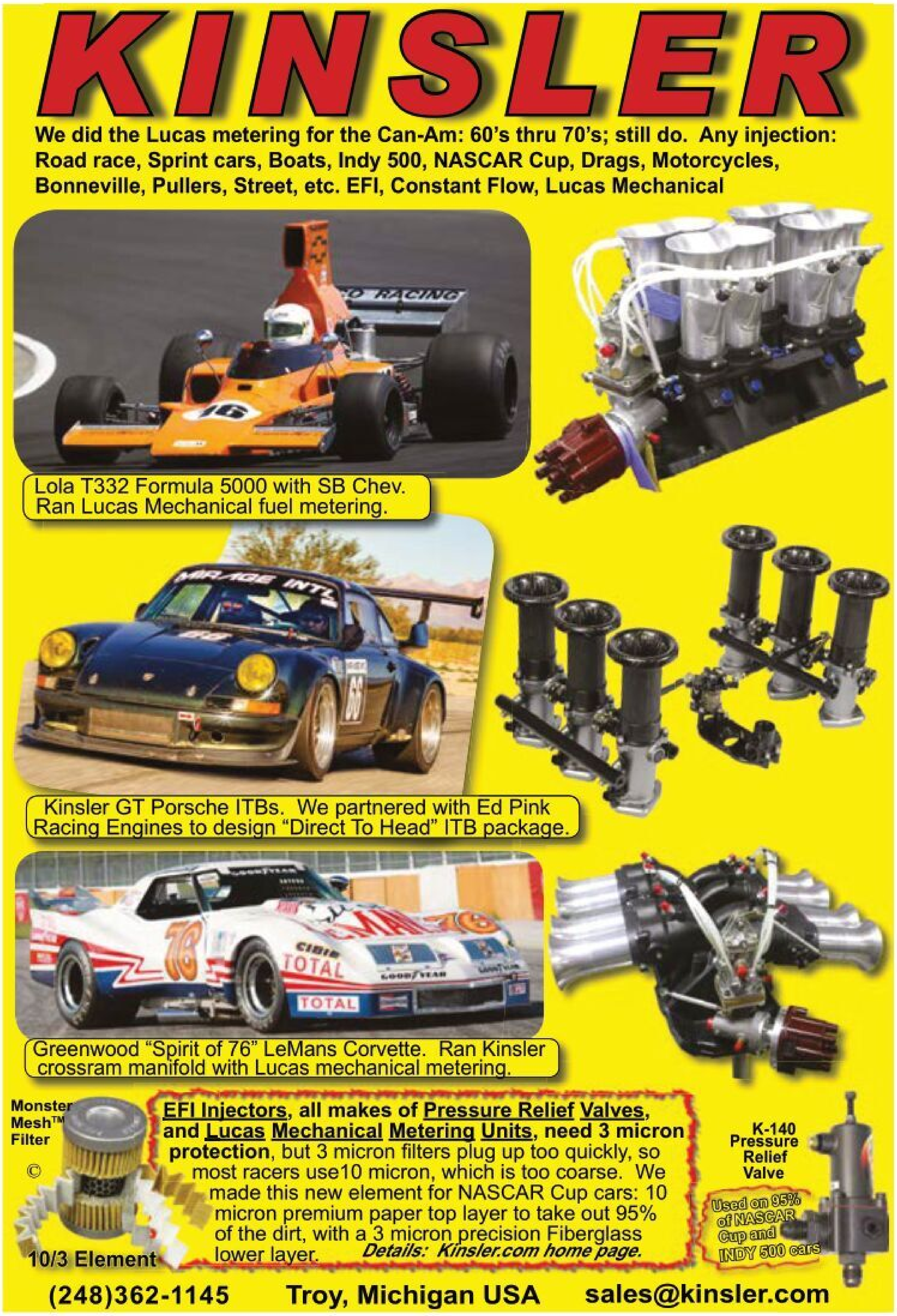

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plots under the floor of a full-size racecar while it floats above your head is a fantastic experience for anyone who has ever used CFD software or worked in a wind tunnel. Admittedly, it is not as detailed as seeing a smoke plume in a wind tunnel, and the smoke does not disperse and thin out as it separates over some surfaces, but as an interactive guide to show a client why you are working on a front end plate to improve rear downforce, for example, it is a great visual aid to ease understanding.

User interfaces

Currently, the software is set up to only allow a single user interface, which means this could only be used one-to-one with a client and CFD engineer, but the technology is continually improving.

When studying complex geometries and flow structures, there is certainly a benefit to this system and, for regular users of CFD who analyse simplified sections of a model and are used to viewing and interpreting post-processed data plots on a flat screen, it provides a marginal improvement.

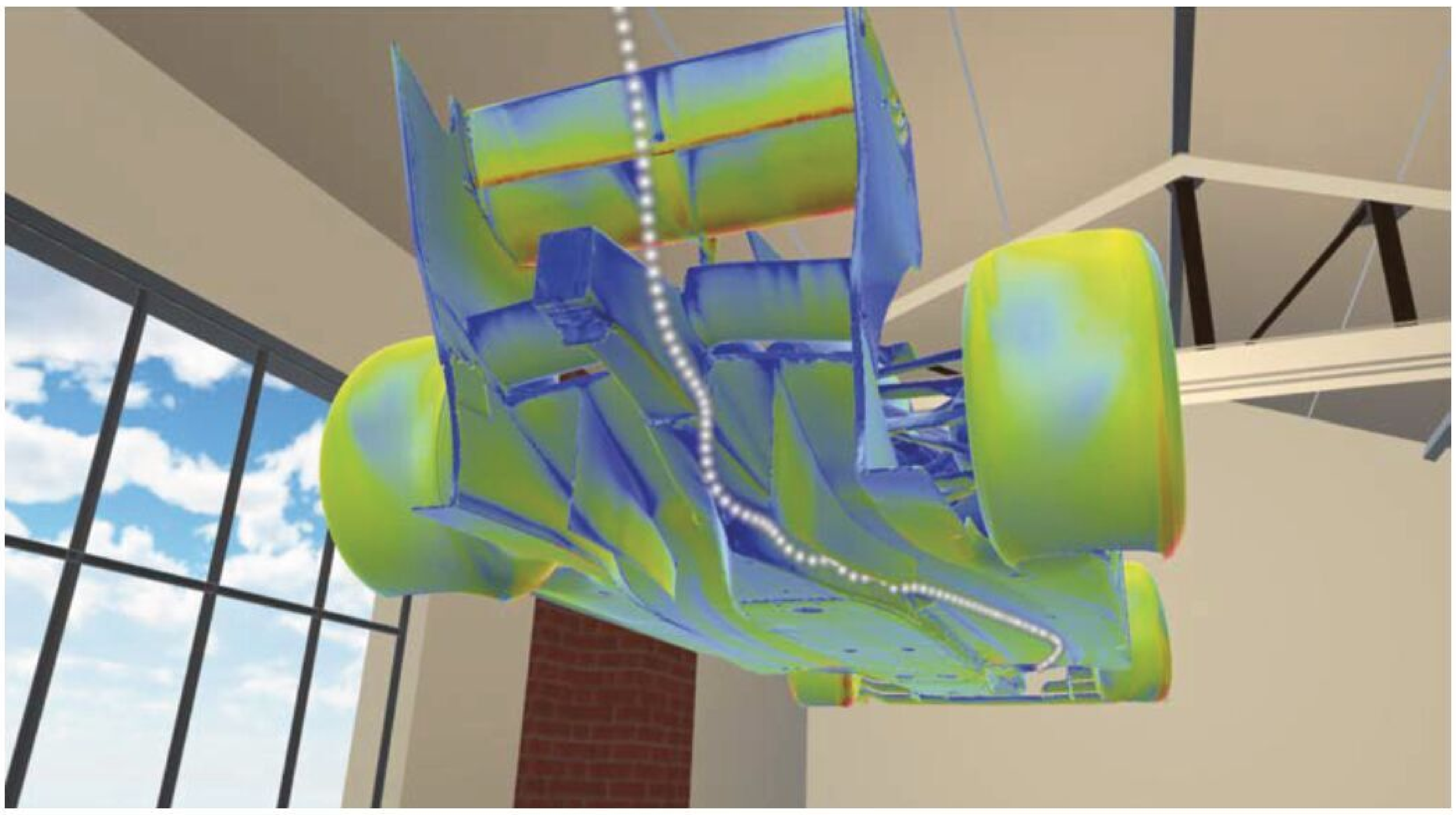
The additional cost of a VR headset (around £699 for the one used here) would likely give you an easier time when reviewing the complex flows around a racecar, and help with initial understanding of a new system or component design.

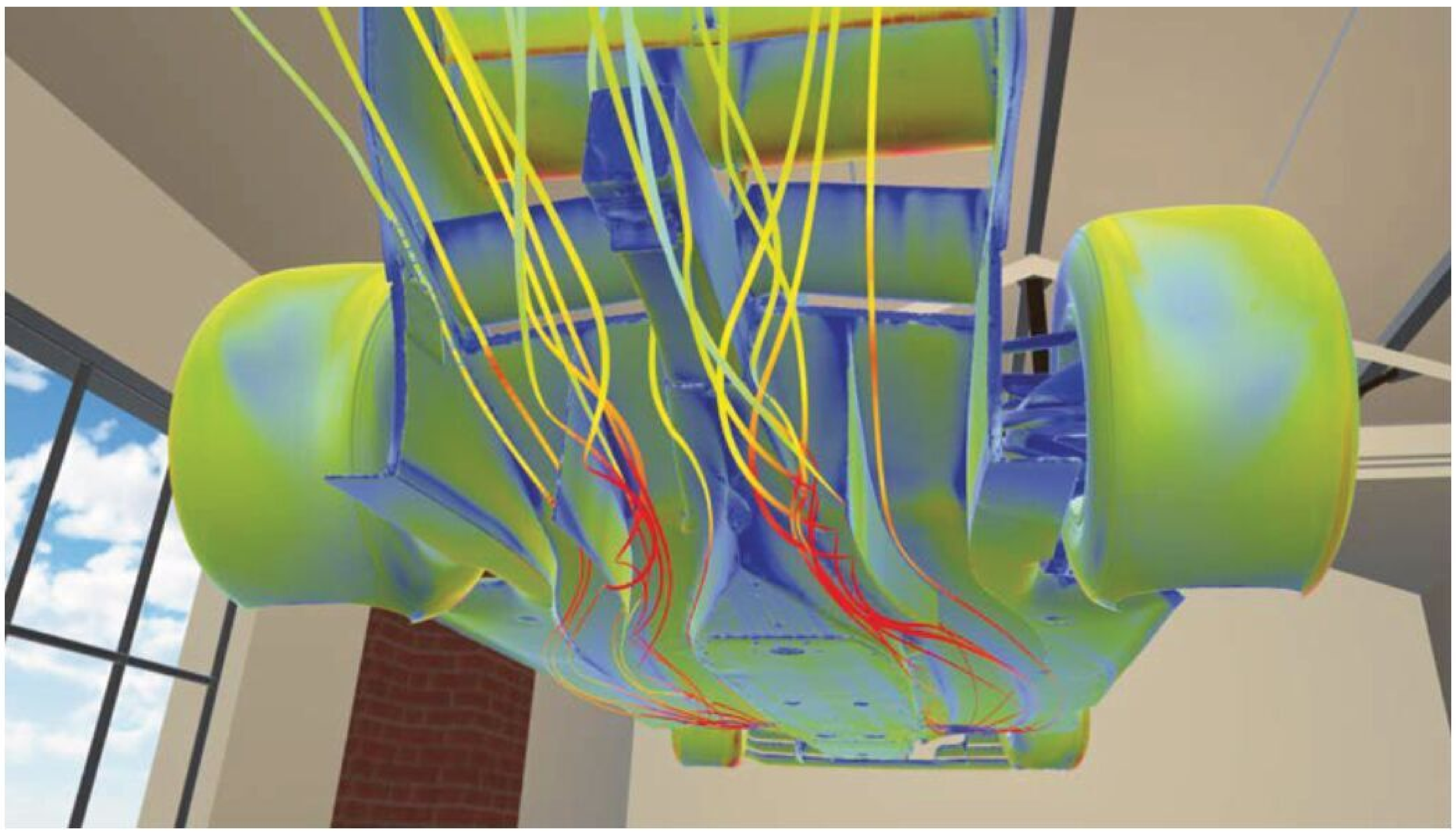
This leads us on to the real point of the ReVED system. TotalSim and ReVED are planning on increasing the amount of user interfaces in the future, and this will be a significant evolution in the way we hold inter-departmental meetings. Currently, when developing a new car you have the chassis engineers, powertrain design team and stylists all in a meeting awaiting the aerodynamics review. Usually, this entails hours of sitting while the aero team reel off pages of 2D screenshots on a projector, interspersed with the various departments stopping the presentation to ask why the airflow cannot be better in that area, or explaining, with the use of pen and paper and rough sketches, how the design could be modified.

With the ReVED system, all teams could meet in a virtual workshop (particularly pertinent in our new Covid-regulated conditions), stand and walk around a full-scale model of the car in the world's quietest wind tunnel running at 100mph+ and discuss the same issues. At the same time, teams can demonstrate, virtually, how the three-dimensional bodywork could look and what flows they are hoping to utilise.

And this is the crux of the matter. This system is not meant to revolutionise CFD analysis, or usurp the use of wind tunnel and track testing. It is meant to improve the way we view the data and our ability to communicate findings. Being able to roll a full-size racecar onto its back so a group of engineers can look at the smoke trails going over the floor in real time makes the whole design process more involving and stimulating.

Add in the fact it costs time and money to have engineers travel to wind tunnels, this system helps reduce learning time, which can only be a good thing with the ever-increasing pressures on budgets and project schedules.





Figures 6 and 7: Floor flows are not as detailed as seeing a smoke plume in a wind tunnel but, as an interactive guide to show a client, or to discuss a design detail with a team of engineers, this system has huge potential

This system is not meant to revolutionise CFD analysis, or usurp the use of wind tunnel and track testing, it is meant to improve the way we view the data and our ability to communicate findings

Future developments

With the current rate of development in the field of virtual reality, being driven hard by both gaming and industrial sectors, we could easily see the next decade provide some incredible new ways of viewing and sharing engineering data. Imagine an entire interactive wind tunnel that allows users to move components on a model as if working on a real car, giving them instantaneous data on changes, all while sitting in different offices around the world. Okay, so we are rapidly crossing the divide between fantasy and reality here, but the engineering capabilities we have witnessed on the big screen have already started flowing into our everyday lives. To paraphrase the words of Jean-Luc Picard, captain of the USS Enterprise; '*Engineering, make it so.*'

Racecar's *thanks to TotalSim and George Maxted and Henry Pang for their time. For more information, see www.getreved.com*

Craft work

If it's highly skilled, hands-on work you're after, then fabrication could be just the thing.* Racecar *spoke to Joe Lofthouse to find out more about making and mending in motorsport

By MIKE BRESLIN

Bresmedia

Joe Lofthouse has been a fabricator for almost 20 years, and during that time has made parts for use in most motorsport disciplines

Both MIG and TIG welding are used in motorsport, but TIG (shown here) has developed into an art form

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Some fabricated racecar parts can be so beautifully crafted that they could easily be mistaken for sculpture and exhibited in an art gallery. Which is a fitting testimony to those working at the top level of this profession. People like Joe Lofthouse, for instance, who has been involved in high-end motorsport fabrication for close to two decades, in that time creating and welding parts for just about every major motorsport discipline.

Lofthouse is now manufacturing director at fabrication and race preparation outfit, Venture Engineering (see box out on p78), but on most days can still be found wielding a welding torch, a craft he first came to enjoy while taking a motorsport engineering course at Banbury and Bicester College (then Oxford and Cherwell Valley College) in the early 2000s.

'The course started off as very generic engineering, where you're learning all aspects of motorsport,' Lofthouse remembers. 'Then after about six months, they said we had to specify what we wanted to do, and so I chose welding. That meant once a week we had a day in the bays getting welding experience.'

Lofthouse then left the course to take up an apprenticeship at F3 team, Alan Docking Racing, where he was involved in its customer fabrication business, honing the techniques he uses to this day.

Practice makes perfect

'I could already weld, so I wasn't going in completely green,' he says, 'but most of the real learning started when I got the apprenticeship. I used to stay on after work just to practice welding. It was all aluminium, that was what they did, and I was very keen to do the interesting motorsport bits. By the time I'd finished my apprenticeship, I was doing the Prodrive Subaru WRC and Group N radiators, intercoolers and bits and pieces like that, and I absolutely loved it.'

Prodrive became his place of employment in 2012 and, through the motorsport engineering giant, he became involved in WEC with its Aston Martin programme.

There's only so much a fabricator can do over a race weekend – they tend to only be called upon when things go wrong

'I did quite a few years in World Endurance, where I was a travelling fabricator,' he recalls. 'Half the time you're in the workshop, building the cars over the winter, and then in the race season we would be travelling all around the world.'

As there's only so much a fabricator can do over a race weekend – they tend to only be called upon when things go wrong – they will often be required to add another string to their bow. So, while at Prodrive, and later at the ill-fated Nissan GT-R LMP1 project in 2015, Lofthouse also worked as a refueller.

A fabricated Williams FW07 oil / water heat exchanger, which is identical in every respect to the original. It features an internal oil cooler core with water jacket

Instagram-worthy (!) detail of TIG welding on a wishbone from a Dakar racer. It is made of extremely heavy duty 15CDV6 steel with over 3mm material thickness

Old school fabrication is a major part of historic race preparation. This is Lofthouse's work on a 1970 McLaren M14a oil tank and breather pot

There is still always a chance that a quick fix might be required during a race weekend, though, and so Lofthouse has to be ready to dip into any other role required. 'You basically take a minimum amount of kit, so there's always a little fabrication area set up,' Lofthouse explains. But it's not just the kit, sometimes ingenuity will be needed, too.

'During the Rolex 24 at Daytona one year, the gearbox cradle in the rear of the Aston Martin cracked. When you race there, your base is the truck. There are no garages, and we didn't have time to get the car back to the truck where all the kit was.

'But we managed to get over the wall into the car park and we borrowed a MIG welder from somebody, but he didn't have a mask, so I was in the car with the MIG welder, shutting and opening my eyes as I worked, yet I managed to weld it up and the car finished the race.

'When we got back to Prodrive, they took the part off and hung it in the office because it looked so awful!'

The Nissan LMP1 was one car that called for a great deal of trackside fabrication during Le Mans, as Lofthouse remembers. 'The rear wishbone was tiny,' he says. 'It was like half-inch tube, because it was doing nothing, the car being front-wheel drive. But they kept breaking and we ran out of spares, so we were actually making wishbones in the truck during the course of the race.'

Making things is, of course, the very meaning of fabrication. But in the motorsport context it's fair to say it is a dying aspect of the craft, except perhaps where historic racing is concerned, an arena Venture Engineering is heavily involved in.

'When I was learning, it was all about pattern development, and marking out, and creating and forming,' Lofthouse says. 'Whereas now, most bits come in ready made. But if you go back 25 years and beyond, the whole car was fabricated. That's why we love working on the old stuff, because everything is handmade. It's a fabricator's dream.

'We always need the old school guys that can create something, or reverse engineer things, because of the classic F1 stuff we do. It's all one-off, so it's creating something from nothing, essentially, or replacing a part that's damaged. We don't have the time to fully scan parts, or draw them and go that way, it's more a case of there's that, now make it.'

The MIG and TIG of it

For motorsport applications, welding is either with MIG (Metal Inert Gas) or TIG (Tungsten Inert Gas) machines. 'We're probably 20 per cent MIG, and 80 per cent TIG,' says Lofthouse. 'MIG is where the wire is stored inside the machine and comes through the torch, so all you're doing is pressing a trigger. It's more entry level, and you don't need a massive skill set – although you do if you want to make it look nice and to do good welding.

'TIG is definitely more specialist. You have a foot pedal, and you have a welding wire in one hand and the torch in the other, all three doing a different thing at the same time, so

It's very much about practice. You won't find anyone who will just pick it up and be good at it, it's about that hand-eye coordination

it's very much about practice. You won't find anyone who will just pick it up and be good at it, it's about that hand-eye coordination.

'The TIG bead is very small, so it is much more precise,' Lofthouse adds. 'It is also strong, and it cools slowly, so makes a very strong joint. MIG welding has a large bead, which cools quickly, meaning it can be brittle in some applications, but it certainly has its uses. We use MIG more for heavy duty steel jobs.'

Low-carbon steel

These days, the steel of choice in motorsport is 15CDV6, a low-carbon material known for its strength and durability, and ease of welding. 'It's really versatile, really strong, easy to form and it doesn't need heat treating, so you just weld it and you're done,' says Lofthouse. 'Whereas with the old stuff, 4130, it's quite an exact process and you have to pre-heat it to a certain temperature before you weld it. You then have to let it settle, and then you have to get it post-heat treated. Then it can distort and you have to get it machined, so it's all a bit of a faff.'

But while welding high-end steel might be a little easier now, aluminium will still prove a challenge for many. 'People always think aluminium is the hardest to weld because, obviously, it's softer, generally thinner and it absorbs a lot of heat. You do have to be a bit more careful with it,' notes Lofthouse.

'But when I was at Docking's, all we did was aluminium. So, coming from there I found it quite easy to go the other way, though people often find it more difficult to start on steel and then weld aluminium.

'It depends on the application, but with steel I guess you can get away with a bit more, whereas with aluminium you do have to know what you're doing in terms of the settings, otherwise, particularly with radiators and the like, you can get into a bit of trouble.'

Machine familiarity

The equipment used is as vital as the skills acquired, and Lofthouse firmly believes that when it comes to welders, using a machine you're familiar with has its benefits. 'We've got six Miller inverters, and they are all the same, but I've got mine,' he says. 'It's about feel, and maybe it's in your head, but there's so much invested in it with your coordination, the way it runs, the way you've got it set up, that you don't want to go to someone else's machine and have to start again. Even if we get a new unit in, I don't want the new one, I want mine.'

While keen not to overstate the matter, Lofthouse admits the work can be physical, especially when you're folded into a car trying to weld around a rollcage, but much of the fabricators' work is done on the bench.

And it's not all car parts either. A motorsport fabricator will spend time making pit equipment, or other less glamorous items.

'We do this for a lot of F1 teams,' Lofthouse says. 'It is all stainless steel, and brightly polished. The teams are constantly developing new ideas and, when they have new bodywork, that can change things like the bodywork stands. In the F1 pit lane, no one ever puts bodywork on the floor, they'll put it on a little frame, and we make all that.'

Looking the part

Sometimes, it's not even clear what they are being asked to make. 'A little while ago we did a piece like a tray, and it had this very extravagant mechanism to spin round. Only later we found out it was for someone to put their laptop on when they're starting the car!'

Joint Venture

When *Racecar* visited Venture Engineering in June, it had just moved from its original site in Bourton-on-the-Water to a brand new, 15,000sq.ft facility in the suitably-named Tungsten Park, Witney, Oxfordshire, deep in the heart of Motorsport Valley.

It's a smart, ultra-modern facility, with enough space to align with the company's ambitious plans for the future.

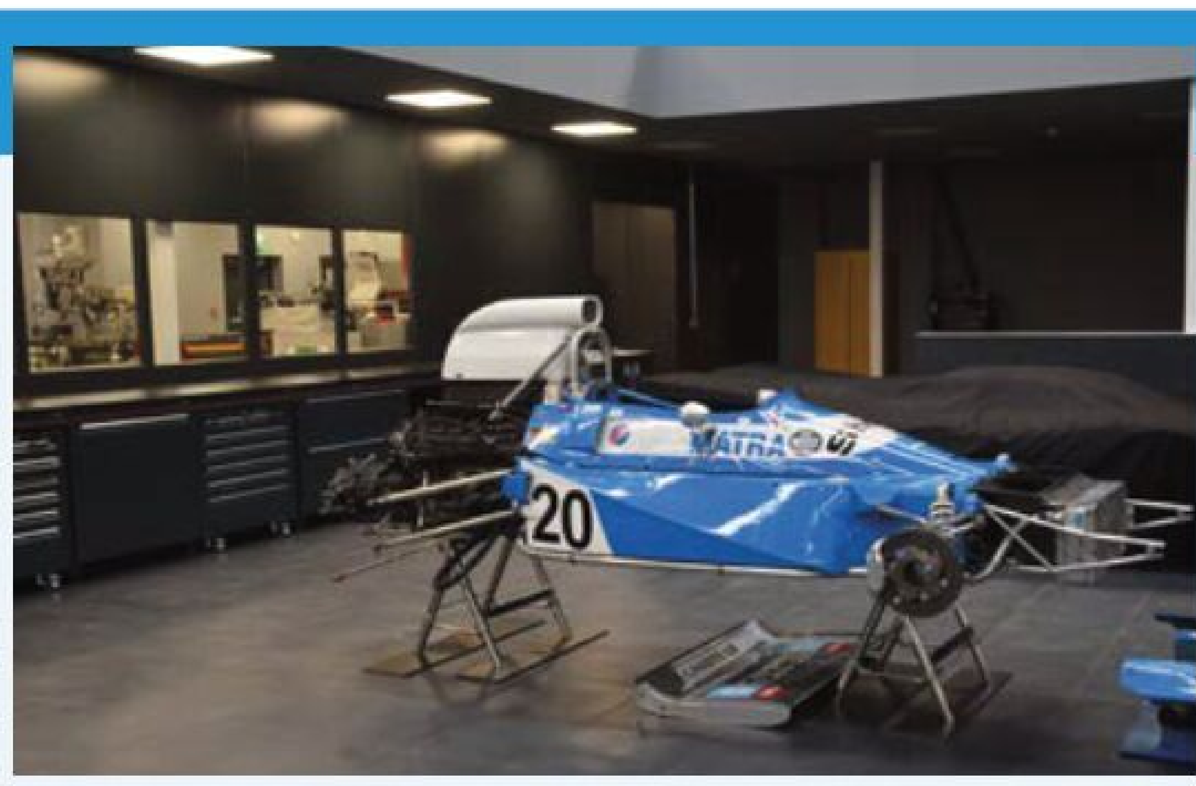
Not that Venture hasn't done plenty already. It was set up in 2015 by three Prodrive employees, former Aston Martin Racing engineer Stuart Gale, purchasing manager Adrian Perkins and fabricator Joe Lofthouse. It was initially to be just a fabrication concern, but now the company is pretty much a one-stop shop for all motorsport engineering solutions.

'The business was 100 per cent fabrication to begin with,' says Lofthouse, 'but very quickly we realised we had more skill within the building, so why not use it.'

Those skills include design, using proprietary 3D CAD, and race preparation, running everything from Historic F1 to LMP and GT. And, of course, fabricating parts, for both race teams and OEMs, in its state-of-the-art machine shop.

Clients include the ROFGO Collection (which celebrates and competes with an armoury of Gulf Oil-sponsored historic racecars), many current F1 teams and Formula E (fabricating boxes to transport batteries), while the company was also heavily involved with Multimatic in the build of the Ford GT racecar.

Even a well-known boat builder has used Venture, for which it fabricated thick-walled aluminium electronics boxes, which were designed for, of all things, a submarine.



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Ex-Chris Amon Matra MS120C in the new Venture Engineering base in Witney, UK. The machine shop can be seen in the background

Of course, in high-end racing *all* equipment must look the part, however mundane, and that's where pride in your work comes in, as Lofthouse explains: 'I couldn't say I've ever made anything that I'm 100 per cent happy with, because I'm always trying to be better. But everything we do is always fit for purpose, otherwise it wouldn't leave here.

'It's going that extra mile that's important. Where someone picks it up and says, "That's good." That matters. We take a lot of pride in the work we do. And I think you get that with welding, because it's a real skill.'

And being a learned skill, there's a bit more to becoming a motorsport fabricator than schoolwork. The advice Lofthouse would give any aspiring welder / fabricator is to get hands on, at every opportunity.

'I was never hung up on school. If you want to be working in a hands-on job like this, you're not going to get any further up the ladder by getting a degree. It's much better to get experience. For me, the moment I got a job was the moment I started learning. There is not a lot you can learn in a classroom about something you need to do with your hands. So get the experience. It doesn't have to be paid, just get yourself into a team at the weekends, for example.'

You're not going to get any further up the ladder by getting a degree. It's much better to get experience

That said, Lofthouse does see the value of motorsport engineering courses. 'The fact that I went to college meant the big teams and companies were actively going there to say, "Have you got anyone that's interested in this work?" That's how I got started.'

But however much experience you gain, practical or academic, it will count for nothing if you do not have that pride in your work. 'A lot, I think, comes from pride, and pushing yourself further. So always looking to progress, and never saying 'that'll do'. If you want to carve a career in motorsport, that's a good attitude to have, because people *do* care about what things look like.'

And if a piece of your fabrication work happens to look like sculpture, then you're not going too far wrong.

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A motorsport fabricator will often be called upon to make pieces of pit equipment, such as these polished stainless steel chassis stands

More F1 pit equipment. This is part of a TIG-welded assembly designed to lift the chassis when the rear end of the racecar is removed

Of slip and grip

The fundamentals of vehicle dynamics – part two

By DANNY NOWLAN

'The four footprints of your tyres are the only thing that lie between you and St. Peter'
– Mark Donohue.

As far as I am concerned, if you want to know what vehicle dynamics is all about for racing purposes, the above sentence nails it. Mark Donohue was one of the most astute students of the game, who regretfully left the party way too early.

Last month, in part one of this series, in order to understand what Mark was getting at in this sentence we had to understand tyre loads, where they came from and what generates motion in the chassis. We did that by studying the quarter car and beam pogo stick models. Now we understand this, we can bring in some simple tyre models to know what to focus on in vehicle performance. That is what we will be looking at this month.

But first, I need to get a pet peeve off my chest. If I can put my finger on one of the many areas where vehicle dynamics go pear shaped for so many people, it's believing **Figure 1** applies to everything.

The inherent assumption with this diagram is that slip angles are negligible. From this, we get the derivations for Ackerman steering and turn radius, but there is one small problem with this. It all works fantastically when you have to deal with Aunt Maude parking an SUV in a supermarket car park, or when we want to engineer Ben Hur in the local chariot race so we can get a ticket to the ultimate toga party. However, the millisecond you start introducing slip angles, all assumptions in **Figure 1** break down very quickly.

Figure 1: Car turning circle with no slip angles

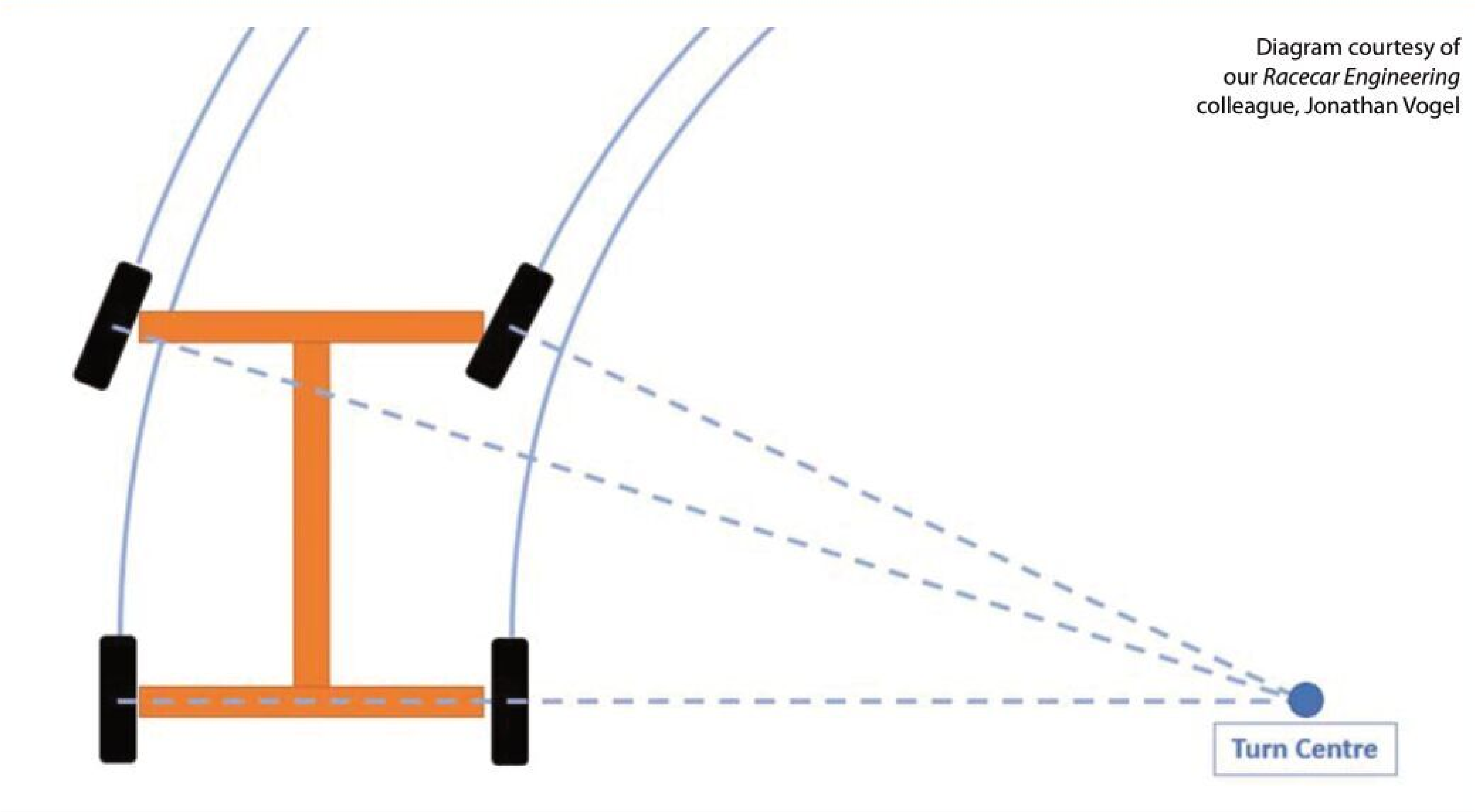
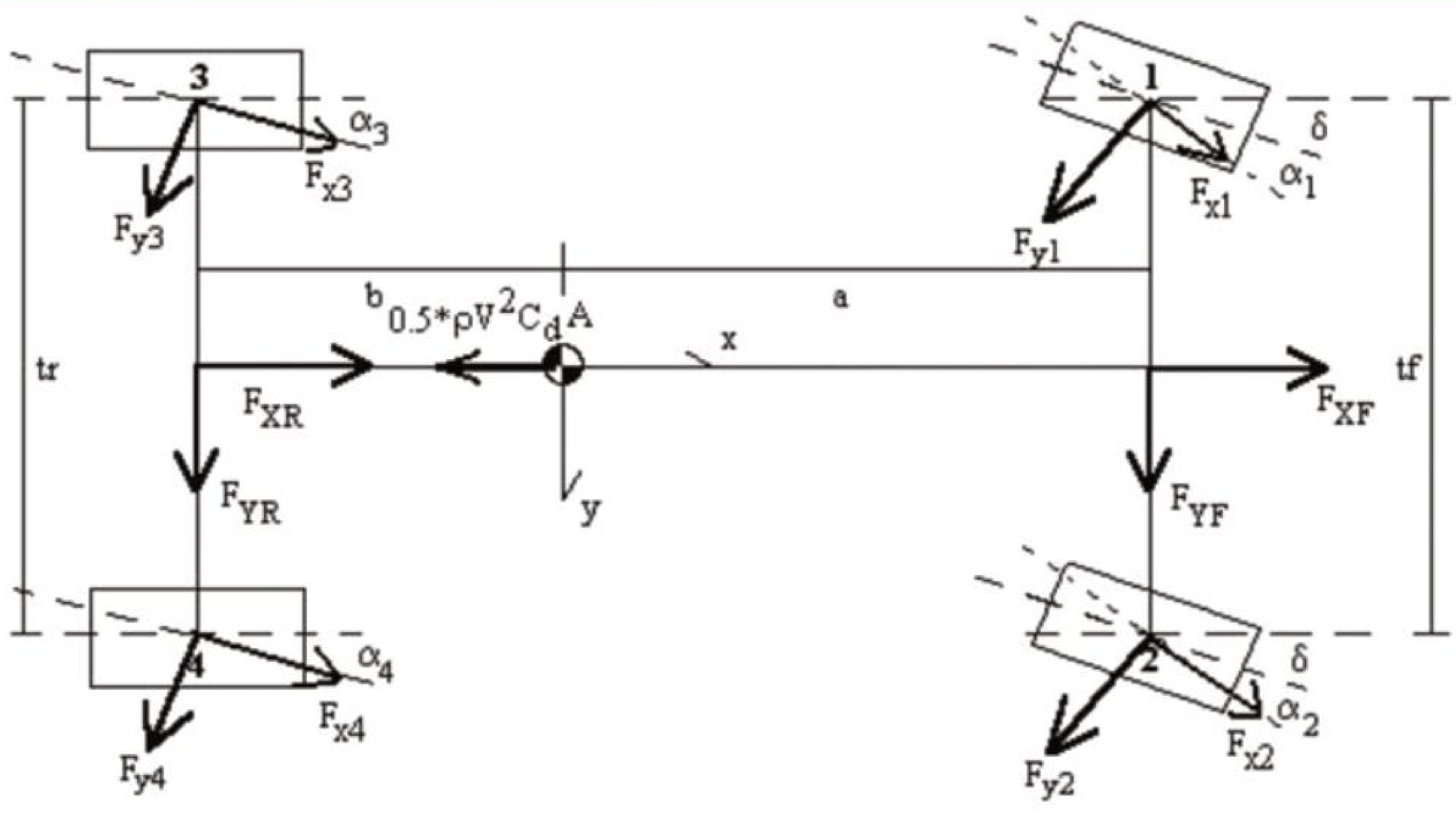


Diagram courtesy of our *Racecar Engineering* colleague, Jonathan Vogel

Figure 2: Diagram of forces acting on the racecar



Where,

F_{y1} to F_{y4}	lateral forces of tyres 1 to 4 respectively	F_{YF}	lateral force applied at the front axle
F_{x1} to F_{x4}	longitudinal forces of tyres 1 to 4 respectively	F_{YR}	lateral force applied at the rear axle
α_1 to α_4	slip angles of tyres 1 to 4 respectively	F_{XF}	longitudinal force applied at the front axle
δ	steer angle of the front wheels	F_{XR}	longitudinal force applied at the rear axle

Primary input

The reason I mention slip angles is they are the primary input that generates tyre force, which turns the vehicle and provides lateral forces for the racecar so it can corner. The fundamental mechanism that manoeuvres the car are shown in **Figure 2**.

The tyre loads we discussed in detail in part one are applied vertically down for each tyre. To keep the discussion simple, we'll assume equal steer angles. However, extending the representation is straightforward and **Figure 2** makes it clearly obvious what needs to be changed.

All tyre forces are applied along the slip angle line. However, due to small angle assumptions, F_{XF} and F_{XR} may be visualised

Slip angles are the primary input that generates tyre force, which turns the vehicle and provides lateral forces for the racecar so it can corner

EQUATIONS 1-14

$$F_{XF} = F_{x1} + F_{x2} \quad (1)$$
$$F_{XR} = F_{x3} + F_{x4} \quad (2)$$

$$F_{YF} = F_{y1} + F_{y2} \quad (3)$$
$$F_{YR} = F_{y3} + F_{y4} \quad (4)$$

$$\alpha_1 = \delta - \frac{a \cdot r + V_y}{V_x + tf \cdot r} \quad (5)$$
$$\alpha_2 = \delta - \frac{a \cdot r + V_y}{V_x - tf \cdot r} \quad (6)$$
$$\alpha_3 = \frac{b \cdot r - V_y}{V_x + tr \cdot r} \quad (7)$$
$$\alpha_4 = \frac{b \cdot r - V_y}{V_x - tr \cdot r} \quad (8)$$

Where,
V_y sideways velocity
V_x forward velocity
r yaw rate

$$m_t(V_x' - V_y r) = F_{XR} + F_{XF} - \sum_{i=1}^{2}(\delta + \alpha_i) \cdot F_{yi} - \sum_{i=3}^{4}\alpha_i \cdot F_{yi} - 0.5\rho V^2 C_D A \quad (9)$$

$$m_t(V_y' + V_x r) = F_{YF} + F_{YR} + (\delta + \frac{\alpha_1 + \alpha_2}{2}) \cdot F_{XF} + \left(\frac{\alpha_3 + \alpha_4}{2}\right) \cdot F_{XR} \quad (10)$$

$$I_z \cdot r' = a \cdot (F_{YF} + \delta \cdot F_{XF}) - b \cdot (F_{YF} + \left(\frac{\alpha_3 + \alpha_4}{2}\right) \cdot F_{XR}) \quad (11)$$

Where,
m_t = total mass of the car
I_z = the rotational inertia of the car about the z axis

$$V_x r = a_y$$
$$a_y = \frac{V_x^2}{R} \quad (12)$$
$$\therefore m_t \cdot \frac{V_x^2}{R} = F_{YF} + F_{YR} + (\delta + \frac{\alpha_1 + \alpha_2}{2}) \cdot F_{XF} + \left(\frac{\alpha_3 + \alpha_4}{2}\right) \cdot F_{XR}$$

$$m_t \cdot \frac{V_x^2}{R} \approx F_{YF} + F_{YR} \quad (13)$$

$$F_y = fn(\alpha) \cdot k_a \cdot (1 - k_b \cdot F_z) \cdot F_z \quad (14)$$

Where,
F_y = lateral force on the tyre (N)
A = slip angle applied to the tyre (rad)
k_a = initial coefficient of friction
k_b = how the normalised coefficient drops off with load (1/N)
F_z = vertical load on the tyre (N)

References
(1) J Y Wong, *Theory of Ground Vehicles*, Wiley and sons, 1978

as acting along the longitudinal axis. Using small angle assumptions then, **equations 1** and **2** may be concluded.

Using the same assumptions, we can also conclude **equations 3** and **4**.

From the derivation presented in Wong[1], the slip angles are then found to be as shown in **equations 5-8**.

Equations of motion

We are now ready to construct the equations of motion of the racecar. To this end, what we will be doing is summing up all the lateral and longitudinal forces presented in **Figure 2** and **equations 1-8**. We will also be adding in the cross effect terms due to steering angles and slip angle effects.

Due to small angle assumptions, the slip angle and steer times multiply the individual lateral and longitudinal force components on each tyre. This will give us effects, such as cornering drag and yaw moment contributions due to braking and accelerating. Inspecting **Figure 2** and resolving forces and moments about the c of g, the differential equations of the racecar for lateral and longitudinal motion become as shown in **equations 9-11**.

Equations 1-11 will tell you everything you need to know about what the racecar is up to. This is the beating heart of vehicle dynamics, and what is shown in **Figure 1** turns into a subset of this.

Now, there are some immediate takeaways here. In the static case, V_y' is zero. So, using static analysis, we can write **equation 12**, where a_y is the lateral acceleration and R is the turn radius.

Where the slip angles are small, the approximation shown by **equation 13** does the job quite nicely.

I am the first to admit **equation 13** is far from perfect, hence my use of the word approximation. However, if you go through and run the numbers for tarmac applications, this is 90-95 per cent of your grip. For rallying / dirt / snow applications, this is 85 per cent of your grip so, as a starting point, **equation 13** is fit for purpose.

One further thing I'll add to this is to remember that if you are looking for perfection in calculations, you'll never get out of the car park. The goal of the type of equations shown here is to be a calculator to put some precision to your deliberations.

Tyre model

Now that we have established this framework, we need a simple tyre model to put some colour to it. The one we are going is to be using is summarised in **equation 14**.

Equation 14 is the normalised slip curve multiplied by the traction circle radius as a function of load. These elements are visualised in **Figures 3** and **4** respectively.

A couple of key observations about the tyre model are presented here. Firstly, the normalised slip curve is effectively the trigonometric terms of the Pacejka model. With the second order traction circle radius model, one of the implicit assumptions is we have incorporated camber effects into the initial coefficient of friction, k_a.

While this is not the perfect tyre model because we haven't taken into account pressure and thermal effects, if there is one thing I've learnt from the lap time simulation efforts in ChassisSim model, it's that models like this are excellent for correlation purposes. Also, as we are about to see, they light the way considerably to see what actually drives the behaviour of the racecar.

Model choice

Now the question is how we choose the right tyre model to use for our racecar. In terms of the slip curve, you can use any model you want, but that in **Figure 3**, particularly up to peak slip angle, is fit for purpose.

In terms of the k_a and k_b elements, I covered this in my 2015 article about creating tyre models from nothing. There, we used some data and some intelligent guess work to fill in the blanks. For those who want a refresher, Google ChassisSim tyre modelling from nothing and the link will come up.

With that out of the way, let's re-visit part one of this series for the tyre loads, as shown in **equations 15-18**.

For the total lateral force, there are some simple assumptions we can use to put all this information together. So, rather then solving for the total cornering speed using Boolean logic, and an iterative algorithm to solve for a given vehicle speed and corner radius, we can solve as shown by **equation 19**.

The beauty of all this is you can readily put this into an Excel spreadsheet. To make your life easier, assume a cornering speed, an aero load and a set-up to work out the lateral load transfer distribution and you are off.

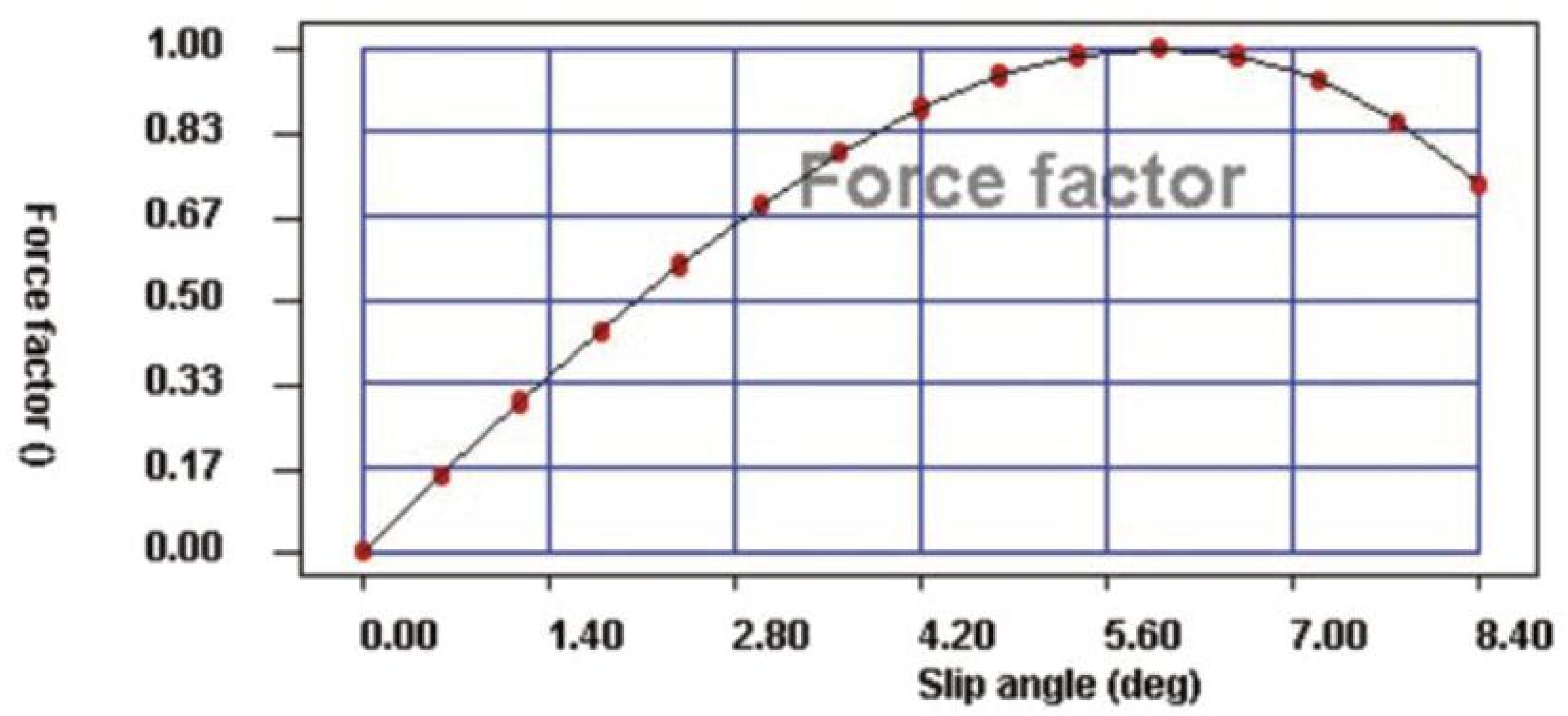
If you refer back to part one, where we walk through the calculation of the lateral load transfer / magic number, you can actually incorporate your set-up information. More importantly, as you start changing springs, bars, roll centres and aero, you begin to see what pays off with grip and identify areas of concern in the set-up.

Stability index

However, where this approach really pays off is determining racecar stability. Recall from my earlier magic number article we used the stability index to light the way, and for the stability index we had as shown in **equation 20**.

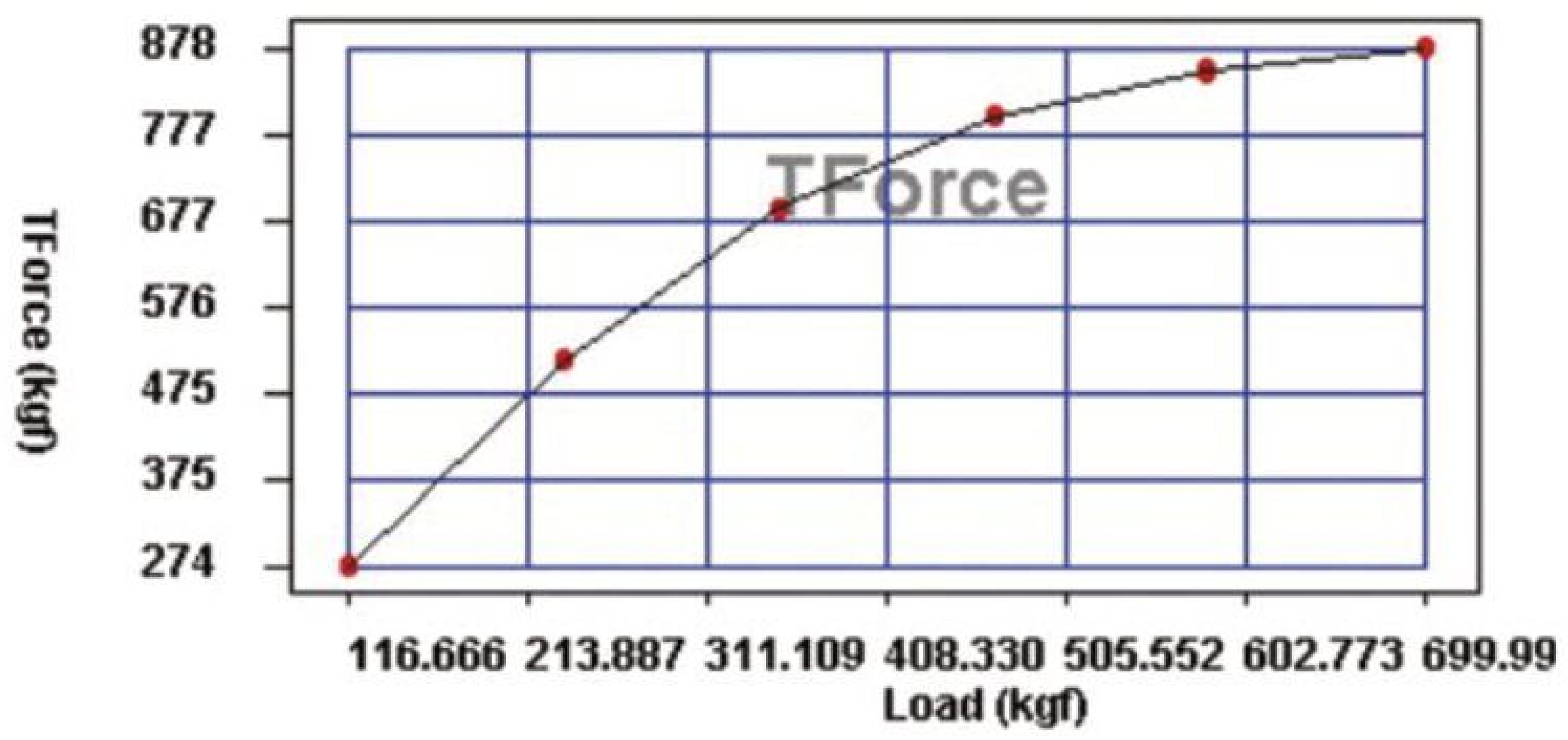
Our little assumption to make life easier here was to introduce a force balance and hold the rear slip angle constant at 85 per

Figure 3: A visualisation of the normalised slip curve



S angle	0.00	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00	6.60	7.20	7.80	8.40
FFact	0.00	0.15	0.30	0.44	0.57	0.69	0.79	0.88	0.94	0.99	1.00	0.98	0.94	0.85	0.73

Figure 4: A visualisation of the turning circle radius vs load characteristics



Load	116.666	233.331	349.997	466.663	583.329	699.994
TForce	273.975	512.495	689.500	797.987	850.263	877.961

EQUATIONS 15–19

$$L_1 = (wdf*m_t*g + Faero\_f)/2 + prr*(Fyf + Fyr*)h/tm \quad (15)$$
$$L_2 = (wdf*m_t*g + Faero\_f)/2 - prr*(Fyf + Fyr*)h/tm \quad (16)$$
$$L_3 = (wdr*m_t*g + Faero\_r)/2 + (1 - prr)*(Fyf + Fyr*)h/tm \quad (17)$$
$$L_4 = (wdr*m_t*g + Faero\_r)/2 - (1 - prr)*(Fyf + Fyr*)h/tm \quad (18)$$

Where,

L_1 = front left tyre load
L_2 = front right tyre load
L_3 = rear left tyre load
L_2 = rear right tyre load
m_t = total mass of the vehicle
$Faero\_f$ = front aero load
$Faero\_r$ = rear aero load
Fyf = lateral force applied to the front axle
Fyr = lateral force applied to the rear axle
Prr = lateral load distribution at the front

$$\begin{aligned} wdf \cdot m_t \cdot V_{xf}^2 &= k_{af} \cdot \left[\left(1 - k_{bf} \cdot L_1\right) \cdot L_1 + \left(1 - k_{bf} \cdot L_2\right) \cdot L_2\right] \\ \left(1 - wdf\right) \cdot m_t \cdot V_{xr}^2 &= k_{ar} \cdot \left[\left(1 - k_{br} \cdot L_3\right) \cdot L_3 + \left(1 - k_{br} \cdot L_4\right) \cdot L_4\right] \end{aligned} \quad (19)$$

Where,

V_{xf} = maximum possible speed from the front axle
k_{af} = front tyre initial coefficient of friction
k_{bf} = front coefficient drop off
V_{xr} = maximum possible speed from the front axle
k_{ar} = rear tyre initial coefficient of friction
k_{br} = rear coefficient drop off

Figure 5: Total grip vs magic number

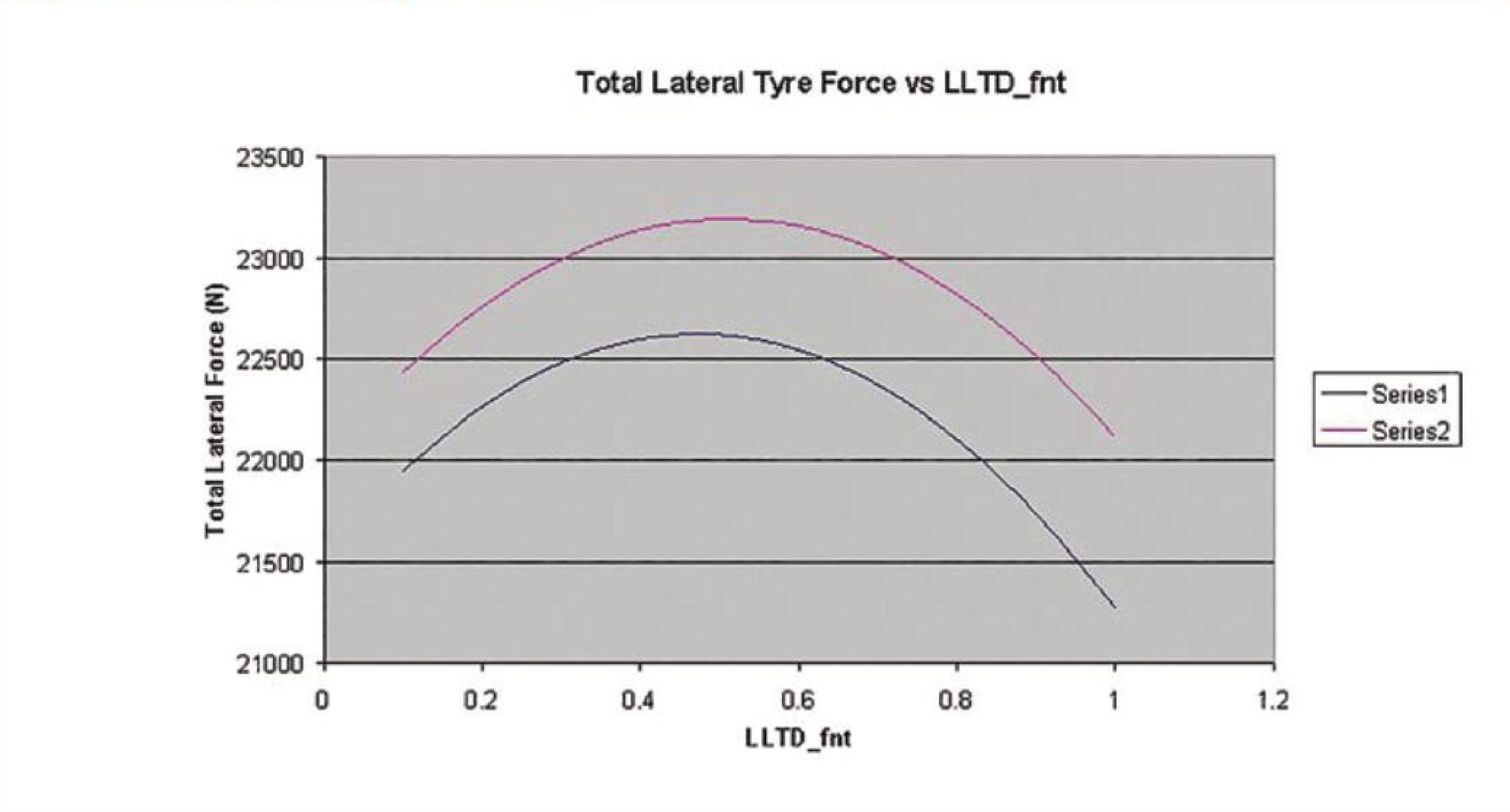
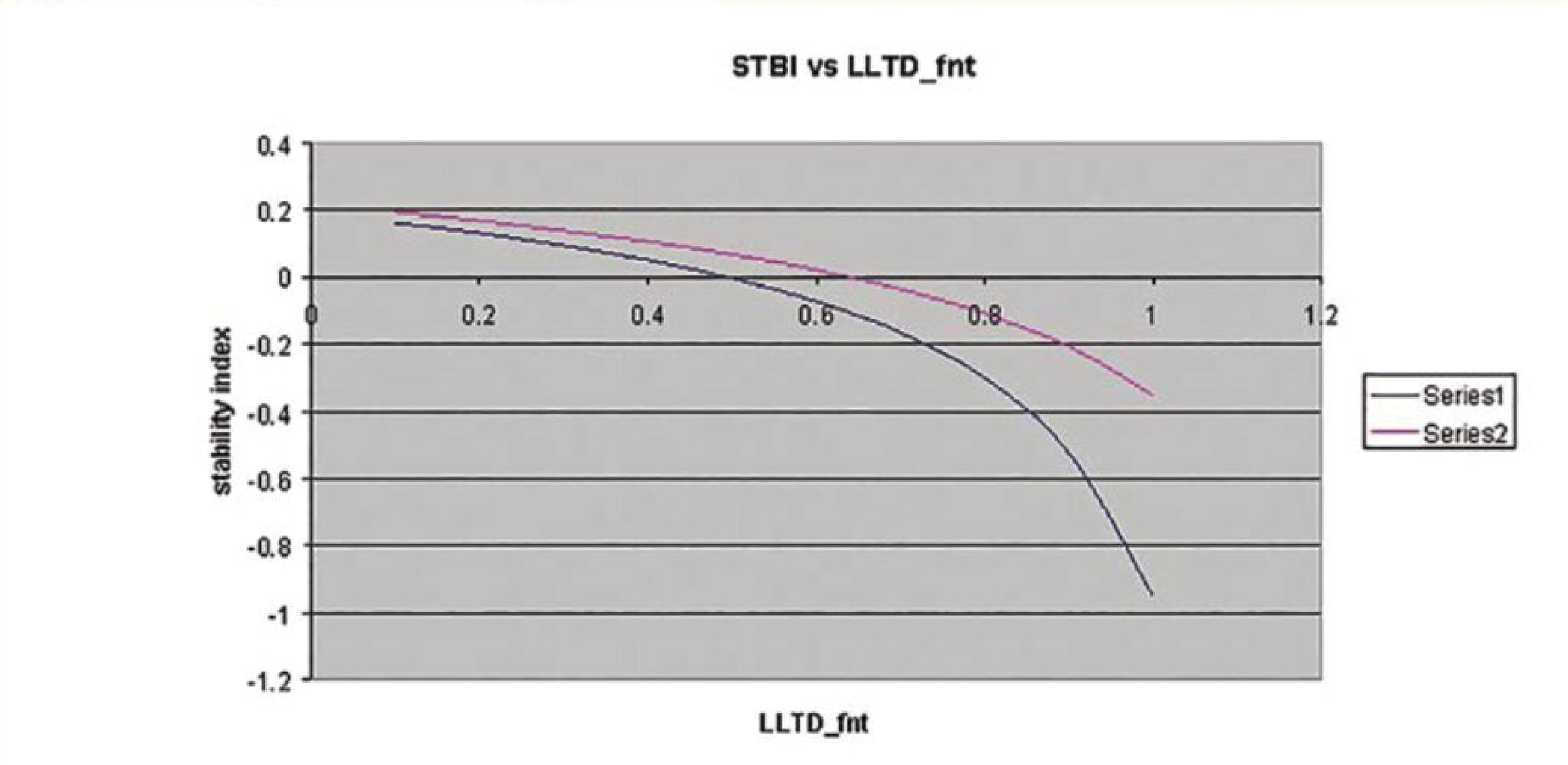


Figure 6: Stability index vs the magic number



EQUATIONS 20–21

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\bigg|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2})$$
$$C_r = \frac{\partial C_r}{\partial \alpha_r}\bigg|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4}) \qquad (20)$$
$$C_T = C_f + C_r$$
$$stbi \approx \frac{a \cdot C_f - b \cdot C_r}{C_T \cdot wb}$$

Where,

$dC_F/da(\alpha_f)$ = slope of normalised slip angle function for the front tyre
$dC_R/da(\alpha_f)$ = slope of normalised slip angle function for the rear tyre
$Fm(L_1)$ = traction circle radius for the left front (N)
$Fm(L_2)$ = traction circle radius for the right front (N)
$Fm(L_3)$ = traction circle radius for the left rear (N)
$Fm(L_4)$ = traction circle radius for the right rear (N)

$$\alpha_F = \frac{b \cdot (Fm(L_3) + Fm(L_4))}{a \cdot (Fm(L_1) + Fm(L_2))} \cdot \alpha_R \qquad (21)$$

Where,

a = moment arm of front axle to c of g (m)
b = moment arm of rear axle to c of g
α_f = front slip angle
α_r = rear slip angle

cent of the peak slip angle. Doing that, the approximation for the front slip angle became as in **equation 21**.

Again, this can be tacked on to the same Excel spreadsheet you did for **equation 19**. What this now means is you can plot total grip and the stability index as a function of your aero and lateral load transfer. When you do this, you get something that looks like **Figures 5** and **6**.

The purple and blue traces shown are for two different tyre compounds. **Figures 5** and **6** are what I refer to as the race engineering equation, and this is what drives the dance between tuning for that combination of maximum grip vs what the driver can deal with. Everything you will do as a race engineer is driven by **Figures 5** and **6** and we have just discussed the basis of how you can derive this for your own purposes.

Further thinking

Before we wrap things up this month, there are a few things to mention.

One thing we haven't discussed at all is damping. On a surface level this would appear to be a large omission, but if we go back to part one and re-investigate the beam pogo stick model, damping becomes an important super set of what we have discussed. Firstly, appropriate damping stabilises the plant so the roll centres, cambers and platform isn't going all over the place. This becomes even more critical for aero cars. The other area where large damping makes its presence felt is driving the lateral load transfer function. This, however, is a series of articles in itself, which we will re-visit another time.

The other thing we have omitted is the effect of tyre temperature, pressures and wear. Where this manifests itself is primarily changing the traction circle radius vs load characteristic, the *ka* and *kb* terms. There will be changes to the slip angle curves too, but the changes in these two parameters dominate. This can be readily verified using tools such as the ChassisSim Tyre Force Modelling toolbox when you model data sets from new vs used tyres.

The key reason we are bothering with all this is it forms the basis for you to numerically quantify your car, and what we have presented here gives you the mathematical tools to do that. If necessary, the resources discussed can be found on the ChassisSim blog.

In closing then, in part one we discussed where tyre loads come from and what generates them. In part two, we have taken the fundamental equations of motion and, using static approximations and a simple tyre model, delved into what drives racecar behaviour. It's now up to you to apply it. I can lead you to water, it's up to you to drink.

Audi's GT3 evolution

New car is an evolution, rather than a blank sheet of paper design, with various changes made to improve driveability and set-up options, with professional drivers particularly in mind

Audi has launched its new GT3 challenger, the R8 LMS GT3 2021, that will take part in customer-based endurance racing from 2022.

The new car is still in the test phase and has not yet been signed off, but will be ready for customer teams in time for the Daytona 24 hours in January.

'The innovations improve the driveability and will allow professional drivers in particular to make better use of the power potential and torque curve for consistent lap times,' says Audi's head of sport, customer racing, Chris Reinke. 'The chassis features a new shock absorber solution that makes it easier for teams to set the car up. 'Modified software means the traction control can be used even more individually to suit particular needs and different tyre characteristics.'

The car features a rear wing mounted from behind the main blade, which gives a larger percentage of downforce compared to the old model according to Audi, a new engine intake system with a better torque curve and improved traction control.

Audi remains committed to the Intercontinental GT Challenge for a sixth successive year, the Macau Grand Prix in 2022, and the second edition of the Motorsport Games this season. The car is offered for sale at €429,000+VAT.

New rear-mounted wing design offers greater downforce figures over the outgoing model

Global connections

Marelli Motorsport and 1NCE, the world's first fully-fledged operator of Internet of Things network services, are joining forces to develop new, real-time tracking solutions in the world of motorsport. The two will create a globally standardised cellular connectivity system.

'By offering globally available and easy to implement cellular connectivity, we found 1NCE to be the perfect partner for our needs,' says Ricardo de Filippi, CEO of Marelli Motorsport. 'Combining a worldwide presence and a simple pricing structure, 1NCE delivers the ideal connectivity solution for our upcoming telemetry products. Once set up, we can start using them immediately on any of our motorsport locations around the world.'

Marelli Motorsport and 1NCE are working together to create a globally standardised cellular connectivity system for motorsport worldwide

Electric Dakar

Audi is using the gruelling desert series as a test bed for future motorsport drivetrain development, bringing together elements of Formula E and DTM

Further to the reveal of the new GT3 car, Audi has also launched its Dakar challenger, the RS Q e-tron, which features a 2.0-litre, four-cylinder, turbocharged engine taken from the manufacturer's DTM unit, mated with a generator taken from the company's Formula E programme, which combine to provide 300kW of power driven through all four wheels.

Audi says it wants to be the first company to compete for overall victory in Dakar with an electrified drivetrain. The car features an MGU, lightly modified compared to the Formula E application, on the front and rear axles, while a third MGU is part of the energy converter and recharges the battery while driving. The battery weighs 370kg and has a capacity of 50kWh.

The front and rear axles are not mechanically connected and torque distribution is managed by software that creates a virtual and freely configurable centre differential, saving weight as there is no propshaft or mechanical differential.

'Even before the Dakar project, we asked ourselves what a future drivetrain system in motorsport could look like,' says Stefan Dreyer, head of development at Audi Sport racing. 'We wanted a drivetrain that is efficient and performs well, while at the same time can handle long distances. That's how the energy converter concept came about.

'The MGU and inverter were both developed in-house by Audi Sport for competing in Formula E and they already achieve a system efficiency of about 97 per cent. There's not much leeway there. The situation is different with the battery and energy management. That's where the greatest development potential lies in electromobility in general.'

RS Q e-tron is four-wheel drive with an MGU on both axles and a third MGU for battery recharging

Key areas of development, Audi says, are in energy conversion and battery management

Parts of the in house-developed drivetrain have already proven very efficient in Formula E

IN BRIEF

Jaguar has committed to the **FIA Formula E World Championship** for the Gen3 era, which is set to commence in the 2022 / '3 season.

'The Formula E programme will contribute to Jaguar Land Rover's Reimagine strategy – a commitment to achieve zero tailpipe emissions by 2036, and net zero status across supply chain, operators and products by 2039,' says the company in a press release.

McLaren Racing has announced a multi-year partnership with **Alteryx**, which will provide the F1 team with an easy-to-use, automation-first approach to its analytics and data science, supporting the team's digital manufacturing, race day logistics, fan engagement and back office automation.

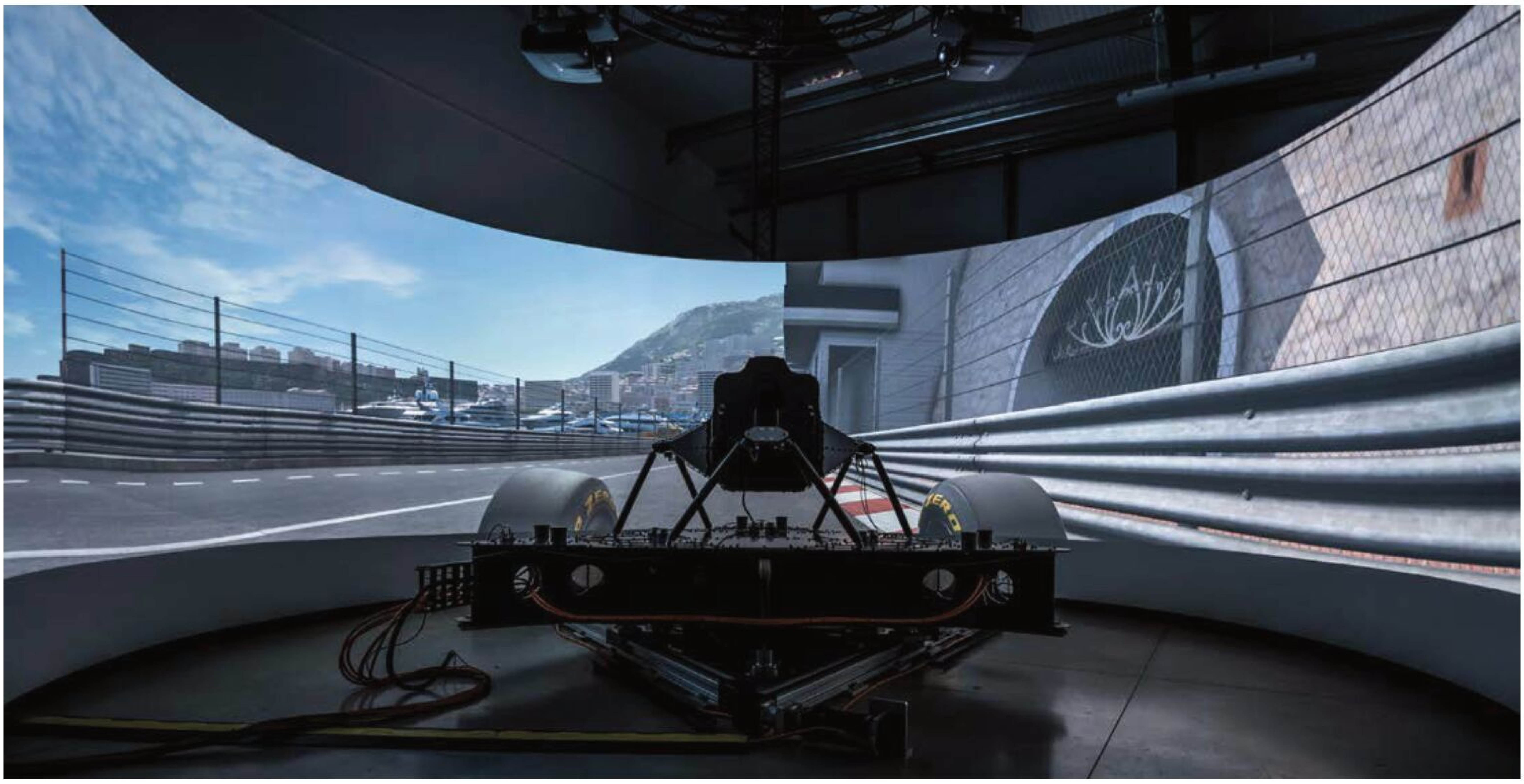
Ravenol and **Abt Sportsline** have launched a collaborative technology partnership in the field of engine, gearbox and limited slip differential oils, as well as brake fluids.

NASCAR and **United Rentals**, the largest equipment rental company in the world, have announced a multi-year partnership that will designate it as the official rental equipment partner of the series, starting in 2022.

The **BTCC Hybrid test car** continued to clock up miles in July in the hands of former series champion, **Andrew Jordan.** The car ran with the new-for-2022 TOCA engine produced by M-Sport fitted to a Toyota Corolla. All of the major hybrid components, including the motor, battery and electronics are the same as when the car first ran in July 2020, with no component failures or maintenance needed.

German suspension company, **Bilstein**, has opened a new site next to the **Nürburgring** with a new vertical dynamic seven-post test rig, available to manufacturers, race teams and tuning companies. Customers and partners will be able to draw on Bilstein's technology and advice for suspension analysis and development. The rig allows any race track to be driven in one place.

Dynisma supports Ferrari



After two years of intensive development, the new, state-of-the-art, 360-degree motion simulator will be put through its paces in the development of 'project 674', Ferrari's 2022 Formula 1 car

British company, Dynisma, is putting the finishing touches to the Scuderia Ferrari simulator that will be used to develop the 2022 grand prix car. Calibration work is now being carried out ahead of the system coming online in September.

This will be on the cutting edge of vehicle dynamic simulation, the company tells us, and reproduces in a 360-degree environment the lowest latency and highest bandwidth motion curing of any motion simulator on the market. It is based on a completely new concept, the result of a collaboration between Scuderia Ferrari and the independent, UK-based company headed up by former Ferrari engineer, Ash Warne.

'Simulation and digital technology are going to play an ever more important role in the development of a Formula 1 car, and we believe we have made the best possible choice, focusing on creating a tool that will enable us to make a generational leap in this sector,' commented Gianmaria Fulgenzi, Scuderia Ferrari's head of supply chain.

'To produce it, we chose Dynisma, a young and dynamic company. It has taken two years to complete this project and now we are ready to start using it on the 674 project, which is the name given to the car that will be produced based on the new technical regulations that come into force in 2022.'

'All my experience in Formula 1 informed me that motion simulators were just not realistic or responsive enough,' says Warne. 'We set up Dynisma to change that, with the mission to create the world's most immersive simulator, and to widen access to the best high fidelity, responsive motion generators drivers and engineers could want.

'We are proud our first commission is for the world's most famous motorsport team and it's proof Dynisma has created world-leading technologies. We have redefined the sector by looking at the problem in an entirely new way.'

New Formula 4 car breaks cover

The FIA has unveiled its second generation Formula 4 car that features an upgraded survival cell able to withstand stringent load tests, along with new anti-intrusion panels that increase safety for this entry-level car.

An upgrade to the powertrain also offers the versatility to fit a hybrid system, while maintaining the power-to-weight ratio of 3.6kg/bhp across all cars in the various championships.

The car was unveiled in Monaco by outgoing FIA president, Jean Todt, along with Formula 1 single seat sporting director, Michael Masi.

Advances include improved safety and versatility for future powertrain options

Vnuk: motorsport's seven-year itch

It's been a turbulent few years for the UK motorsport industry. The ongoing uncertainty surrounding Brexit, followed by a global pandemic, has truly tested the resilience of motorsport companies, suppliers and teams. Remarkably though, those were not the biggest threats facing our industry.

'The Vnuk ruling threatened the entire future of the motorsport industry and the sport itself,' says Chris Aylett, the CEO of the Motorsport Industry Association (MIA). 'The unintended consequences of this piece of European legislation meant that all two or four-wheeled motorsport across the UK and Europe would cease. That's *all* kinds of motorsport from Formula 1 right down to grass roots racing.'

In 2007, a Slovenian farmer, Mr Vnuk, was knocked off his ladder by a reversing tractor-trailer on a private farm. He sought damages against the defendant insurer of the tractor and the case was referred to the European Court of Justice (ECJ).

In 2014, the ECJ ruling essentially meant that all competition vehicles required compulsory third party insurance cover, whether on a public or private road. Due to the high-risk nature of racing, and the number of incidents large and small, the insurance market would not provide this insurance; making motorsport uninsurable, and consequently illegal.

Despite limited experience of the inner workings of European parliament, the MIA ignited a campaign to challenge the Vnuk ruling and exempt motorsport from it.

'We spent the first three years just trying to make motorsport companies believe this threat was real,' says Aylett. 'They couldn't believe it at first.

'The MIA has always been alert to decisions of government, knowing that laws can be passed that unintentionally damage businesses. We've learnt to bring together a collective voice of business to capture their attention. Individually, they never hear you, but by using the strength of organisations such as the MIA, FIA and SMMT, we can influence governments and laws.'

Of course, anyone in the UK reading this may be wondering why this matters. Surely a benefit from Brexit is that EU law no longer affects the UK. Well, in 2014 when Vnuk kicked off, Brexit didn't exist and it seemed the UK would always be a member of the European Union. When Brexit became a reality, the MIA worked with the UK government, who agreed they would not put this law into place. However, it remained critical for the motorsport industry to stop Vnuk in Europe.

'If Vnuk went ahead, the entire European motorsport market would disappear overnight,' reveals Aylett. 'Our focus at the MIA has always been to promote and protect the motorsport industry. In simple terms, there would no industry if we couldn't race in Europe.'

The MIA used social media and online events to drive interest in Vnuk and educate the industry and politicians. UK and European companies were encouraged to write to their MEPs and, in 2019, the FIA got involved and the campaign shifted up a gear. On 22 June 2021, the ECJ finally agreed to exclude all motorsport vehicles from Vnuk.

'Ultimately, it took seven years of determined work to create just 71 words in a piece of legislation,' concludes Aylett. 'It's a timely reminder that an apparently small incident can result in extremely damaging consequences if not fully understood.

'The collective voice of MIA members and business associates is a vital resource. Let's learn from this experience and avoid such situations in future. It's vital that many more motorsport businesses join the MIA community right now, adding their weight to the voice of motorsport at this time, when we need it most.'

Interview – Greg Stucker

Black art

Goodyear continues its involvement as sole supplier to NASCAR, but the new Gen-7 car brings with it a whole new tyre philosophy

BY ANDREW COTTON

NASCAR launched its Gen-7 car in May, and along with the focus on the 'Stock' element of the design, there was a change in the tyre department to make the product more relevant to contemporary production cars by introducing an 18in tyre.

The move brings the company into line with other racing series around the world, including Formula 1, which will also make a similar switch next season.

It was one of the key elements to changing the look of the car, which also features a smaller greenhouse, less downforce and an overall design more akin to what is available on the street.

The old 15in tyre did nothing of the sort and so, in collaboration with NASCAR and the manufacturers, it was agreed to make the findamental change. Initial discussions were had on whether to go for 16, 17 or 18in wheels, but the feeling was that the latter was the most relevant, although Goodyear says it was prepared to go 19 or even 20in, as it has experience in all sizes through its global motorsport tyre programme.

'We have plenty of history in racing 18in tyres, both in the US and in Europe,' says Greg Stucker, director, race tyre sales at Goodyear. 'The difference here is that this will be the first application of the 18in tyre in this kind of environment.'

Unique environment

'For example, this will be the first time operating in an oval environment with this kind of vehicle load. The NASCAR Cup car has continuous speeds on an oval, which translate directly to the individual tyre loads and operating temperatures. The entire operation will be unique.

'We have a tremendous history operating in that environment with the 15in tyre, though, so I will say that we haven't turned the world upside down [in switching to the new tyre size]. We have taken all the pieces we know with the materials we currently run, our history elsewhere with the 18in and worked those together to try to find the right balance.'

Greg Stucker, director of race tyre sales at Goodyear Racing in America

With the tyres required to run on various types of track surface, and on both ovals and street courses, the tyre has to remain versatile enough to handle the different conditions. That has clearly led to some serious development work on the new car as the tyres will behave differently compared to the old design, as will the cars. However, Goodyear is confident of its product and knowledge base and has kept changes to a minimum.

We have plenty of history of racing 18in tyres, both in the US and in Europe. The difference here is that this will be the first application of the 18in tyre in this kind of environment

The overall diameter of the new 18in tyre is the same as the previous generation 15in rubber, but…

It's all change at NASCAR with the Gen-7 car and its new wheel and tyre package, which means a whole shift in tyre technology from Goodyear, as well as a difference in car set-up for the teams

Clearly the move to different tyre sizes has a dramatic effect on the shape of the tyre, its usage for the teams and also for temperature control, all of which have led the American development team to exchange information with Goodyear in Europe, which has produced various spec 18in tyre sizes for LMP and GT racing for years.

The company is also looking at the possibility of new materials to be used in the tyres, as being sole tyre supplier makes it simpler to introduce such things without compromising performance against a rival manufacturer.

NASCAR's new 18in tyre has yet to be signed off, though initial testing has now been completed by the company as part of the early test phases for the Gen-7 car. The package now has to be tested by teams representing the different manufacturers to gather as much data as possible ahead of its proposed introduction at Daytona in 2022.

'The weight is roughly the same as before, but the aerodynamics are different with the undertray,' says Stucker. 'We are going to be generating the downforce differently, and I think that it is going to be telling once we get multiple cars on the racetrack and see how that downforce is affected by traffic.'

…there is a 3in reduction in sidewall height, so careful tuning of the tyre components is required

Change in attitude

The sidewall has reduced by three inches to accommodate the larger rim, and that has led to a change in attitude from the tyre, and a reduction in the amount of damping created, so teams will need to change their suspension set-up for each circuit next year.

'We haven't changed our construction materials,' confirms Stucker. 'We haven't changed our compound formulation or philosophy, but we are running a lighter car than we have historically so I think the car uses the tyres differently.

'We seem to be able to shift slightly softer in compound selection, but it is still virtually the same materials and we are still going to target an operating range the same as the previous tyre, so 200-260degF, and that's the optimum for us.'

In terms of tyre squish, Goodyear's engineers have accommodated as much as they possibly can in order to maintain the characteristics of the old tyre, but clearly there are significant differences in sidewall stiffness compared to the old tyre. 'We are operating in the same overall diameter that we had with the 15in tyres, so we haven't gone taller in order to elongate that sidewall. That's a challenge for us, particularly on an oval application. The sidewall is able to absorb a lot of that deflection due to load and so now we have a much shorter distance over which to absorb all that deflection.

'That then goes back to the tuning of the components: carcass angles, belt angles, mould shapes, all those things come together to make sure we are absorbing the load as we need to with that shorter sidewall.'

Extra width

An increase in the width of the wheel on which the tyre sits helps with the absorption of load, and has led to a new tyre profile.

'It is unique in its shape and character from that perspective,' explains Stucker. 'The changes in shape are fairly subtle, but that's the sort of thing you apply with learnings of mould shape technology and so on.'

In another fundamental change, NASCAR has switched to an aluminium wheel, replacing the old steel ones in a bid to save weight at the four corners, but the car has not gone on the diet that Goodyear expected, so overall weight is closer to the old car than intended.

Tyre gauge is also similar to the old tyre as there is no incentive to travel further on a set of tyres.

Gone are the old, traditional 15in steels on the Gen-7 NASCAR, replaced with wider, lighter, 18in aluminium racing wheels

Being the sole tyre supplier opens up other opportunities. The reduction in competition means the supplier can start to introduce other technologies without penalties in terms of competition

The single, central wheel nut will speed up tyre changes compared to the old five-lug wheels that will see out this year, but the nature of the racing is such that there is no need to go any further on a set of tyres.

'Our target is a fuel stop,' confirms Stucker. 'The direction we received from NASCAR and from the drivers is they like a certain level of tyre degredation and then drop off over the course of a run because you then have to manage the car, and the tyres, over the course of that fuel mileage. We are not looking to run a 500-mile race on one set of rights and one set of lefts.

'In some cases, because of the track surface, you may change only the right tyres and that sort of thing, but our goal is still the package that performs well over a full fuel run.'

New single centre lock wheel bolt will speed up tyre changes, but there is no increase in the target for tyre longevity, which remains at one fuel stint

Forward thinking

Being the sole tyre supplier opens up other opportunities, as Michelin discussed for its Hypercar tyre at Le Mans. The reduction in competition means the supplier can start to introduce other technologies without penalty in terms of competition. Although Stucker stops short of confirming puncture proofing is going to be introduced, he does concede that options are opening up for the brand.

'That is certainly one of the things we have benefited from with our relationship with the guys in Europe. Obviously, they are further ahead with it than us so we are sure we will continue to move in that direction.'

At the launch of the new car, NASCAR dropped a heavy hint that hybrid technology is around the corner, and the new way of delivering power will obviously have an effect on the tyres.

'There is still a lot to be determined if the fire source becomes different,' says Stucker. 'How will that change? How does that change the loading of the vehicle and the application of torque? All those factors probably won't change drastically in a steady-state environment like Daytona, or the mid-range speedways, but when we get to the short tracks and you are on the brakes and throttle, and the road courses, which we have more of now, there will be a lot more lateral load. I have to believe there are some differences there with hybrid, or a different powertrain technology.'

For now, though, the final tests are underway and sign off on the new tyre construction will come soon, allowing the company to start building the tyres that will take it through to the next generation of NASCAR Cup.

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Reality check

The future looks bright, but it also needs to fundamentally change

The Le Mans 24 hours will celebrate its centenary in 2023 and will do so with a plethora of manufacturers in its top class. With the anticipated arrival of Renault and GM, that will bring the number to ten competing in the top class, including Toyota, Glickenhaus, Ferrari, Peugeot, Porsche, Audi, Acura and BMW. That assumes the latter two will confirm a European race programme. Never before have so many manufacturers competed for overall victory at the endurance event, and the short-term future looks rosy.

What is actually coming down the road, however, may look slightly less appealing. Porsche, Audi, Acura and BMW will build LMDh cars, supposedly based on an LMP2 chassis with an engine and aero kit. This follows the design process started by IMSA in 2017 which has worked to brilliant effect. With Balance of Performance negating any manufacturer styling cues, the cars have their own visual and aural identity. Racing is cost-effective, and close.

However while the LMDh cars are in their design phase the FIA, ACO and IMSA have yet to create technical regulations for the LMP2 chassis on which the cars are supposed to be based. Previously, the bodies have worked in sequence, starting with their top class and moving to the second-tier Prototype before turning their attention to GT. The need to bring LMDh in with its Hypercar programme, itself delayed after a series of disasters, has changed that sequence and has meant manufacturers are designing the chassis for their programmes, and the constructors will then have the job of turning them into LMP2 cars.

The racing bodies need to turn their attention away from manufacturer racing

Not so clever

Manufacturers are surely going to design something optimal for *them*, with *their* engine concept primarily in mind. The customers that will take the cars in 2024 will just have to manage with what they have.

It is not quite that bad, say the FIA. The manufacturers have to run their designs past the technology team to make sure they don't do anything outrageous, but who is going to stop them? GT3 manufacturers ran their design ideas past the GT commission, got grumpy when they didn't get what they wanted, and with the FIA worked on a set of rules precisely to avoid this uncertainty.

Could you imagine that they will be comfortable doing such a thing for the top class at Le Mans, particularly when, in the case of Audi and Porsche, they would prefer to sell customer versions of their LMDh car than the LMP2?

The FIA, ACO and IMSA all say they are comfortable with the idea, but teams in the WEC Monza paddock in July were less convinced. This is certainly not the original idea of the LMDh category and the outcome for LMP2 could be poor.

Thoughts naturally turned towards the cost of running Prototypes. A figure of between €2.5m (approx. $2.95m) and €3m (approx. $3.54m) per car in LMP2 could be doubled for the LMDh which will be fitted with a spec hybrid system. That starts to put it outside the reach of the wealthy amateur driver, and into the realms of the super rich, or a team with manufacturer support. The manufacturers are not in it to support customers to that level, particularly if they are running a factory team.

Customer retention

So, will there be a future for customer Prototype racing? Certainly there will, but the racing bodies need to turn their attention away from manufacturer racing and focus on those who choose to spend their money with them. Escalate the costs, remove any viable alternative and the customers will leave.

Looking through the entry list for Le Mans 10 years ago, the 2011 race featured Aston Martin Racing, Audi, Peugeot, Lola, ORECA, Pescarolo (formerly Courage), Zytek, HPD (designed by Wirth) and Norma in the top class. Each of these built their own chassis, or used an external supplier. At Le Mans in 2021, Toyota, Glickenhaus, ORECA, Dallara and Ligier provide the prototype chassis. Of all the manufacturers coming in only Multimatic and Peugeot will be new. Dallara will be responsible for the BMW and GM LMDh cars, as well as the resultant LMP2 car, plus the Ferrari LMH. ORECA will build the Acura LMDh car and produce the LMP2 from that design, while it is also in the running to build the Renault/Alpine. Ligier is also under consideration for the Renault deal, while Multimatic will build all the VAG chassis including Audi, Porsche and if it gets the green light, Lamborghini. More business for fewer manufacturers was the original plan from the FIA and it has succeeded in its quest, but the variety and the smaller manufacturers are painfully absent and LMP2 could provide an alternative solution for endurance racing.

I hope that we will see other companies also able to compete in the customer-based prototype class, including the likes of Ginetta and Wolf. Le Mans always benefited from variety, and will do so again, if the rules permit.

ANDREW COTTON Editor


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