>> FIA president Jean Todt on racing's future p74

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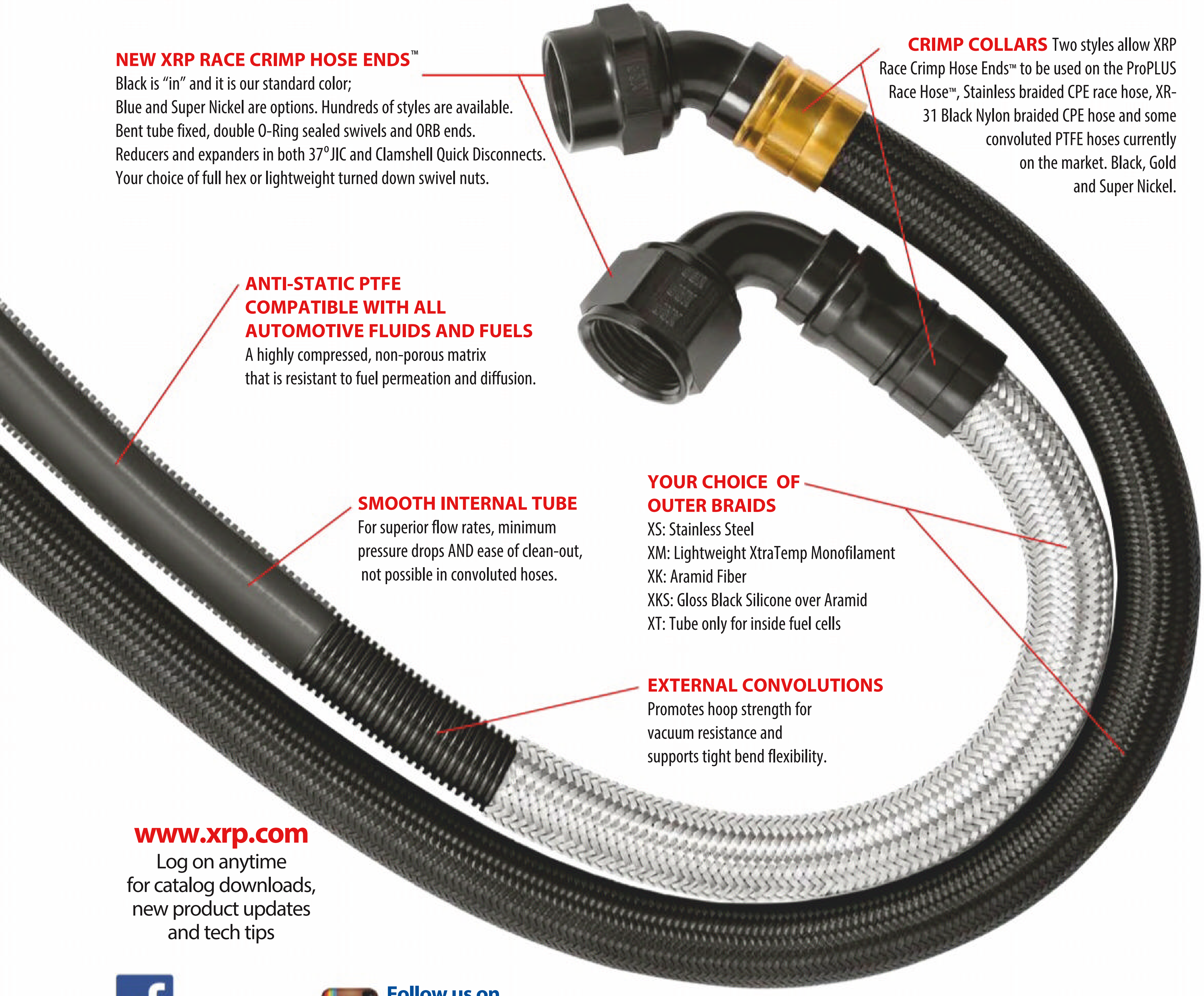

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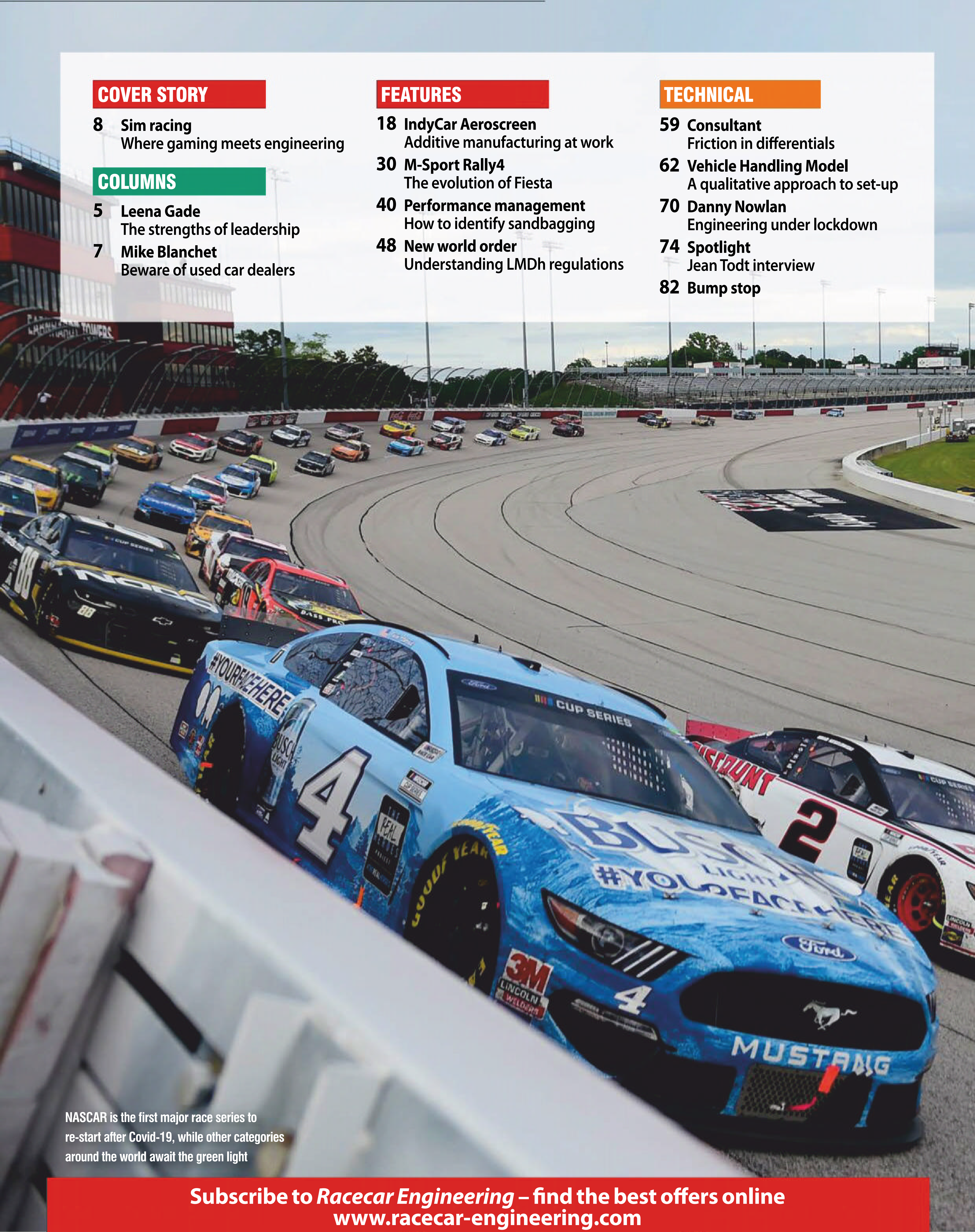

NASCAR is the first major race series to re-start after Covid-19, while other categories around the world await the green light


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Lead from the front

Good teamwork requires much more than just a strong leader

Teamwork under pressure relies on individual skills, teamed with trust and respect. It needs leadership that is strong but fair and capable of making tough and sometimes unpopular choices. It also relies on each member of the team feeling valued enough to question and suggest solutions. In motorsport, the pressure comes from the need to act quickly and decisively, and the fact that you have an audience watching your every move.

In 2011, as a rookie race engineer at Audi Sport Team Joest, I was very much 'thrown in at the deep end'. Convinced I was going to be fired, the first two races of the year were a disaster, and Sebring race day was an experience I will never forget. Within hours of the start, the catalogue of strategic errors, car damage, mistakes and penalties began, and carried on for another 12 hours, quickly putting the car out of contention.

The bulk of the race was run with almost non-existent telemetry, a problem that plagued the car all weekend, leaving the engineers blind. An early tyre compound change at night could help the sister car but, as this discussion was taking place between myself and the Michelin tyre engineer, the car started a 25th lap, one more than the fuel tank allowed. I'd asked my assistant to keep an eye on the car metrics whilst this discussion took place, but I hadn't empowered him to grab my attention when it mattered. Add to that a sketchy fuel alarm and it was the perfect storm, and all my mistake.

Running on fumes

I can't tell you how awful it felt when Timo Bernhard shouted over the radio 'No power, no power!' I knew immediately what had happened, instinctively asking him to switch to the Safety Car map to save what fuel was left. There was just enough to roll into the pit lane, but the car stopped far from the box. Four mechanics were sent to push the car, but the fuel pumps primed and Timo returned to our pit. By then though, the mechanics were on the wrong side of the wall.

The debrief the next day was brutal, and rightly so. With so many issues highlighted, it was difficult to see a way through. Steps were taken and, a few months later, we headed to Spa for the next race.

The weekend was dominated by an inexplicable fuel tank shrinkage that reduced its capacity. Every night, the fuel cell came apart and the bladder was replaced. On race day, the first fuel fill was one litre short, and at Spa that meant one less lap. A few stops later, and a huge mistake from me in interpreting the telemetry, just like Sebring the car started one more lap than was possible.

Open discussion

If there is anywhere you don't want to run low on fuel, it's Spa with its elevation to the pit entry. The car made it to the pit eventually with our driver Marcel Fassler on board but, as it left to complete its next stint, the reported fuel fill was less than expected again.

After a shaky start, it all came together in 2011 when Gade became the first female race engineer to lead a team to victory at the 24 Hours of Le Mans

The mistakes at both races lay at my feet. If I wasn't fired, I figured I should quit because I wasn't cut out to lead. That realisation that the crew lacked a strong leader was crucial to what followed. The debrief with the three drivers and all the mechanics on the car was an open discussion on what was wrong with our team.

You have to be thick skinned in this game. Casting your ego aside, you cannot be sensitive to personal criticism when a race team needs to win. There were so many issues, including talking too quickly on the radio, not being clear, panicking, not being approachable, not listening, not trusting. I was hearing about someone I didn't recognise. Somewhere during that year, I had lost my skills to be a leader and my team was paying the price.

The next race was Le Mans and we had one chance to change where things were headed. I recognised what was important for the team to perform and, to this day, it's how I now structure and lead my crews at every race.

- Any communication, especially over the radio, needs to be simple, with the minimal number of unique words so there is no confusion.
- Trust in your team to make a choice, right or wrong but based on their experience and knowledge. Empowering team members means they feel able to make a decision without being managed.
- Everyone should be supported whether a choice is right or wrong. This is so important for morale and motivation.
- Even when everything around you is imploding, a calm and collected leader can make the difference between finishing a race in a wall or on track at the chequered flag.
- Mutual respect and the ability for a team to self-analyse at the right time allows a team to learn and progress. Teams adapt during a race, but reinvent between races.
- Every member should feel their input carries equal value and should not be afraid to share their opinion.
- At a critical moment when a decision is needed to keep a race moving, a bad decision is better than no decision. There's a confidence required to do this, sometimes coming across as arrogance. Whether the decision was correct isn't what is important here, it's the ability to keep the machinery rolling mid-race when there is no pause button.

It wasn't just those two races that taught me what a team should look like. At every race since then I have learnt other skills. It's very possible such skills aren't adequate for every situation, but there are parallels to be drawn during crises.

Being the leader of a nation carries significantly greater responsibility than a race engineer, and there are many more balls to juggle. But that strong leader uniting a team helps carry a nation forward during these challenging times.

Leena Gade is the vehicle dynamics centre manager and race engineer at Multimatic Engineering, UK

A bad decision is better than no decision


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New or used?

Never has *caveat emptor* been more appropriate than in the case of a 'pre-owned' F1 car

Amid the recent pro and counter arguments concerning the possible sale of 'manufacturer' F1 cars to independent teams, be they the previous years' redundant machines or new-season latest designs, there are a number of practical considerations that appear to be overlooked. There is logic in wanting to eliminate the R&D, design and manufacturing costs less well-financed outfits face in producing their own car. However, as always, the devil is in the detail, and there are a lot of devils that could happily undermine even the best-intentioned strategies.

Looking at the pre-owned (such a nicer description than 'used', don't you think?) car sale route, the most obvious spoiler concerns regulation changes from one year to the next. Clearly, if these are major in nature then forget it. However, even relatively small changes can involve a lot of R&D and engineering work to accommodate, plus manufacture of the different components required. Cue the high expense subsequently incurred in the front wing rules change 2018 to 2019.

It is extremely unlikely the team selling will be able, or willing, to devote its own resources to any updates when it will be feverishly finalising the design and construction of next season's weapon. Similarly, even if one assumes the car deal includes a large spares inventory, there is the problem of ongoing supply of parts. The buyers will therefore have to do their own thing, either in-house – which means still needing to possess a high level of engineering, aero capability and facilities – or by paying outside specialists and contractors.

Bear in mind that, unless the manufacturer team has been willing to supply a lot of advance information while the previous racing season is still underway, the time to make these modifications and all the operating kit will be very limited, therefore requiring extra resource. This begins to cut into the primary advantage of following this route which, let's remember, is to drastically reduce the buying team's budget.

The next issue is the rather obvious necessity for the buyer to be signed up to the same power unit supplier as the seller. The days of hacking about the rear of the monocoque to accept a different engine are very long gone, such is the complexity and interconnection of the package, including cooling and aero.

Existing PU supply contracts might not be easily terminated without financial penalty. As matters stand for 2021, the main candidates would be Ferrari and Mercedes-powered teams.

Advantage slip

Consider now the other primary benefit of purchasing a proven, but soon-to-be-outdated competitive car from the likes of Ferrari, Mercedes etc. This should be a step forward in competitiveness for teams regularly at the back of the grid, at least at the start of the racing year. But without an ongoing development programme this advantage will slip increasingly race by race.

XPB

Formula 1 banned the practice of shared chassis in 2010. Before then, Scuderia Toro Rosso used the Red Bull RB4 with a Ferrari engine bolted into the back of it in 2008

As such, we come back to still needing a significant level of expensive resources. Also, unless the same wind tunnel as the seller's can be used, the correlation problems that arise in employing an alternative tunnel could be a major handicap. Maybe the same regarding software. Not least is whether a wind-tunnel model and ancillaries come with the deal. If not, it isn't the work of a couple of weeks to create these, nor is it inexpensive.

Whichever way one views it, the team is always going to be in the hands of the chassis supplier. Even with the best intentions, the latter's needs will always necessarily come first.

Unfortunately, many of the same drawbacks exist if new-season cars were offered to lesser teams, plus a few more. Unlike the obsolete chassis, they can't be bought cheaply, or even donated (as one optimist has suggested). For a start, the extra production requirement would present a worrying challenge to the vendor team when least wanted.

Would performance updates come as part of the arrangement, even if always one step behind? How can the proposed budget caps deal with all this and retain semblance of fairness?

Reverse engineering of the car design by the customer team to form the basis of its own possible future machine, plus general transfer of know how must be a risk to the seller, but this might be policed. And what, after all this, if the new design proves troublesome and uncompetitive?

Like investments, past performance is not a guarantee of future success. Deep knowledge and data concerning operating the car, coupled with the resources necessary to optimise these, is essential. It's not a given that presenting Team Haas with a Ferrari, or Williams with a Mercedes will suddenly propel them to the top ten. It might just elevate them a couple of positions – albeit earning more valuable points.

Longer term

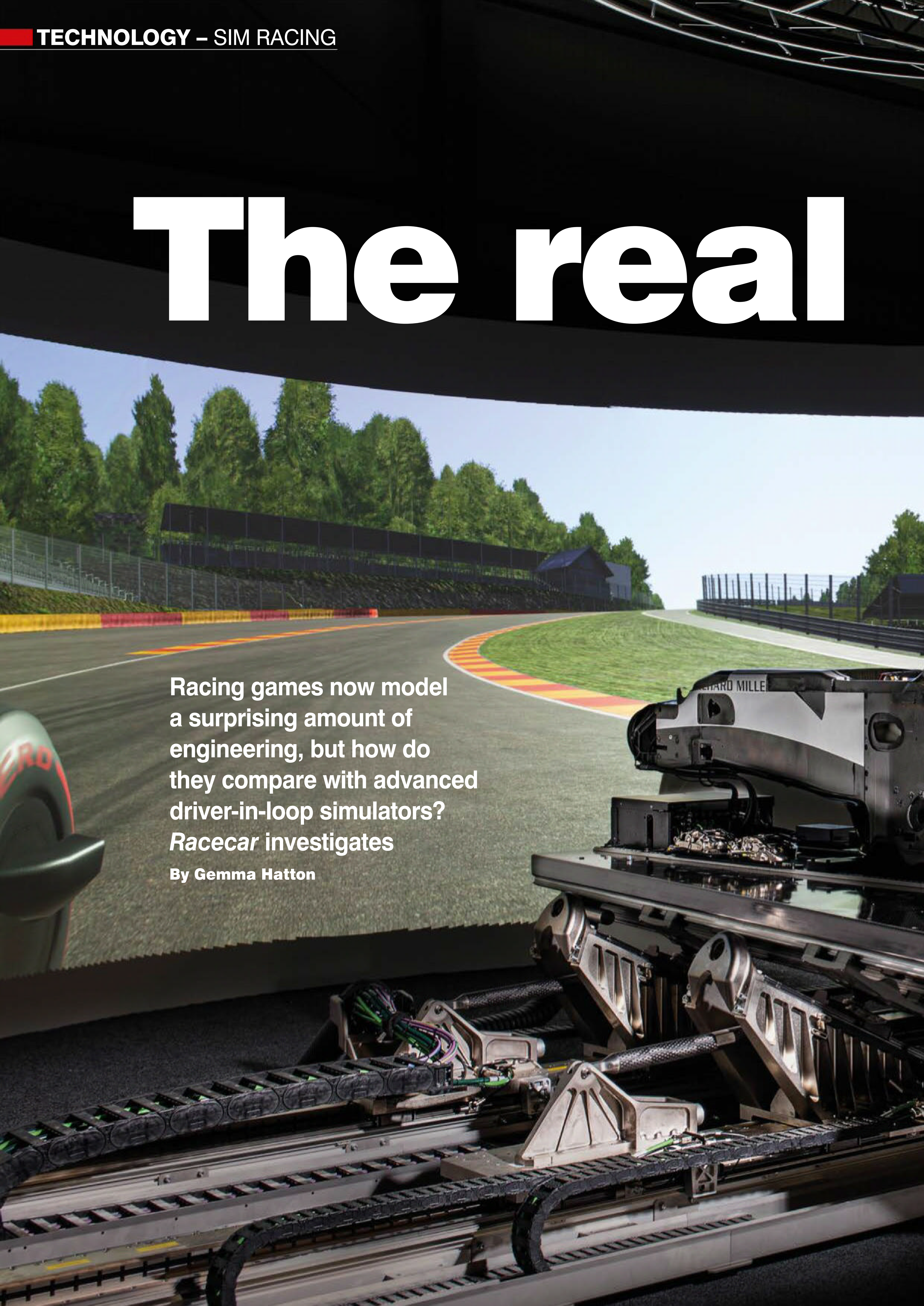
So both concepts have major limitations. If either is essential in maintaining the survival of several F1 participants then it needs consideration, even if just temporarily, but it's obvious the only long-term solution is the fairer distribution of F1 funds and reduced data reliance, allied to a sensible and enforceable price cap.

Longer term, the aim should be the financial self-sufficiency Mercedes is apparently close to achieving. Meanwhile, Haas and Racing Point appear to have adopted practical strategies: the US *équipe* purchases as much as permitted from Ferrari and subcontracts chassis manufacture to Dallara. The Aston Martin-in-waiting British outfit imitates Mercedes' championship-winning design and buys its transmissions. Both routes allow them to operate on less money, and I see no harm in this. But the former will need to adapt to a changed design philosophy, while the latter badly requires a major step up in its engineering capabilities.

We will see. Hopefully.

Like investments, past performance is not a guarantee of future success

The real



Racing games now model a surprising amount of engineering, but how do they compare with advanced driver-in-loop simulators? *Racecar* investigates

By Gemma Hatton

thing?

Simulators can be used for driver training and for engineering, and both need to create a realistic environment for the driver. Engineering simulators, however, require more complex vehicle and track modelling run on real time hardware

Simulating reality is not just a challenge for motorsport engineers, but for today's game developers, too. With computer capacity relentlessly increasing, racing games are now modelling more parameters than ever before. So, why has Esports become so popular? How effective are these virtual racing games at representing the real racing environment? And, what are the differences between these gaming platforms and high-level engineering simulators?

The popularity of racing games has soared recently. Yes, partly due to locked-down countries courtesy of the Covid-19 pandemic, but also because major championships have jumped aboard the gaming bandwagon and established their very own Esports series. Before the pandemic, the likes of F1 had already completed two championships of its Pro Series where each F1 team competed with its own professional Esports drivers. With live streams, commentary and sponsors, Esports has become its own category of motorsport.

Interactive engagement

Perhaps more importantly than that, Esports engages motorsport fans at a much more interactive level. Unlike other sports, if you want to race yourself you either have to settle for go-karts, participate in track days or have enough money to pay for a seat in a entry-level racing.

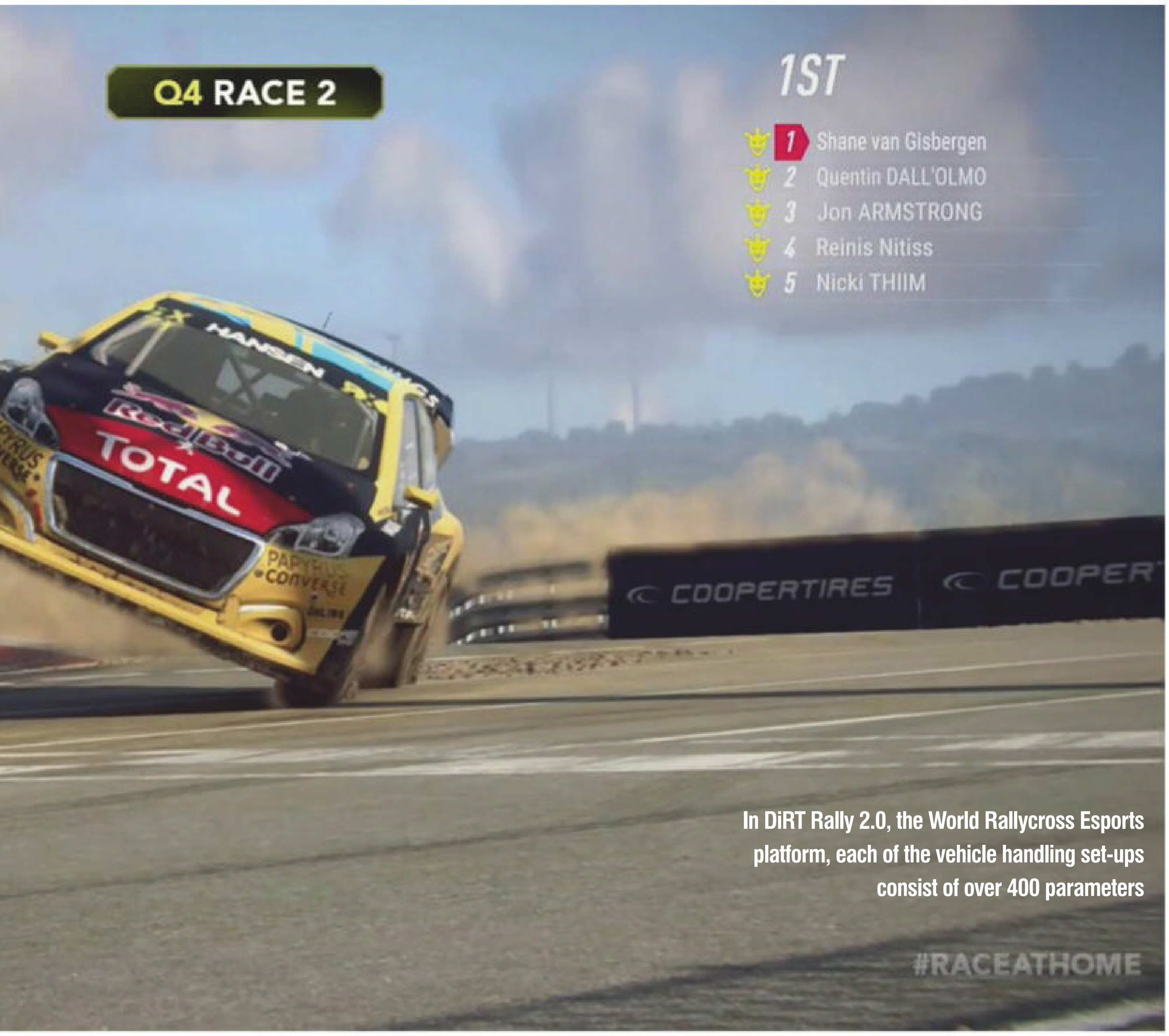
'Living in this era where people want to consume information, if people don't understand the complex technology behind racing, or it is not explained to them, they can lose interest and switch to other sports,' says Aristotelis Vasilakos, head of vehicle handling and R&D at Kunos Simulazioni, the company behind the Assetto Corsa software. 'In simulated racing the driver has to be their own race engineer and their own team because they have to make set-up changes themselves. This gives them a much deeper understanding of what it's really like in motorsport.'

This is particularly true as modern games now simulate a whole variety of additional vehicle and track conditions. 'We model all elements of the Formula 1 power unit and drivetrain, including the behaviour of the MGU-H and MGU-K,' says Lee Mather, F1 game franchise director at Codemasters. 'We also model the internal combustion engine, along with multiple fuel modes. These work as they would in real life. Running more power generates more heat and wear on the power unit for example. We even simulate the effect of running in dirty air, where cooling becomes an issue.' This not only contributes to a more realistic gaming experience, but also helps to educate fans.

'There is also something romantic about sim racing. We have models of circuits and cars that no longer exist so people can drive around historic tracks they would never have the possibility to do in real life,' highlights Vasilakos. 'There is a saying in the simulation community: "Yes, it's true that I will never drive a real racing car among real drivers, but can you drive a Lotus 49 at the old Spa?" In sim racing, you can.'

Major championships have jumped aboard the gaming bandwagon and established their very own Esports series

Gaming companies such as Codemasters also focus on making the driver's cockpit as realistic as possible



In DiRT Rally 2.0, the World Rallycross Esports platform, each of the vehicle handling set-ups consist of over 400 parameters

Whether it is a racing game or a full-motion simulator, the aim of any simulation tool is to virtually re-create an authentic experience. This is achieved by stimulating the drivers mind with carefully co-ordinated sensory cues that trick the driver's brain into thinking they are racing in the real world.

Tools of the trade

Racing simulators can be utilised in two main ways: as driver training tools or engineering tools. The former predominantly relies on visual and audio cues to provide the brain with the most information on the vehicle's motion relative to the surroundings. Hardware such as steering wheels and pedal boxes can also be used and provide force feedback to the muscles. These three elements combine to achieve a 'first level' simulation, which can be utilised for driver training. This category of racing sim encompasses a wide variety of solutions, ranging from racing games and homemade set-ups to professional driver training centres. How effective and accurate this driver training tool is depends on the software platform used, the individual hardware and the investment made.

The second category of racing simulators are those used as engineering tools for optimising set-up. These achieve a 'second level' simulation where the driver has much higher mental engagement with the simulator, allowing them to detect detailed set-up changes. This requires the simulated environment to be as realistic as possible, which can be achieved by additional sensory cues that simulate the effect of lateral and longitudinal acceleration, as well as yaw, pitch and roll through an advanced full-motion platform. In some cases, these advanced simulators can even incorporate a series of airbags to exert pressure on specific areas of the driver's body, replicating the effect of sustained *g* forces on the muscles.

In sim racing the driver has to be their own race engineer and their own team because they have to make set-up changes themselves. This gives them a much deeper understanding of what it's really like in motorsport

Aristotelis Vasilakos, head of vehicle handling and R&D at Kunos Simulazioni

Cost in context

'To give an idea of budgets for high-level simulators, a mid-range Formula 1 team might spend £2-4million on a simulator but, as soon as you drop below F1, the sums of money drop significantly,' reveals Matt Hubbard, chief technical officer of AB Dynamics which develops dynamic simulators for motorsport. 'For example, a lot of the Formula E teams run lower performance simulators in the £200,000-£500,000 range because they don't have the cash to spend on high dynamic platforms, while lower tier privateer teams may spend around £100,000-200,000, or even just rent time from a simulation provider.'

Underpinning both driver training and engineering simulators are complex vehicle models. A vehicle model is essentially a network of modules or blocks, where each module represents an area of the car. Within these modules lies a system of engineering equations and transfer functions that, when linked together, simulate the behaviour of a certain component according to the inputs at that particular time step.

Talking in code

The vehicle models in games such as F1 and DiRT Rally 2.0 are written in languages such as C++. 'We have a number of highly skilled physics programmers within Codemasters, working on all of our titles,' highlights Mather. 'Due to the huge number of elements we simulate, and the performance difference between a console and PC, we write our own tech, which offers the versatility to run effectively on all platforms. It's all written in heavily optimised C++.'

The likes of iRacing code their simulation in a programming language called C, but then run them in a machine learning language called Forth. 'Our cars are defined in flat files and a lot of what's in there are just purely parameter definitions,' highlights Chris Lerch, vehicle dynamics engineer at iRacing. 'But the scripting language is a numerically and computationally efficient platform that is well suited to running in real time. We can still code in it so there are a number of performance aspects of the car that we can update in real time.'

On the other hand, the vehicle models used in high-level engineering simulators are commonly written in programmes such as Simulink or Dymola.

To actually run a simulation, the vehicle model first needs to be parameterised. This is where parameters, which can either be fixed values or look-up tables, are assigned as inputs into the model. 'To give you an example, each of our vehicle handling set-ups comprises over 400 parameters, as well as us modelling a range of suspension types and differentials in great detail,' explains Ross Gowing, DiRT Rally game director at Codemasters. 'You can see and feel the difference between fixed axle characteristics when driving the 1970's Ford Escort Mk2, compared to the unique characteristics of hydro-pneumatic suspension that we modelled for the Citroen DS21.'

Collating the necessary information to parameterise a model is a time-consuming process and consists of merging data from the regulations, test sessions and manufacturers. 'We take as much data as we can from [F1] test sessions at the start of the year, logging lap and sector times,' reveals Mather. 'We regularly have someone attend these sessions to get a good early picture of how the cars will behave. We set out to make sure our cars deliver their lap times in the same way as their real counterparts. We're also very lucky to be able to discuss things with the technical team at Formula 1.'

Information request

iRacing, on the other hand, sends a comprehensive information request to manufacturers. 'This includes pretty much all the details we need to build a model. So suspension geometry, pick-up points, front and rear springs, as well as ranges of adjustment, anti-roll bars, damper information, bump rubbers etc.' says Lerch. 'We'll also try to get as much information as they're willing to share on the engine such as bore and stroke, compression ratio, oil capacity and cooling capacity because, believe it or not, we do include those. It's the same for the gearbox, differential and brakes, and then we like to know the minimum dry weight, weight distribution and inertias.

'But the most important information we need, as it has the biggest effect on our simulation, is tyres and aero, and of course that's the information manufacturers are least excited to share.'

In the past, the aerodynamics on gaming models were simulated using an infinite number of single wings, each with their own drag, downforce and ride height sensitivity. The problem was that the wings did not influence each other. So when the car pitched, the model would gain some downforce from the front splitter only, when in reality the downforce and drag levels of every wing would change.

'We can now input complete aeromaps from the manufacturer into our simulations,' highlights Vasilakos. 'That means that as the car pitches, rolls and yaws you not only get different downforce and drag levels, but the actual point of pressure of the car also moves forwards or backwards. This is now included in Assetto Corsa Competizione, so the aerodynamic set-up and behaviour is much closer to reality.'

Rather than just reducing the overall grip level when simulating rainfall, Assetto Corsa Competizione models a film of water on the track's surface. The grip level varies according to the depth of this film and players' tyre choice

Black art

With the 'black art' of tyres a challenge to fully understand in the real world, you can appreciate the difficulties developers face when re-creating rubber in the virtual world. Yet this is another area where racing games have taken major steps in recent times. 'In DiRT Rally 2.0 we use a tyre wear model, but the tyres on rally cars can obviously take a much larger degree of punishment than an F1 tyre due to the types and range of surfaces they are required to perform on,' says Gowing. 'When combined with our track degradation tech, players can really notice the difference between setting off near the start of the running order of a rally on fresh rubber, compared to navigating heavily rutted

'We can now input complete aeromaps from the manufacturer into our simulations… so the aerodynamic set-up and behaviour is much closer to reality'

Aristotelis Vasilakos

‘Our tyre model is based on first principles, so we model both the mechanical and thermal behaviour of the rubber’

Chris Lerch, vehicle dynamics engineer at iRacing

stages lower down the order and trying to hang on with a heavily worn set of tyres.’

To simulate tyre behaviour, companies turn to tyre models where they can either use or adapt off-the-shelf solutions such as the Pacejka brush model, or develop their own. The majority of gaming platforms start off with a brush model and then modify this to replicate the effect of different types of tyre temperature on the overall grip level. These can include surface heating, carcass temperature and internal air temperature, as well as rim heating and heat radiated from the brakes.

Feel the grip

‘The approach we take is that it’s not enough for the user to feel some sense of grip and then that grip going away,’ says Lerch. ‘We want the grip to come in over the first few corners, gradually increase over the rest of the out lap and then hit a peak on timed lap two or three, and then gradually fall off. We want to capture those long-term grip effects, as well as the shorter-term effects such as when the car is in a slide.

‘Our tyre model is based on first principles, so we model both the mechanical and thermal behaviour of the rubber.’

Then there is the challenge of modelling rubber at different atmospheric temperature and conditions, such as on a damp or wet track. ‘In Assetto Corsa Competizione, when it rains we now include a film of water on the surface of the track and, depending on how deep that film is and what tyre is running, either slick or wet, we can simulate the level of aquaplaning,’ says Vasilakos. ‘Previously, simulations would just have less grip when it rained, whereas now we can model how much water the different tyres can drain away. In fact, we even include the effect of how marbles sticking to the tyres can actually help drain a little water on a damp track. So when it starts to rain, drivers can pick up some marbles, which helps them survive for one or two laps on slicks.’

Like all models, tyre models also need to be characterised with real data which is extremely hard to obtain. Manufacturers are often the only ones with accurate data on their tyres and very rarely share this with teams, let alone gaming companies. ‘There have been some situations, such as for lower level categories, where we have been able to buy the tyre and then cut it up to try and figure out what’s going on,’ reveals Lerch.

Training vs engineering

Tyre modelling for engineering simulators, however, is a completely different ballgame. Within high-level teams such as F1, several engineers will be completely dedicated to developing tyre models. Although some will heavily adapt off-the shelf models, most will be re-written in-house to suit that team’s specific development philosophy.

This in-house approach underpins the fundamental difference between simulators used for driver training and simulators used for engineering. ‘Both types of simulator have two main jobs. The first one we share, and that’s to fully immerse the driver into a realistic environment,’ explains Matt Daley, managing director at rFpro, which provides simulation solutions for the likes of F1, Formula E, WEC and IndyCar. ‘But then there’s quite a distinct difference between our second jobs.

‘In the gaming industry their goal is to use a representative vehicle model that gives a good enough impression to the driver of what

rFpro has a dedicated TerrainServer, which runs on real time hardware linked to the customer’s vehicle model. This is run independently but in parallel to the graphics

The refresh rate of the graphics is constrained by projector capability. The standard has been 120Hz, but the latest projectors can now achieve 240Hz

it's like to race that vehicle. Whereas our focus is to develop software that helps engineers optimise the vehicle dynamics of their specific vehicle. So we don't develop the vehicle models, our customers do. Our job at rFpro is to model the virtual world and ensure we're giving the customer's vehicle model the most accurate real-world inputs available.'

Track data

Arguably, the most important input into a vehicle model, whether developed by a simulation company or a team themselves, is the road input. To accurately capture the detailed fluctuations of the racetrack's surface, LiDAR scans are used. This is where a laser beam is emitted from a scanner and the time taken for this laser beam to hit a surface and reflect back is measured. By using the velocity of light, the distance from the scanner to the surface can be calculated and this process is repeated to create a 3D point cloud 'map'. The latest scanners used for mapping tracks are now capable of measuring up to two million points per second, achieving a point density of 27,500 points per square metre.

A race circuit can be LiDAR scanned in two different ways: static and kinetic. 'A static LiDAR scan is where the scanner is placed in a fixed position at multiple locations around the circuit and the data is then manually stitched together to create a single data set,' explains Daley. 'Kinetic LiDAR scanners are the opposite and are mounted on a survey vehicle that drives around the track, allowing the scanner to continuously scan the road's surface. At rFpro all of our data is taken from kinetic LiDAR scanners because it's more representative of how vehicles actually 'feel' the surface of the road.'

With high level simulator platforms utilising kinetic LiDAR scans, gaming platforms utilise both static and kinetic LiDAR scans. 'For every circuit, we will laser scan the track ourselves and carefully create detailed bump maps of the track's surface to ensure that if there's a bump on the real track, it's present in our simulation,' explains Lerch. 'We also measure the kerbing, banking and every other subtle piece of track topography, because capturing accurate track data is essential in achieving a realistic simulation. It's also important to capture representative visual cues too, so we have track artists who analyse every detail of the track's surroundings.'

When it comes to new circuits that may not be possible to scan, there are other ways gaming companies can collate this data. 'When creating a new F1 circuit, we always start with the best data available to us,' says Mather. 'In the case of Zandvoort, the [Dutch] government has mapped the entire region with LiDAR as it's on a flood plain. That data is an amazing starting point. We also generally receive CAD data from the circuits, which we can use to create an accurate track ribbon. Beyond that, we also have a photographer take thousands of detailed images of each circuit for us.'

Power requirements

As ever in simulation, there is the constant trade-off between the amount of data and the complexity of a model vs computing power. This is particularly challenging for the engineering driving simulators, which are constantly pushing the boundaries of virtual reality.

Take the example of LiDAR scans. The temptation is to collect as many data points as possible, but manipulating that high-resolution data to work with a vehicle model can prove challenging.

'A LiDAR scan outputs a point cloud data in a standard format, but to make that scan work with a vehicle model and the simulation software requires some additional visualisation processing,' explains Dennis Marcus, commercial manager at Cruden. 'That is something we now do for many Formula E teams and it always comes down to balancing file size and accuracy. If the file is too large, the simulator software cannot handle it and you can't run in real time. So you have to find the optimum balance between the accuracy of the data and running processes at one millisecond time steps.'

'You have to find the optimum balance between the accuracy of the data and running processes at one millisecond time steps'

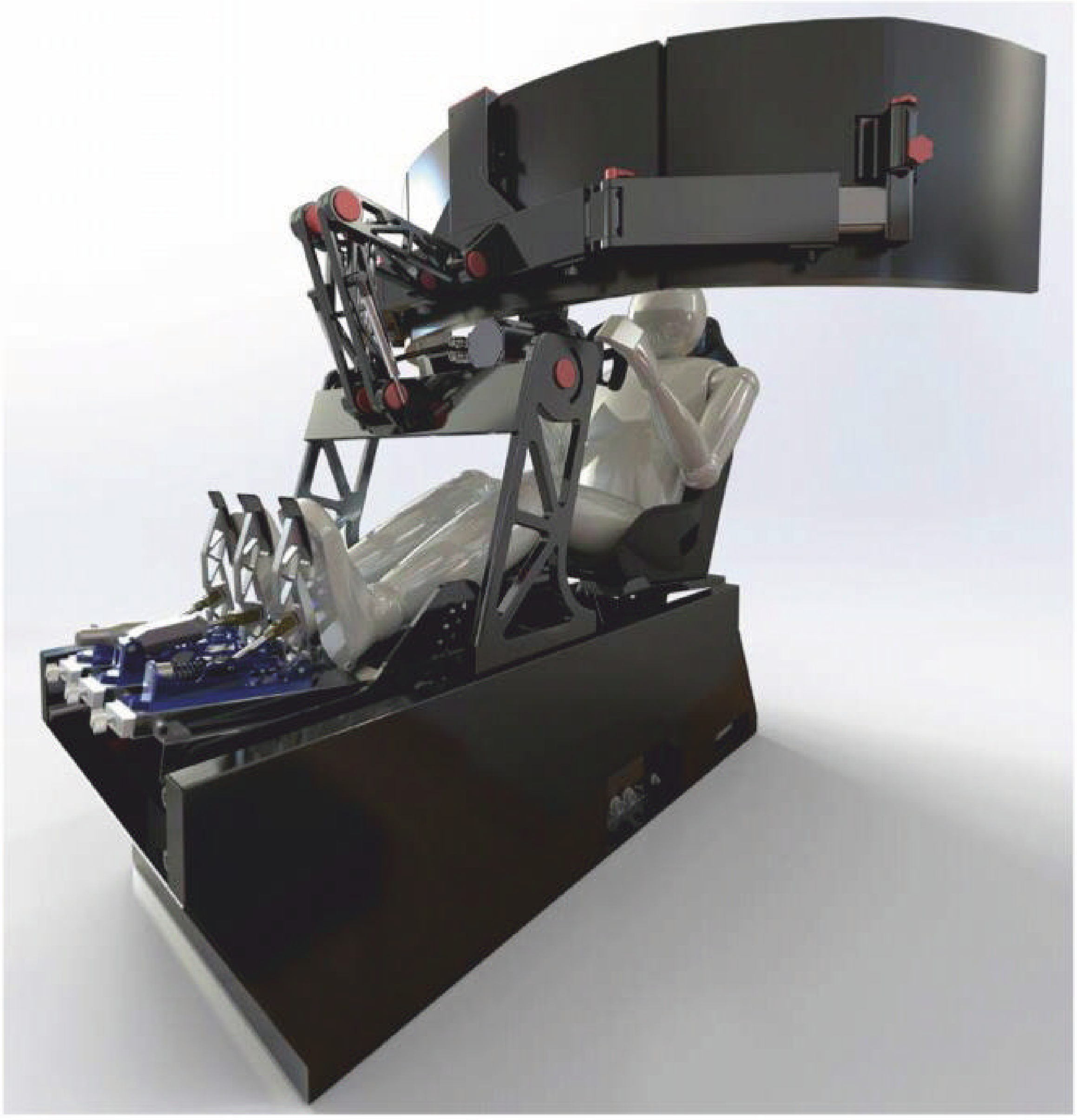
Dennis Marcus, commercial manager at Cruden

THE ULTIMATE DRIVERS RIG

The new race simulation rig from Greaves 3D Engineering is suitable for all ranges of driver from karting to Formula 1. It is the most adjustable of simulators that allows the user to fine tune the driving positions to replicate the desired car. There are no need for tools to adjust the positions.

Features include:

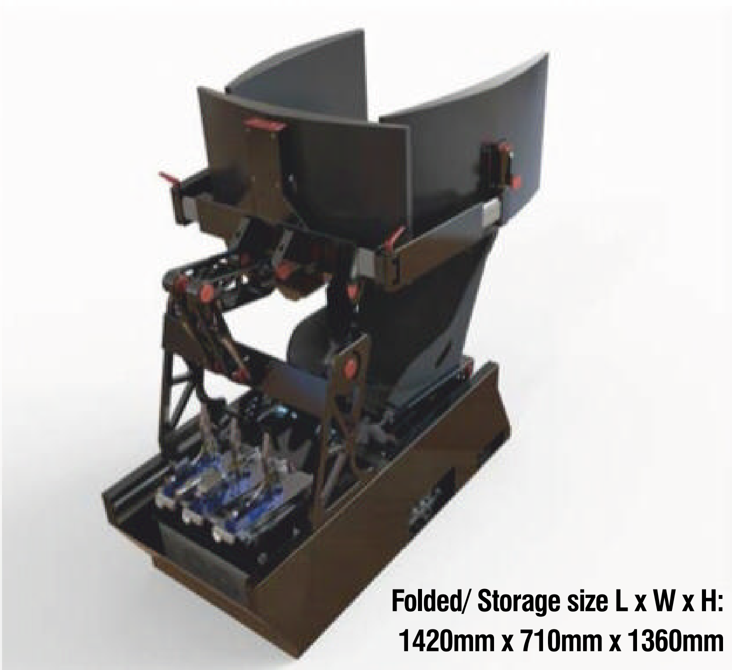
- A complete turnkey solution
- Direct drive steering system and multifunctional sim racing wheel, as used by the professionals
- Sim racing pedals from HPP Simulation, with a purpose designed hydraulic brake pedal to give the true feeling of race car brakes
- Ultrawide field of view with 3 x 32" gaming monitors
- Adjustable seat angle, pedal, steering, and monitor positions. The user can easily change between Karting, GT, Rally, LMP and F1 driving positions
- Folds up easily and quickly to a compact size for storage and easy transportation to the racetrack and events.



The base of the rig houses all the electronics and a bespoke gaming PC. The high end computer system comes with a 2080 Ti graphics card and is fully compatible with iRacing, RFactor 2, Assetto Corsa etc.

The rig comes with castor wheels combined with levelling feet to allow for easy movement and once in position a stable and level platform can be achieved. In addition to all the other features there is a keyboard tray and mounting points for handbrakes and H-pattern shifters.

The simulator can be easily folded away when not in use to a compact size of 1420mm in length, 710mm width and 1360mm high.



Folded/ Storage size L x W x H:
1420mm x 710mm x 1360mm

Accessories and Options

Handbrakes and Gear Shifters
- Various H-pattern and sequential shifter options available
- Handbrake options available

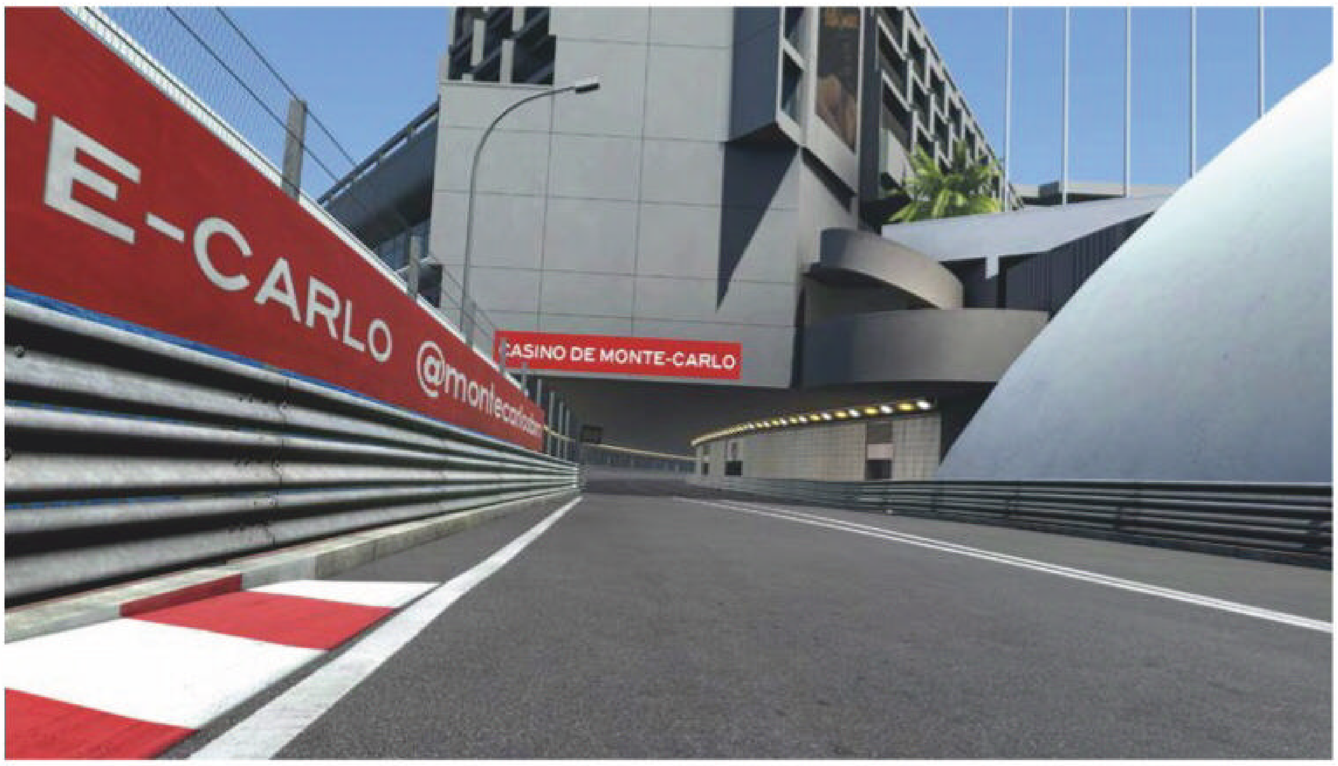
Steering Wheels
- Various steering wheel options available for - GT , Formula, F1, Rally etc
- F1 / LMP style wheels with integrated hand clutches and displays

Accessories
- Multimedia keyboard
- Wireless headphone

Website: www.greaves3d.com
Email: info@greaves3d.com · Tel: +44(0)1733 259400 / +44 (0) 7766040604
Units 1-2 Talon Court, Eagle Business Park, Peterborough, PE7 3FW

GREAVES 3D ENGINEERING

Simulating reality in games and high-level engineering simulators creates many of the same challenges, yet require different approaches



The surrounding environment of the racetrack is carefully replicated as these provide vital visual cues to the driver

The key to achieving the high fidelity required in engineering simulators is to ensure the vehicle models, along with the motion platform, are all running in real time. To achieve this, models are run on a real time hardware system, such as those developed by dSpace. These are essentially a computer that guarantees certain processes will be completed within a time step of a millisecond, or 1kHz.

'There is a big push in engineering to make sure that every test is repeatable, so you have to run on real time hardware to ensure the one millisecond time steps the models are solving are exactly one millisecond of real time,' explains Daley. 'We have a dedicated server, our TerrainServer, which handles the high definition road surface and that runs on real time hardware directly linked to the customer's vehicle model. It is purposely designed to process those huge volumes of data in real time.'

rFpro's TerrainServer is run independently, but in parallel with the graphics. 'This means you can start to distribute the job of doing the simulation across multiple machines,' says Nick Harrison, motorsport manager at rFpro. 'Which is not something gaming companies have the money or capacity to do. Therefore, in theory, you'd be serving your terrain data from one very high-powered machine and render your graphics on another machine whilst doing your physics on a third machine. This means we aren't constrained by the size of these data sets.'

Refresh rate

Another major difference between gaming and engineering simulators is the latency and refresh rate of the graphics. 'At rFpro we do no pre-rendering of frames. In some gaming technologies, they'll take the advantage of adding in an extra frame of latency so they can use that extra time to do additional lighting passes, but in rFpro we don't do any of that,' notes Daley. 'We also run the system at a high frame rate as this is one of the key ways to reduce latency.'

In engineering simulators, the refresh rate of the visuals is dictated by the projectors. For many years, the standard has been 120Hz, but recent developments in projector technology mean 240Hz projectors are now available.

'Visual displays are evolving quite rapidly at the moment, and every year there is a new generation of projector that's brighter and has a faster response,' highlights Hubbard. 'The human eye responds beyond 500Hz, and you need to be refreshing the visuals at 120Hz or above to provide low latency smooth motion to the driver. We blend multiple projectors together to provide a wraparound screen, but LED panel technology and VR [virtual reality] headsets are also starting to become an attractive option as the technologies becomes more capable and affordable.'

For racing games, the frame rate of the graphics is limited by hardware performance and current technology, and the fact that the software needs to run effectively on a variety of hardware configurations. 'Every sim racing developer knows that you have to combine realistic physics with high frame rates, good quality graphics and sound fidelity if you want immersivity,' reveals Vasilakos. 'Sometimes, trying to implement an extra layer of complexity to the model can bring the frame rate down too much so we have to research different ways of implementation to achieve that.'

Of course, simulations only have value when they are correlated with reality. For gaming companies, the approach is to use timing information and any logged data they receive from manufacturers to validate the telemetry data from their sims. They also utilise drivers' feedback to help tune the more subtle areas of the vehicle and track models.

Human input

'Over the last few years we've been lucky enough to get a number of the F1 drivers to play the game, and to feed back to us while doing so,' reveals Mather. 'More recently, you'll have seen the likes of Charles Leclerc and Alexander Albon going head to head in the F1 Virtual Grand Prix series. Even the anecdotal comments they throw out there provide us with useful nuggets of knowledge.'

The engineering simulators, unsurprisingly, require a much more comprehensive approach. Before a driver even gets in the simulator, teams run straight line simulations offline to check the general characteristics of the vehicle model, such as aerodynamic and mechanical balance. After this, dynamic and quasi-static lap time simulations are completed to prove out the model around a circuit. This outputs a potential lap time that is most likely undriveable by a real human and so, to correlate the model with reality, a real driver then needs to be used.

'The most important time for any simulator correlation is that first half an hour on a Monday when the drivers get back from a race weekend and have the latest information on what the car felt like to drive,' explains Daley. 'Teams will usually run the same qualifying set-up in the simulator as they did at the weekend, so the drivers are directly correlating a single lap between the real world and the simulator. They then get the drivers' subjective feedback, along with quantitative data from the vehicle model. Correlation is so important because if your vehicle model correlates well, then you can use the rest of your time to add performance to the car. But if it's not correlating well, there's pretty much no point in doing any performance work.'

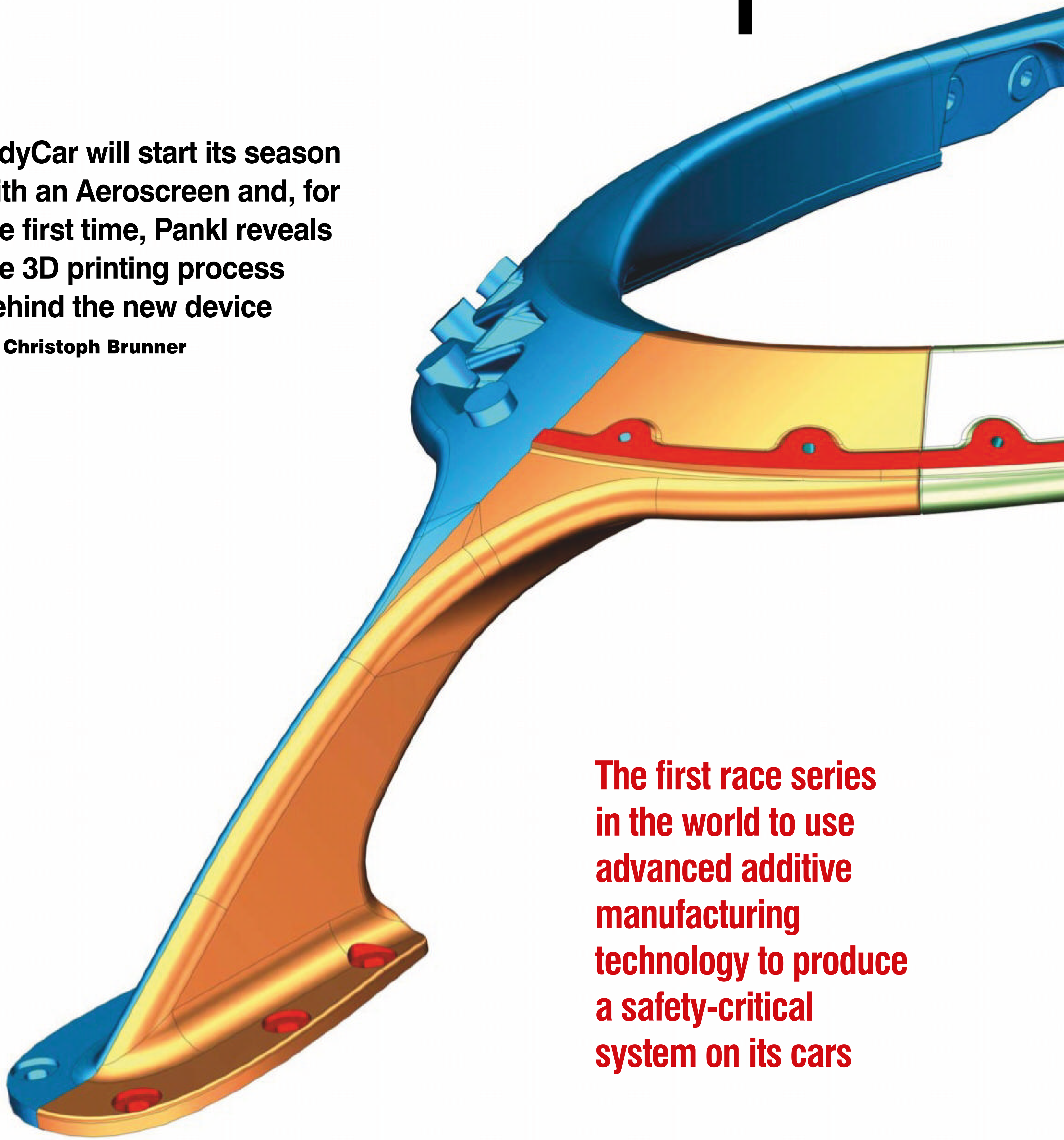
Simulating reality in games and high-level engineering simulators creates many of the same challenges, yet they require different approaches. Arguably, gaming platforms have a tougher job as they can only rely on visual cues to fool the driver. Engineering simulators, on the other hand, have many more capabilities, but consequently require significant ongoing development to ensure each feature has been accurately tuned to represent reality.

Either way, with simulation technology developing so rapidly, the lines between driver training and engineering simulators will start to blur even more in the future.

Frame up

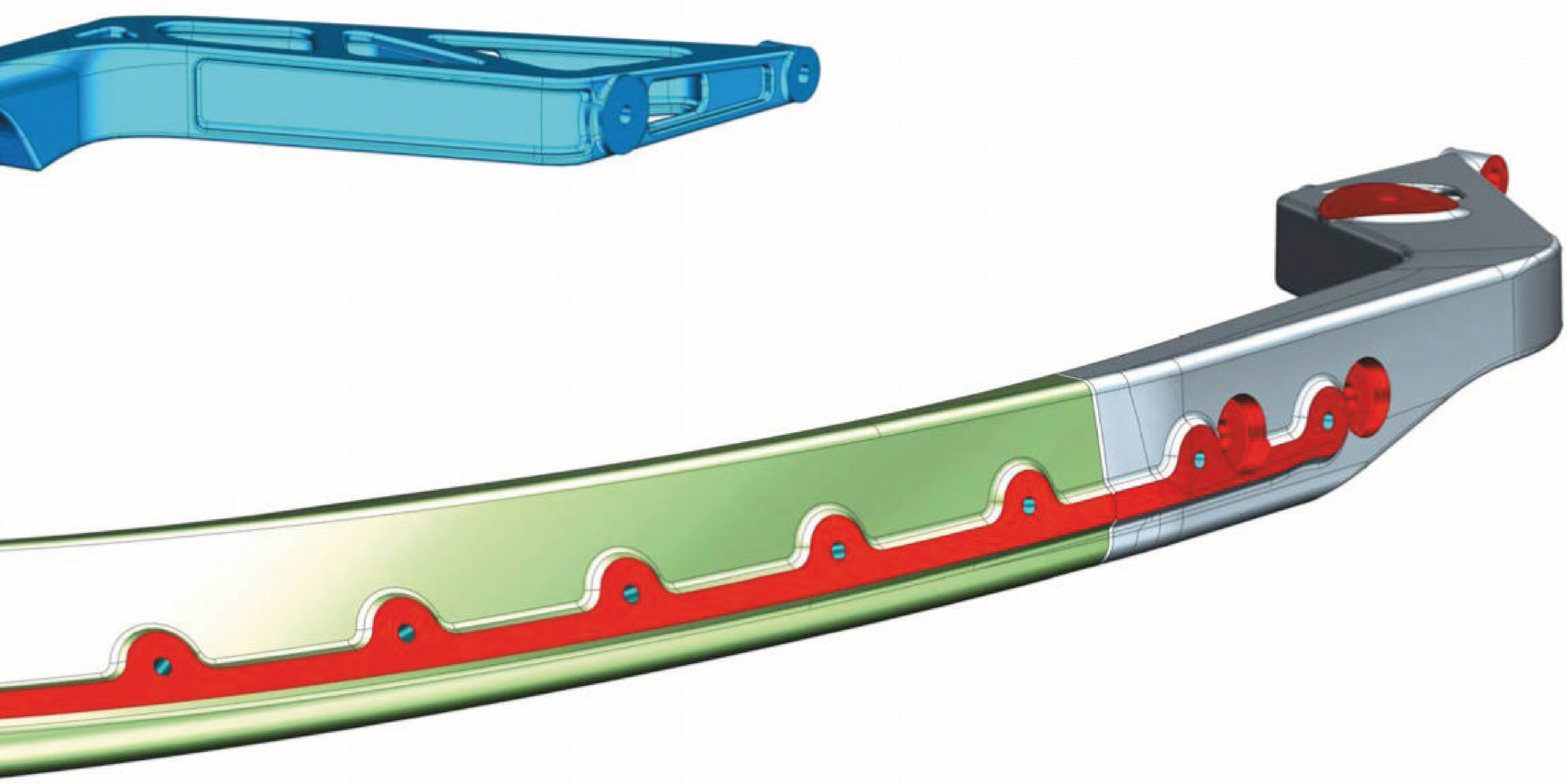
IndyCar will start its season with an Aeroscreen and, for the first time, Pankl reveals the 3D printing process behind the new device

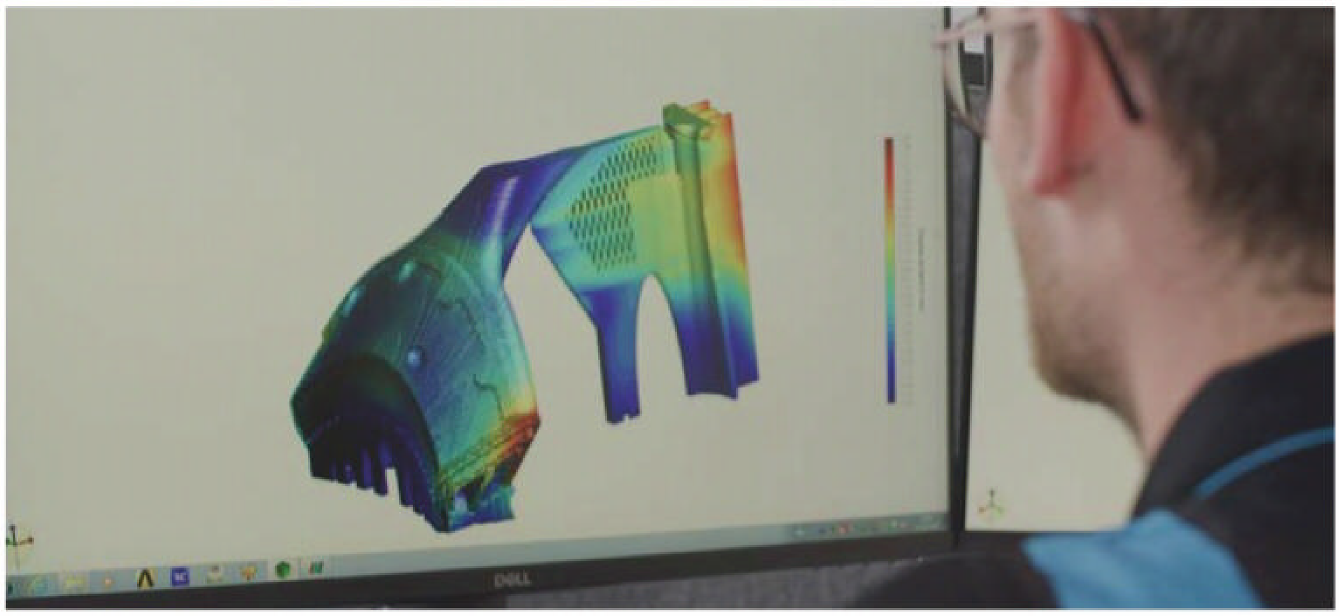
By Christoph Brunner



The first race series in the world to use advanced additive manufacturing technology to produce a safety-critical system on its cars

It is no coincidence the basic shape of the titanium structure that supports the polycarbonate screen echoes that of the FIA-sanctioned Halo safety device





Initial design work was done by Red Bull Advanced Technologies (RBAT), but frame manufacture was undertaken by Pankl

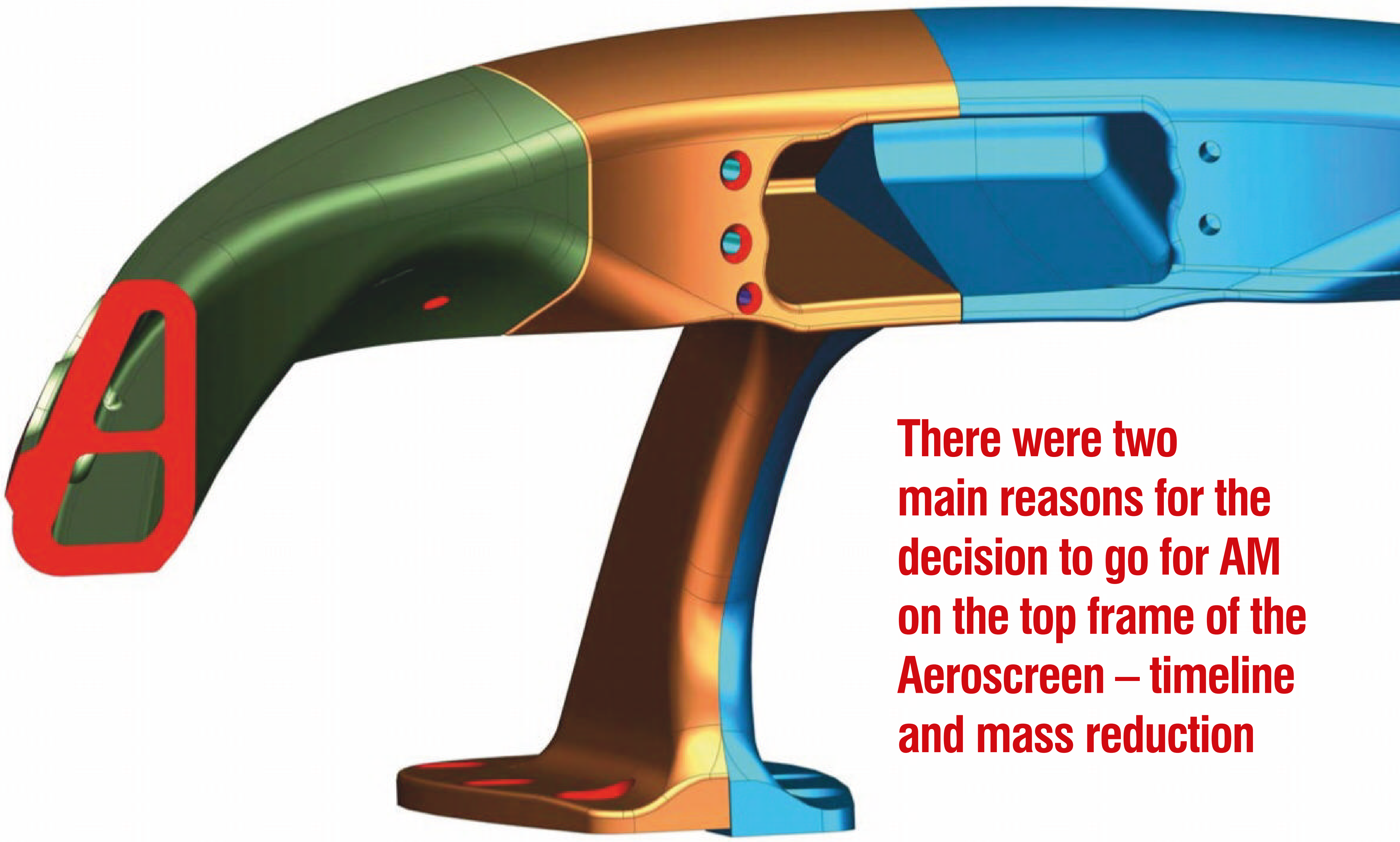
IndyCar's new Aeroscreen will be under close scrutiny this year as it makes its race debut, but the extraordinary device has already been extensively tested and both organisers and manufacturers are confident it will pass muster on track.

The device is made up of a 3D printed titanium framework designed by Red Bull Advanced Technologies (RBAT) and built by Austrian company Pankl. The screen is developed by PPG and is designed to protect the driver against small part intrusion into the cockpit.

However, the tube structure on which the polycarbonate is mounted is a work of art. Weighing just 12.25kg (27lb), the titanium top bar is made from five 3D printed pieces welded together in a form that resembles the Halo safety device that has been widely adopted in FIA-sanctioned racing.

Several manufacturing methods were considered in the first instance as the development cycle began. The initial design was made for titanium casting (Ti-casting), but it became apparent that the timeline to produce the volume of Aeroscreens needed for the first race of 2020 was too tight to use that method. 3D printing then became the most feasible option and Pankl, as a well-known racing industry tier one supplier, became the chosen partner for industrialisation.

The Aeroscreen assembly consists of four sub-systems: carbon fibre frame bonded onto



There were two main reasons for the decision to go for AM on the top frame of the Aeroscreen – timeline and mass reduction

the chassis; top frame (the 3D printed structure); polycarbonate screen and an aero fairing. IndyCar is the first race series in the world to use additive manufacturing (AM) technology to produce a safety-critical system on its cars, so there is a great deal of interest in how the technology stands up to scrutiny.

Certainly, in testing it has exceeded expectations. As covered in *RE* V30N2, the 'screen that was initially lab tested went on to be used on a car, such was the strength of it.

Additive manufacturing

Compared to conventional machining methods where material is usually removed from a solid block to create the final shape, additive manufacturing is the exact opposite. It is adding the raw material, in this case titanium powder, together into the final geometry.

To do so, the 3D file to be printed is sliced into a large number of very thin and flat two-dimensional layers. The part is then built up in those layers using an energy source such as an electron beam or laser to fuse the powder into a solid structure.

After one layer is finished by the laser, a re-coating system puts fresh powder on top and the loop starts again, and so the part grows layer-by-layer in z-axis as the third dimension, which is the reason it is also called 3D printing.

There are several benefits AM can offer compared to conventional production technologies such as casting or machining out of solid. The first is it can help to reduce 'old school' manufacturing restrictions. It offers completely new design possibilities, often together with integrated functions like internal cooling galleries and, due to the fact that complex structures can be printed together as one piece, a reduction in the number of components needed for an assembly.

It also opens up new design options, such as hollow or topology optimised designs, which can additionally help reduce the weight of a part. Any material not needed to fulfil the function of the component can simply be avoided in the printed process. Only in areas where solid material is really needed is the powder melted and turned into a solid structure.

Another big advantage is the potentially significant lead time reduction compared to conventional machining processes. The reason here is that, generally speaking, 3D printed parts do not need any specific tools or jigs which significantly contribute to the cost and time involved in the component manufacturing process. The necessary support structures to hold the part on the build platform are simply printed, together with the part itself, in one shot. If additional machining of functional surfaces with tight tolerances is required on the final part, the amount of time spent in CAM programming and machining is small, compared to producing a fully machined component.

This reduced lead time can allow for additional development loops and testing of several different technical options in parallel on the dyno or on track.

To turn attention towards cost, AM can have an advantage on smaller production volumes, and especially on large but thin-walled and intricate parts as complexity in printing is 'for free'. For high volume, mass production of simple, non-performance components it has to be said conventional machining or casting is still the more cost-effective solution.

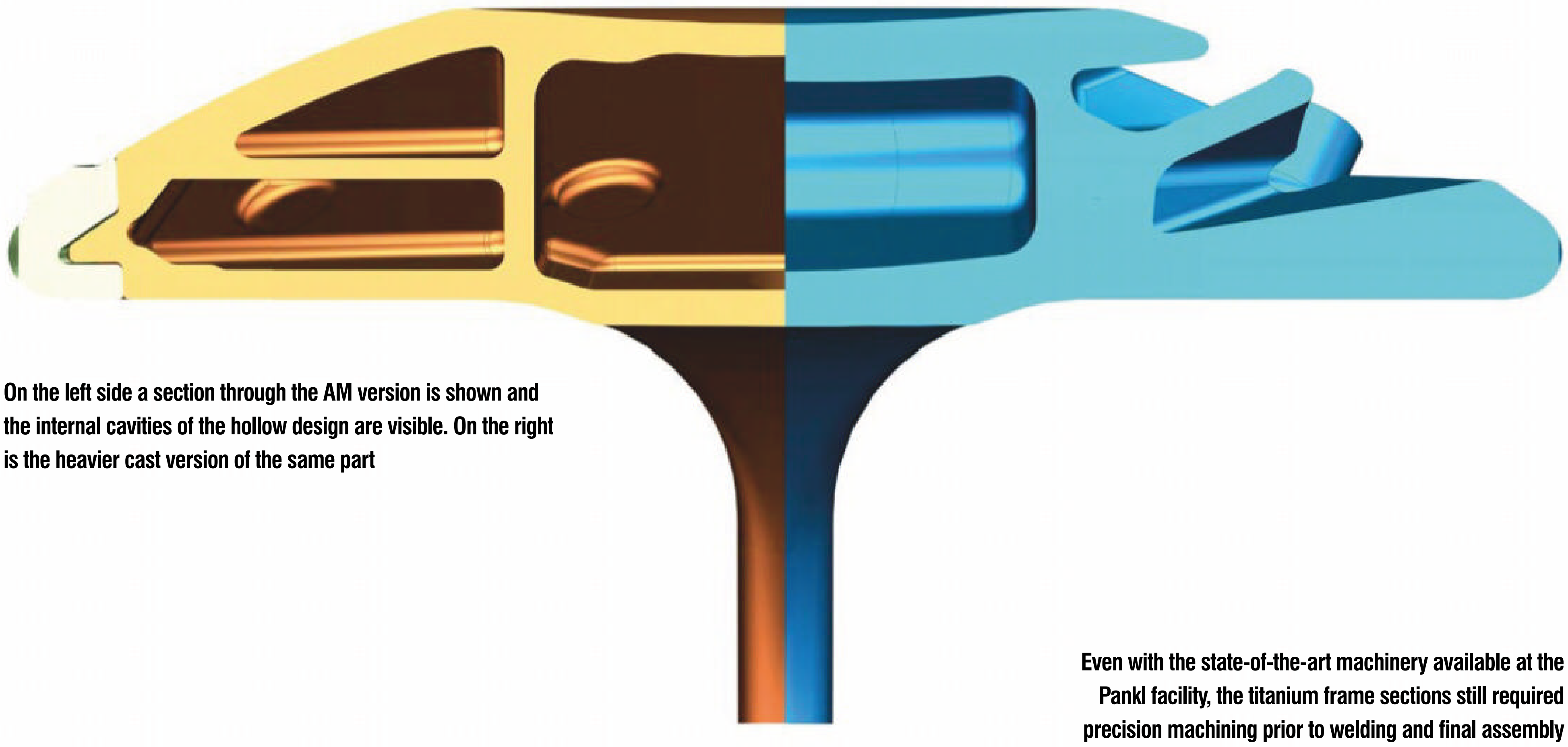
Time and weight

There were two main reasons for the decision to go for AM on the top frame of the Aeroscreen; timeline and mass reduction.

The overall project time schedule was very tight. Starting from the decision to have an Aeroscreen in IndyCar in 2020, the target was to have the first systems available at the first track test, a two-car test with Will Power and Scott Dixon at Indianapolis on 2 October 2019. The target was also to have extra parts available on time for the 2020 season's homologation. With any other manufacturing option this timeline was simply not achievable.

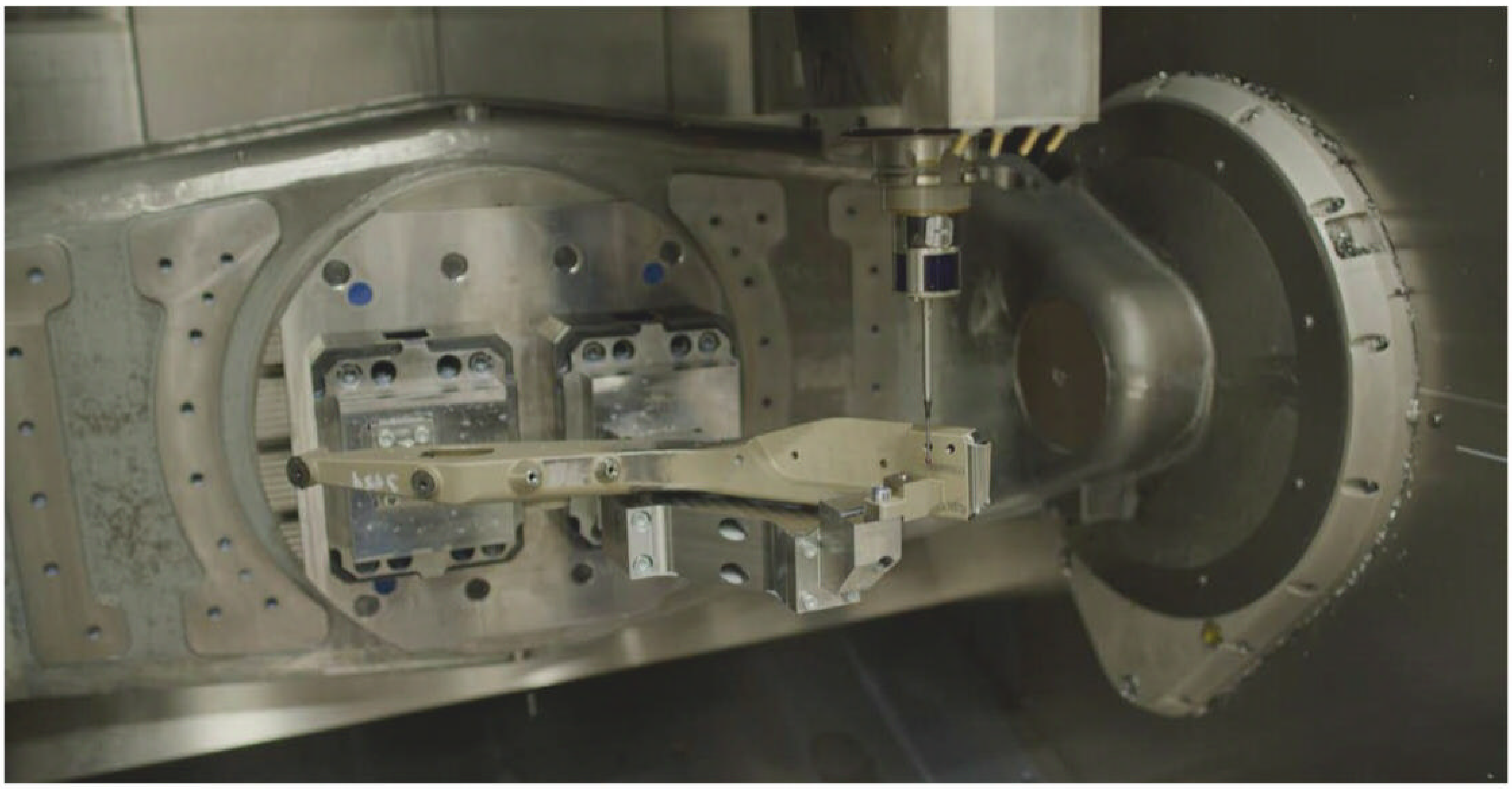
So tight was the timeframe that for the initial test of the Aeroscreen the first top frame prototype had to be flown in the hand luggage of a Pankl designer from Austria to the US.

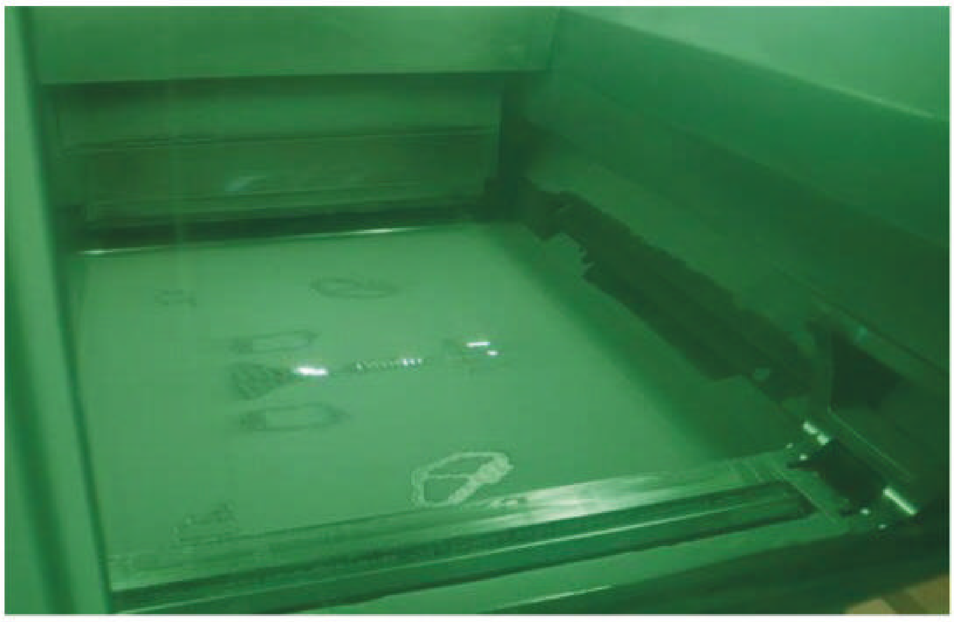
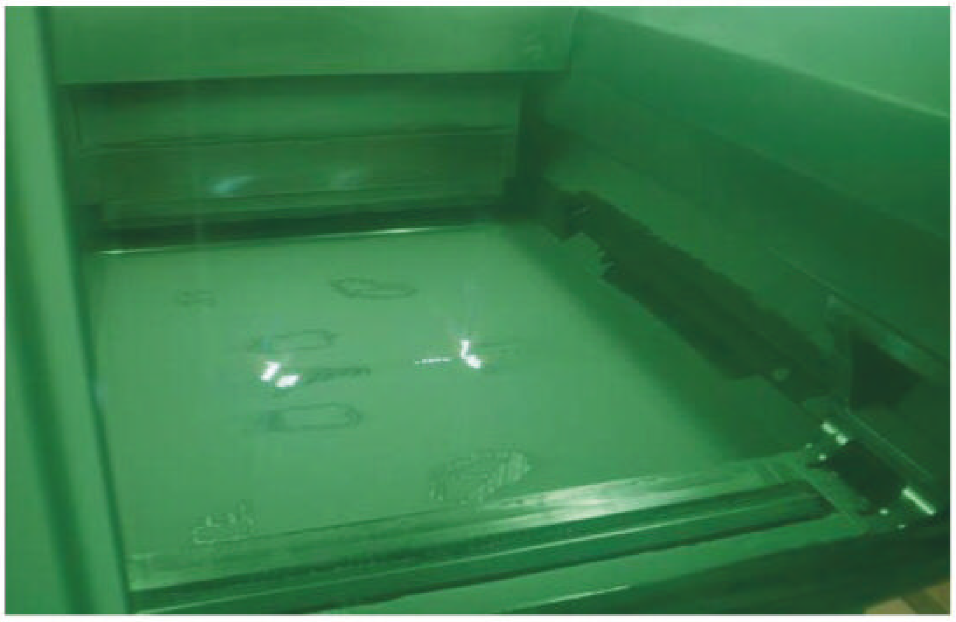
The second reason is a mass reduction benefit compared to casting, which helps keep



On the left side a section through the AM version is shown and the internal cavities of the hollow design are visible. On the right is the heavier cast version of the same part

Even with the state-of-the-art machinery available at the Pankl facility, the titanium frame sections still required precision machining prior to welding and final assembly

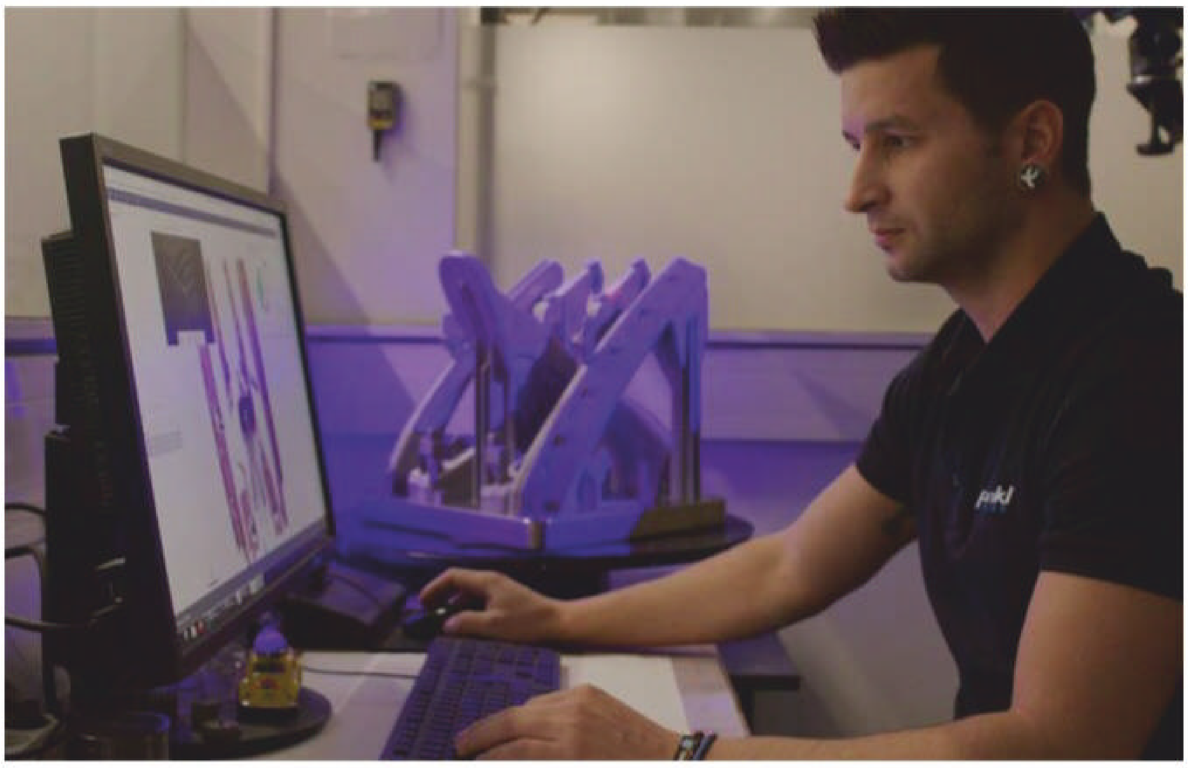


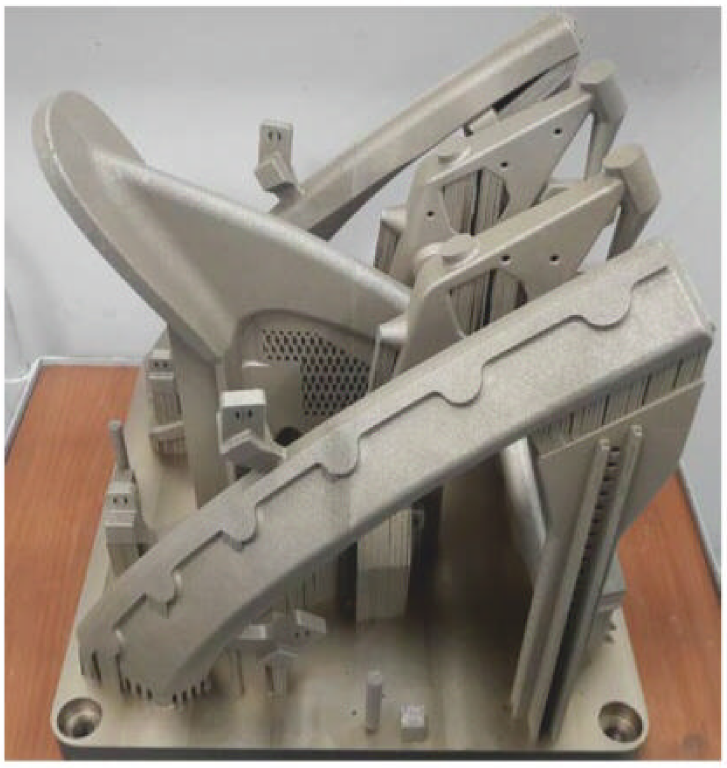
The print job takes around 72 hours and cameras situated near the laser optics take powderbed photos of every layer as they are built up for detailed analysis afterwards

A very tight communication network and immaculate project planning between all the different members was key for success

When the print job is complete, a vacuum cleaner system draws out any residual powder, which is sieved and then re-used



Printed parts are then scanned with a 3D optical scanner and validated against the original CAD files



The printed parts, still attached to the baseplate and with supports

the impact on the overall car weight and the c of g as small as possible.

As previously stated, the AM version of the frame weighs 12.25kg (27lb), about 1.6kg (3.5lb) less than the initial cast titanium design.

System partner

For more than 30 years, Pankl has been a supplier into top-level motorsport, high-performance automotive and aerospace industries. For all these markets the company serves not only as a supplier, but also as a system partner for complex projects.

Together with its partners, EOS and Böhler, Pankl has established an EN9100-certified additive manufacturing competence centre in Austria where it can cover the complete value chain of AM, starting from powder production through printing, heat treatment, including hot isostatic pressing (HIP), validation and final machining of printed raw parts. As AM technology is still quite new, compared to more conventional production processes, there are only a small number of companies worldwide capable of printing titanium parts of the size required for the Aeroscreen. Never before has a component such as this been produced with this technology, so the racing world is watching with great interest.

From Pankl's point of view, covering the complete process chain from cradle to grave is a firm basis for establishing AM as a relevant technology for high-performance parts.

V system

WE ARE FORMING THE IMPOSSIBLE

V System s.r.l. was founded in 2013 thanks to the commitment of **Veca S.p.A.**, who is the majority shareholder, with the intention to extend its long-term experience in manufacturing of machined components for motorsport also in the exhaust systems field.
The factory is situated in **Fiorano Modenese**, near the homonymous test circuit, and includes a covered area of 850 m^2 for the production site, 300 m^2 for offices and a climate-controlled inspection room.
Our core business is the manufacturing of high precision **exhaust systems** for motorsport applications made of **nickel and titanium alloys**.

Tube bending

The company owns the equipment for the production of small and medium-sized batches of pipes by using rolling technology. We are also specialized in **thin-walled pipe bending** (0.7 to 1.2 mm). Pipe bending is carried out by using the latest tube-bending machinery with 9 electric axes **CNC controlled**.

Hydroforming

Hydroforming is a manufacturing technology which allows to obtain pipes shaping (at room temperature) by using **high-pressure water**. This method enables manufacturing of closed sections with non-uniform cross-sectional areas along the pipe axis by using a circular tube as input material.

Welding

All the members of our staff in welding Dept. own **EN certification** of GTAW of Ni alloys, Ti alloys and Stainless steel. They have decades of experience in welding motorsport components manufactured in any type of material. We are able to perform manual and automated welding and in the Company is also available a **cabin** for the execution of joints in **inert atmosphere**.

For any inquiries, please contact:
V SYSTEM s.r.l.
Tel: +39 0536 035.111
e-mail: info@vsystem.it
web: www.vsystem.it

We are a part of:
VECA GROUP
THE NAME OF HIGH TECHNOLOGY

The first heat treatment is a stress relief annealing done in a fully automatic ALD Modultherm oven. Note at this stage the parts are still on the base plate with their support structures intact

It was an exciting project, and a big team effort was needed to deliver the parts on time.

As covered in *RE* V30N2, Pankl's main partners in this project were RBAT, which was involved in the design and validation of the product, and V System in Italy who took responsibility for welding the printed components into the final one-piece assembly.

Each individual process required extra special attention as the development work was done at the same time as manufacture.

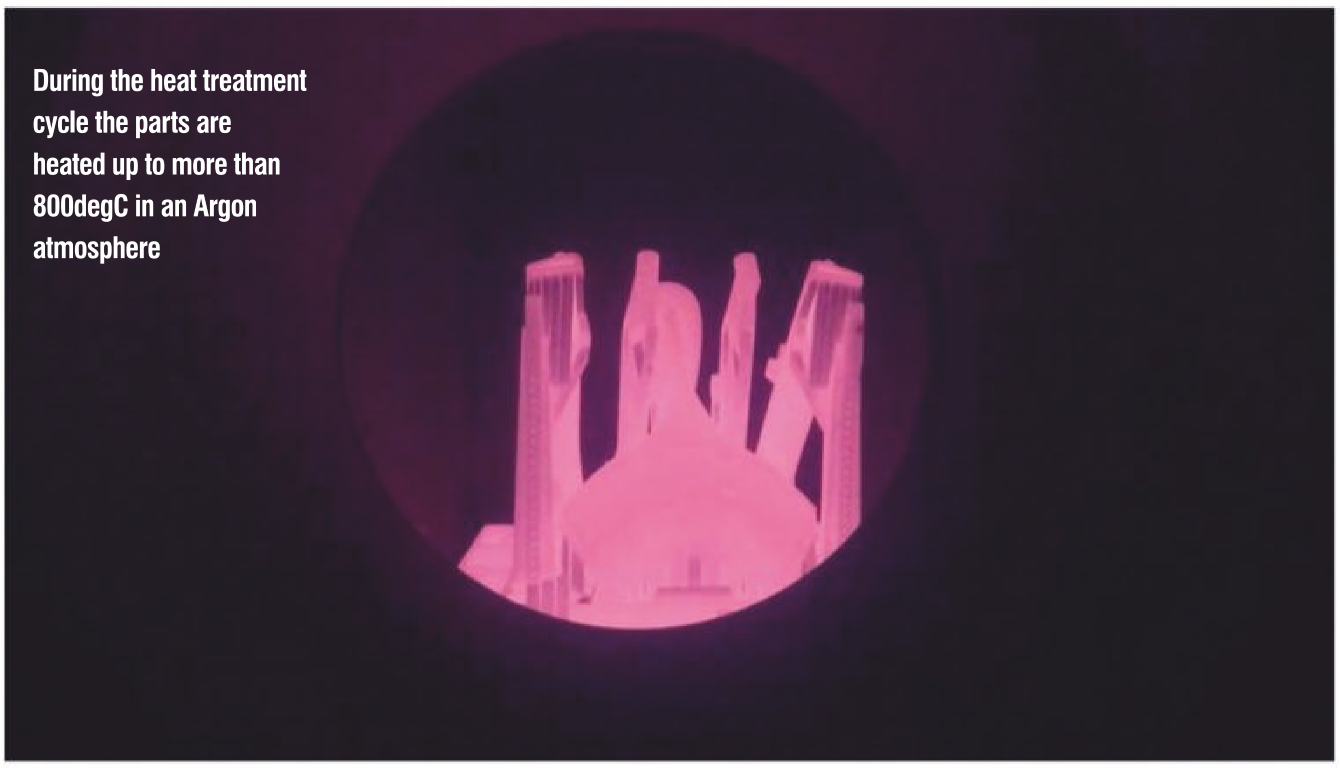
Immaculate planning

On top of that, a lot of steps had to be taken in parallel so a very tight communication network and immaculate project planning between all the different members was key for success.

When the switch was made from Ti-casting to AM, Pankl and RBAT had to re-design the part to make it printable, and that required some additional processes to be accounted for, including minimum wall thickness, removability of the powder from the internal cavities and minimum surface overhang angles, all of which are critical parameters in 3D printing of metal components.

For a perfect result, the designer needs to fully understand key elements of the production process, such as temperature distribution and internal stresses. In AM, the design and production of a component goes hand in hand, and even just a very slight adaption to the part's orientation on the print platform will have a significant impact and require a change of design. It is a key element in metal AM in particular to understand the strong dependence between part design and its impact on the print process to explore all the benefits this developing technology is offering.

An additional challenge was the size of the top frame. Due to the overall dimensions it could not be printed in one piece, even on the biggest printing machines currently available. So Pankl had to cut the top frame design into five single pieces for efficient printing on its EOS M400-4. This state-of-the-art AM production system is a multi-laser machine with a 400 x 400 x 360mm build space. Four 400W lasers work in parallel during the print process to significantly improve the production speed compared to single laser systems.



During the heat treatment cycle the parts are heated up to more than 800degC in an Argon atmosphere

It is a key element in metal AM in particular to understand the strong dependence between part design and its impact on the print process

After the design of the final part is fixed, the raw part design for printing can be generated, with extra material where necessary for machining functional areas, support structures and mounting points for final machining.

These additional points support the part as it is being built and allow for clamping during finish milling, so need to be strong enough to hold the parts securely, but also as small as possible to reduce material wastage, print time and therefore cost.

Once the raw part designs were finalised, Pankl could start to perform several loops of print process simulation to investigate internal stresses and optimise temperature distribution and compensate for any potential deformations during the print job.

This work requires advanced simulation tools but is critical to ensuring each printed component reaches the highest quality

The approach follows the strict guidelines in place for aerospace EN9100 requirements

standards. And as the Aeroscreen's top frame is a safety critical component, the approach follows the strict guidelines in place for aerospace EN9100 requirements.

The entire job file and all related printing parameters such as layer thickness, laser speed and power and process temperature are defined on the homologation parts and frozen to ensure each subsequent printed part is identical.

Production process

The print job takes approximately 72 hours from the start until the final layer is finished. During this time, the EOS M404 printer is working automatically without a human operator.

After the print job is finished, any residual powder in the machine is removed by a vacuum cleaner, sieved and put back into the loop to be used on the next printed part. The baseplate with the finished print job on it is then taken out of the machine and cleaned carefully to remove any further powder residuals

In terms of quality assurance, Pankl uses various tools, both during and after the print process. For example, on each single layer of the print job so-called powderbed pictures are created automatically by a camera installed inside the EOS M404 machine next to its laser optics. These thousands of pictures are investigated using a specific software to ensure no irregularities during the print job.

Tensile test specimens are printed together with the parts and tested immediately afterwards by Pankl to monitor the material properties like UTS, YS and break elongation. Together with the tensile tests, so-called density cubes are also printed. These are cut afterwards in the Pankl internal laboratory to check the density of the printed material is within the specified tolerance parameters.

The finished printed parts are also inspected using an optical 3D scanner, which takes pictures of the parts while they are rotating on a platform. The individual pictures are put together by software into a 3D file that can then be compared with the 3D CAD file used for printing, again looking for any deviations or deformations outside of given limits.

The 3D scanned parts then go to their first heat treatment, a stress relief annealing to reduce the residual stresses inside the parts and their supports structure caused by the thermal energy input during the print process.


Welding titanium is a highly skilled job and V System in Italy developed a series of specific welding parameters for Aeroscreen fabrication


The finished part goes through several validation and quality checks before being sent to the IndyCar facility for assembly

The heat treatment of the printed parts is done in a fully automatic ALD Modultherm oven, located just next to the printing machines to ensure effective logistics and short lead times. During the heat treatment cycle the temperature of the parts reach over 800degC in an argon atmosphere. After heat treatment, a wire erosion process is used to remove the raw printed parts from the build platform and to cut away the support structures.

Machine head

Now it is time for the first of several machining operations in preparation for welding, achieving a level of tolerance on the mating and functional surfaces in microns that can't be reached with the pure printed surface.

The choice of titanium for the Aeroscreen top frame makes for an additional challenge when it comes to welding, but V System is a specialist in such technologies and developed a set of specific welding parameters for the top frame to ensure it is in line with the quality requirements of RBAT and IndyCar.

When the welding process is finished, the complete fabricated assembly is given a second heat treatment, this time to reduce any residual stresses introduced during the welding process and to adjust the final material properties.

The final process in the production of the top frame is the machining of the functional surfaces of the welded assembly to ensure the Aeroscreen fits retroscpectively to the Dallara chassis that was originally introduced in 2012.

After a final quality check, the completed part is put into dedicated packaging, ready for shipment to the IndyCar facility where the top frame is assembled with the other components of the Aeroscreen and finally mounted on the chassis. Only then is the component set for testing and use in competition.

It is always a hope it is never needed but, when it is, the complex part will stand up to the ultimate scrutiny and save a driver's life.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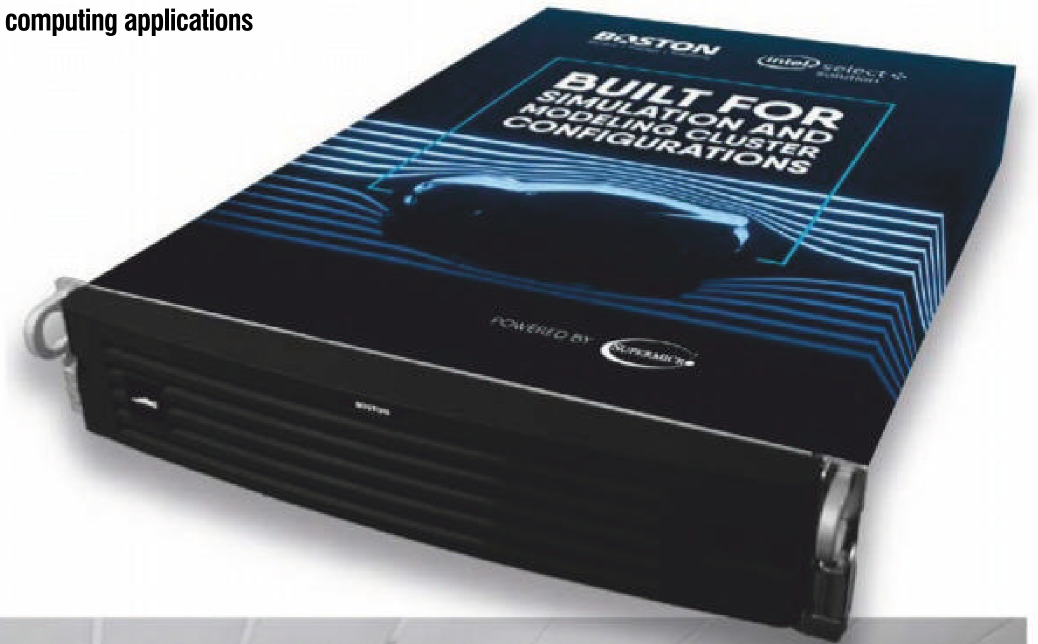
A starting guide to simulation and modeling clusters

When the smallest calculation can make all the difference, you need infrastructure you can trust to run your simulation and modeling workloads at scale

When your workload demands High Performance Computing (HPC) power, a desktop solution won't pass muster. You need to run your simulations at scale and when time is of the essence you can't risk making the wrong decisions over your infrastructure; getting it wrong can be a costly and time-consuming thing to rectify!

Manufacturing and research companies rely on CFD/CAE in an increasingly competitive environment. Such computerisation provides the capability to explore design parameters, reduce prototyping costs and produce optimised products within a short timeframe. Many applications used in CFD/CAE are capable of distributing computation across multiple machines that are configured to act as one; in other words a cluster! An HPC cluster will provide a scalable resource that will deliver support for larger and more complex design models, better-grained models and ultimately vastly higher productivity when compared to a single-system model for simulation workloads.

Boston are experts in computer storage solutions including hosting servers as well as being able to implement high performance computing applications



Multiple clusters are stored in air conditioned rooms that help to maintain a constant temperature that improves reliability across the computational hardware

Getting the HPC configured correctly at the start of the process is critical to saving time and money in the long run; Boston will help customers set up their system from the start

Understandably the idea of designing, installing and managing your own HPC-infrastructure can be daunting. With a multitude of "HPC Solutions" it can come across as a complicated, multi-faceted and sometimes contradictory area of computing that seems like too much of a risk in case it is done incorrectly. Not having the skills or expertise to design, configure, order, deploy and maintain scalable HPC clusters is no doubt a barrier to many.

When it comes to HPC there is so much more to consider than choosing the right core-count CPU, memory and storage configuration. Remote-visualisation, job scheduling and workload management software need to be carefully considered and deployed. In addition, integrating the hardware and the software can swallow up time during assembly – using uncertified hardware and non-validated hardware could mean a lot of time is wasted fixing problems!

Balancing act

Can a balance be struck between the single-system model and scalable HPC clusters? In short, yes! Intel Select Solutions for Simulation and Modeling is a guided path to success. With quick-to-deploy infrastructure that is reliable and carefully crafted significantly reduces the complexity for the purchaser. Boston has been very successful working with key customers in the deployment of Intel Select Solution-based clusters in their CFD/CAE/Simulation and Modeling environments.

Using a standards-based approach defined in the HPC Platform Specification, these solutions provide verified interoperability with common applications used in simulation and modeling.

Intel Select Solutions must also meet or exceed characteristics and performance thresholds that are needed for scaling performance across the cluster. Branded designs such as the Boston Intel Select Solution for Simulation and Modeling have demonstrated these capabilities and are ready for deployment! Furthermore, customers can utilise Boston's expertise in this area, from our technical sales team through to our in-house HPC specialists who can give you as much support in defining your solution as you need.

The recently upgraded Boston Intel Select Solution for Simulation and Modeling typically utilises 2nd Generation Intel® Xeon® Scalable Gold processors, the latest Intel® SSD DC Family for local scratch storage, Intel SSD DC Family storage to augment parallel file system storage and Intel® Omni-Path networking.

This solution can also be customised at Boston to your exact requirements if you need a little more processing power or a different configuration of storage. Our in-house team of experts are available to you from conception to installation to answer any queries or address any concerns you may have. Boston is also pleased to offer remote testing on a number of solutions and configurations at our Boston Labs facility.

For further information, please contact Boston through their website: www.boston.co.uk, email: sales@boston.co.uk, or by phone: +44 (0) 1727 876 100

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2 into 4 will go

Racecar takes an in-depth look at M-Sport's latest iteration of the R2 Fiesta, the Rally4

By Lawrence Butcher

Car is largely stock Fiesta ST body-wise, but the addition of dual air intakes in the bonnet give it a more aggressive look

With the implementation of the FIA's new rally class structure, comprising Rally1 through 5 groups (where Rally1 is the new naming for WRCs, Rally2 replacing R5 etc.), M-Sport was first out of the blocks with a Rally4 version of its Fiesta in early 2020.

M-Sport is unique within the WRC. Though it has a degree of manufacturer backing from Ford, it is not a 'works' outfit in the way Toyota and Hyundai are. Instead, under the direction of founder Malcolm Wilson, M-Sport earns its living building rally cars (alongside an increasing number of projects for other OEMs, such as Bentley GT3). With rising costs in Rally1 / WRC, it sells very few of the top-flight cars, instead relying on sales of its R5 and R2 machinery.

In essence, Rally4 is an updated set of R2 regulations and for M-Sport, the Mk8-based Rally4 Fiesta is an upgrade of its latest R2 car, homologated in 2019. The company was the first to realise the potential of running 1.0-litre, turbocharged engines in the class (as opposed to naturally aspirated 1600cc) when it released the Mk7 Fiesta R2 in 2015. Since then, it has refined the package to improve performance and keep abreast of regulatory developments.

Summing up the latest tweaks, Maciej Woda, who heads up M-Sport Poland where the R2 / Rally4 cars are built, comments: 'The new [2019] R2 was based on the updated regulations, which allowed us to use a different turbocharger [from the OEM road car unit]. We made a lot of changes to the car, so that version was almost entirely new. There are now some small changes to the regulations with the arrival of Rally4 [compared to R2] that, for example, allow for bonnet vents to aid cooling.'

The R2 class was a commercial success for M-Sport. In 2019 alone, it sold 120 cars to competitors in the Junior WRC and European championships. With such a wide customer base, it has been able to gain an insight into areas ripe for improvement with the Rally4 car. Additionally, new competition in the class from the likes of Peugeot provided impetus for further performance upgrades.

Evolution not revolution

To fully understand the evolutions seen in the Rally4 Fiesta, it is necessary to look back to the 2019 R2. This was the first car that was completely designed, built and tested at M-Sport Poland. 'We wanted to make the car faster, cheaper, and more appealing to customers,' explains Woda.

Some of the changes made to achieve that were subtle and focussed on the somewhat subjective area of driver feel. 'The first thing we looked at was the driving position,' says Woda. 'In the previous car, the driving position was compromised, and we wanted to give the driver additional space to position themselves more comfortably in the car.'

TECH SPEC: M-Sport Fiesta Rally4

Chassis
Steel unitary construction

Bodywork
Steel

Engine
999cc, I3, turbocharged, direct injection

Power
210bhp at 6,500rpm / 315Nm torque at 4,000rpm

Transmission
Sadev five-speed sequential, manual shift, 2WD

Front and rear suspension type
MacPherson strut

Dampers
Reiger adjustable hydraulic

Springs
Eibach coils

Brake calipers
Alcon competition four-piston front and rear

Brake discs
Aluminium bells, floating iron discs

Wheels
6 x 15in gravel / 6.5 x 16in tarmac

Wheelbase
2,490mm

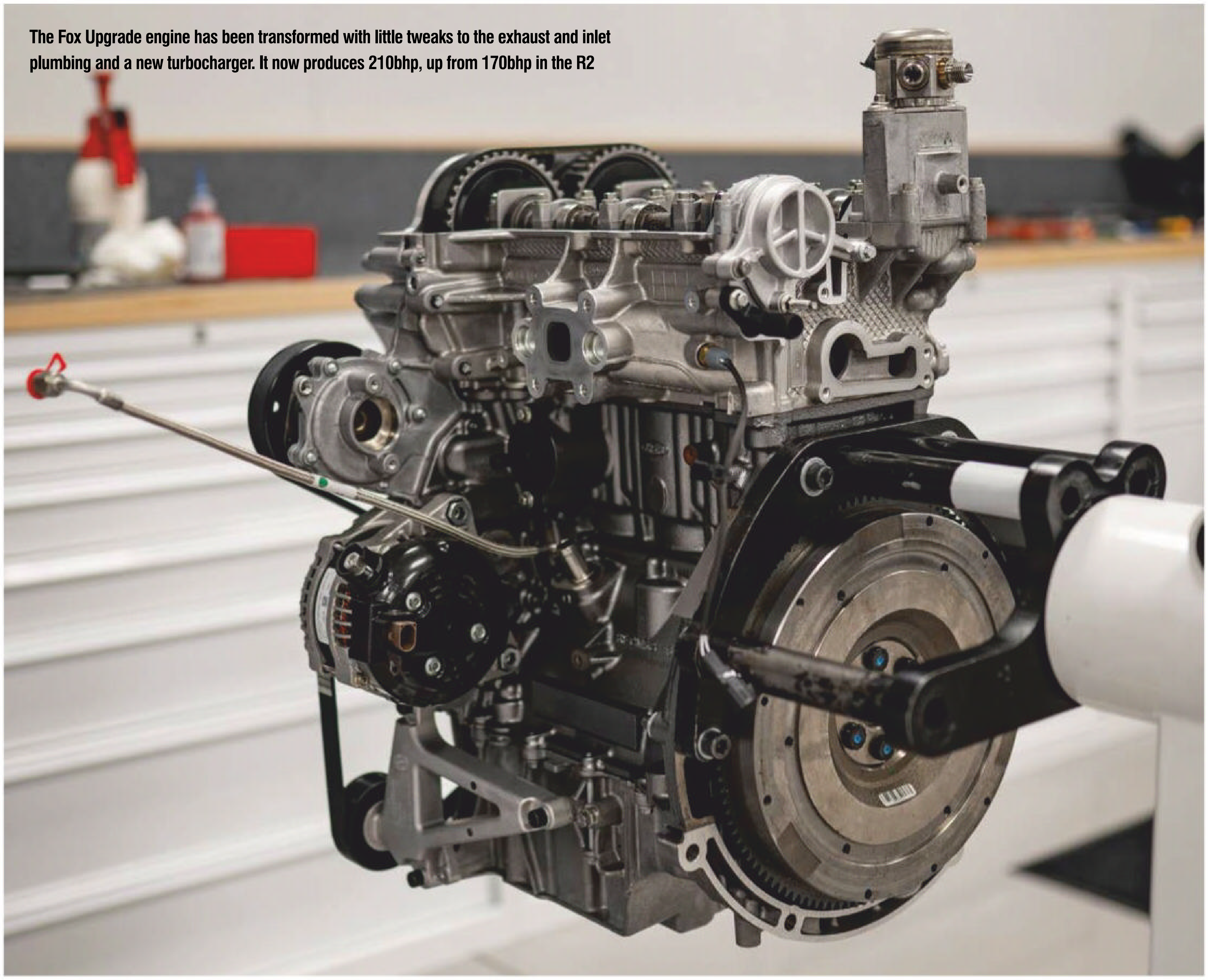
Overall length
3,953mm

Width
1,722mm

Weight
1,030kg

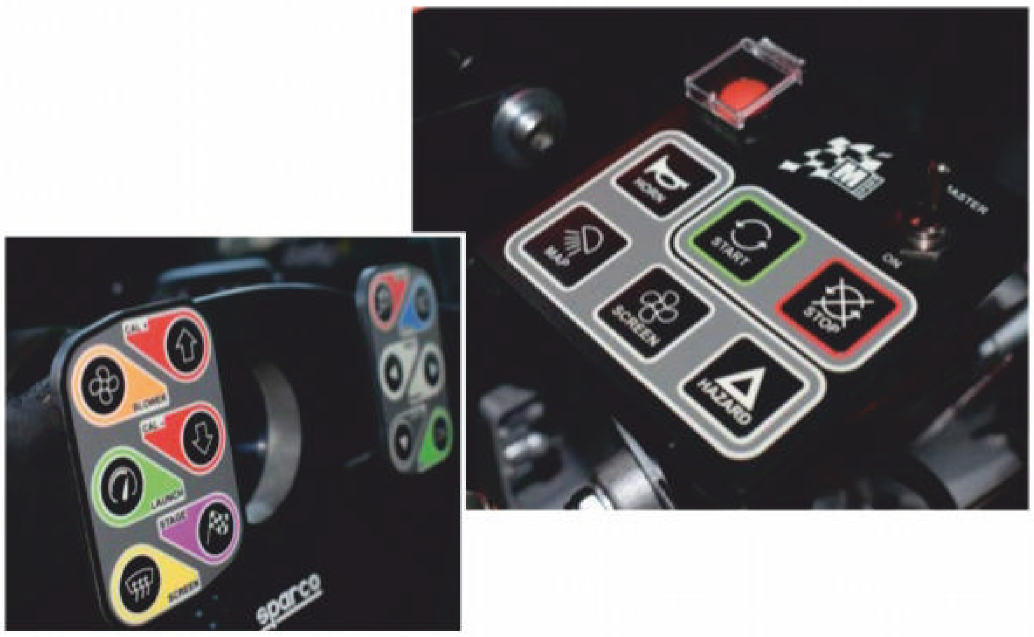
Fuel tank capacity
58 litres

Seat location has been moved back and lower down in the car, improving head room and driver comfort



The Fox Upgrade engine has been transformed with little tweaks to the exhaust and inlet plumbing and a new turbocharger. It now produces 210bhp, up from 170bhp in the R2

Cost is an overarching concern for constructors of cars in this class, with both an overall cost cap on finished cars and price limits on upgrades



As well as simple, easy-to-read switchgear, column-mounted electric power steering from the road car features in the Rally4, which allows fine tuning to suit different driver requirements

Brake use varies from driver to driver and different styles need to be accommodated. Larger front discs are used in gravel spec

Rally4 is not a radical re-design of the outgoing R2 model, but a gradual improvement in a number of areas and a best compromise in terms of performance and price

In practice, this saw greater flexibility in the seat location, allowing it to be placed further back in the car, which created more room above the driver's head and allows the driver and co-driver to sit lower in the car.

'We focussed a lot of attention on the seat mounts, and that is how we managed to find a broader range of seating positions. It is a more expensive seat mount than before, but we made savings elsewhere.'

Further improving the ergonomics of the car, M-Sport also looked at the layout of the controls in the cockpit and introduced revisions to the switches, handbrake and other details which, as Woda puts it, 'help improve the feel'.

Cost vs performance

Cost is an overarching concern for constructors of cars in this class, with both an overall cost cap on finished cars and price limits on upgrades. As such, every update M-Sport made was subject to extensive cost / benefit analysis.

For example, the rules permit the use of bespoke front wishbones if a manufacturer deems them necessary, but instead a modified production part has been retained on the Fiesta. 'It did not make economic sense because we could not improve the suspension travel or geometry,' Woda points out. 'We adopted the same philosophy as before, which is developing the rally car from the road car, using as many road car components as you can.'

Another example of maximising the performance of standard parts can be found in the rear suspension. Tarmac and gravel trim now use different rear beams, with a specific gravel-only production introduced. 'We have implemented a new system on the rear suspension that is more flexible than the previous version,' explains Woda. 'It has not sacrificed much stability, but it improved the grip at the rear of the car. At the same time, we implemented new rear damper shims, so the car is much more driver friendly at the back.'

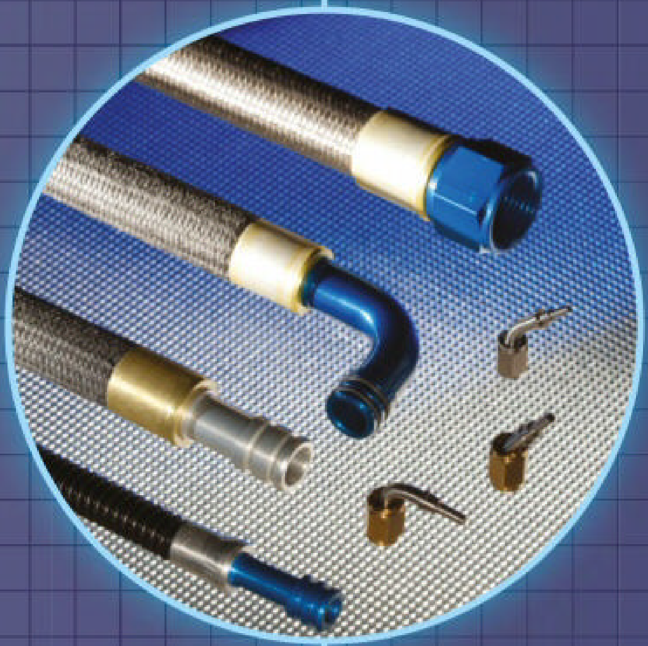
Importantly, the gravel beam is still a standard Ford part. 'It is one supplied on a different version of the Fiesta. It is not that commonly used, and not from the Fiesta ST line [the base platform for the Rally4]. We were looking at this rear beam in 2018 when we first started working on the 2019 version of the R2 car, but we decided not to use it back then. The experience we gained in 2019 led us towards this beam as an option, and we eventually applied it to the Rally4 car.'

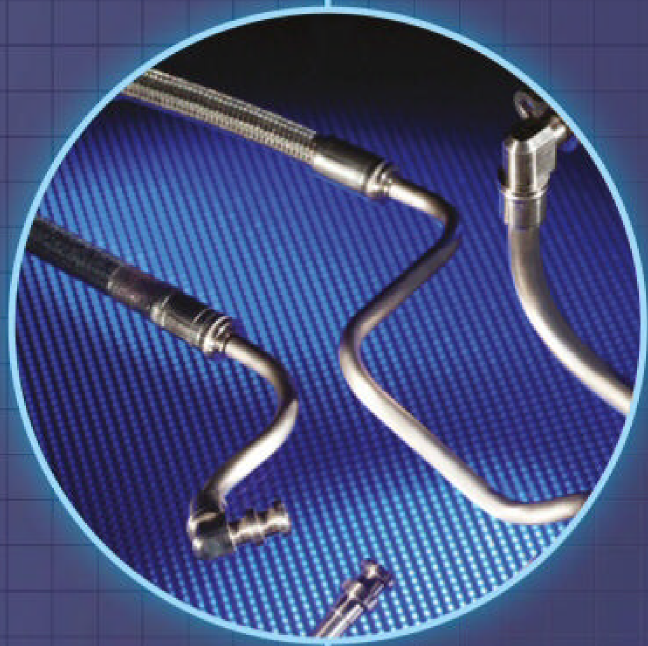
On the subject of dampers, supplied by Reiger, while it is possible to swap parts around to create either a gravel or tarmac-spec unit, this is not the course taken by most competitors, as Woda notes: 'We recommend you have two sets of dampers. That is because it is easier, and it is more cost-effective in the long term. The damper body is the same, but the damper tube is shorter on the tarmac version.'

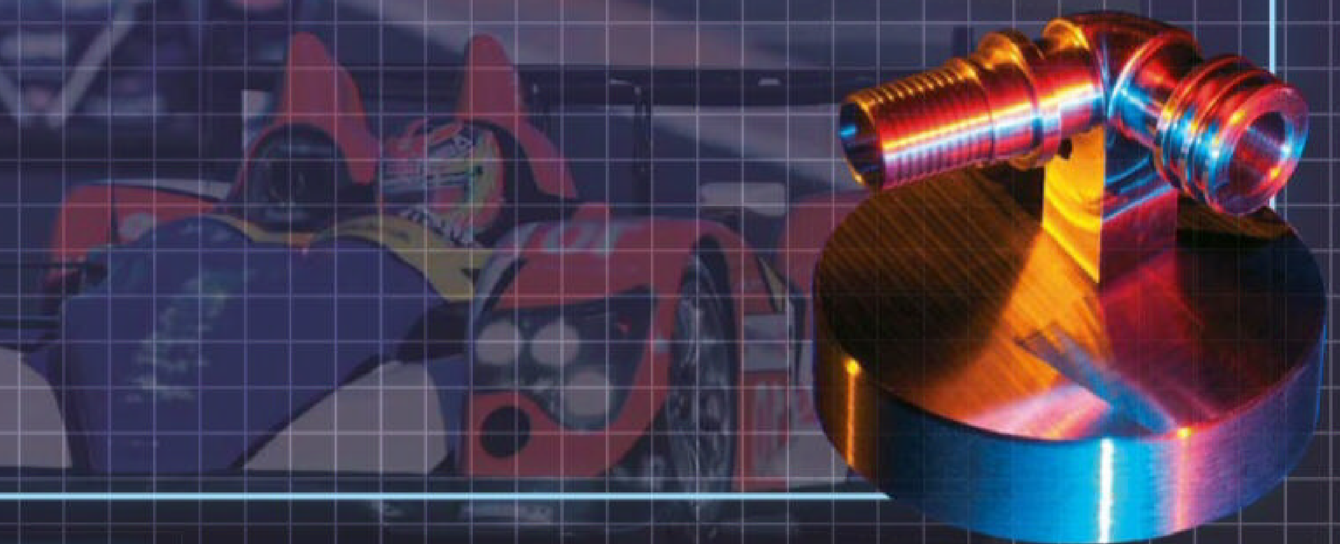
Electric assist

The Rally4 car, like the R2 before it, employs the electric power steering from the road car which, according to Woda, has been faultless. There had been some criticism of the electric-assisted steering used on M-Sport's previous R5 Fiesta, mainly around reliability, but he says this is not an issue with the lower class car. 'On the R2 car, we have the power steering on the steering column, whereas on the R5 car it was on the rack [the latest gen' R5 now uses hydraulic assistance]. It was an entirely different system. On the R5 car, the location of the power steering module made it more vulnerable to damage during a rally. It was also working in a much harder environment than the unit placed on the steering column. As such, we decided to stick with the electric steering that is on the steering column in the Rally4 car.'

Being able to map the steering assistance is a major advantage of an electric system compared to a hydraulic one. 'You can calibrate the steering much more finitely than you can with a mechanical and hydraulic system.' This flexibility is very useful but, cautions Woda, 'We







do not want to mix it up too much from driver to driver, but the settings we have come up with are quite good from most of the drivers.'

The Rally4 Fiesta has ostensibly the same transmission as the R2 car, but this has also been subject to some updates. 'We have been working with Sadev to improve the gearbox,' says Woda, explaining that it is an almost off-the-shelf unit, but fitted with a bespoke bellhousing to suit the Fiesta engine.

Joker gears

Significantly, the Rally4 car sees the introduction of fresh gear ratios (only one set can be homologated). 'We homologated a joker set for the Rally4 car. Compared to the previous gearbox, this new version has the first, second and third gears longer and fifth gear shorter.

'We discovered that in gravel rallies we were getting wheelspin in fourth gear. By making first, second and third gear longer, we were able to improve grip, and also reduced the number of gear changes required. We knew that making the fifth gear a little bit shorter meant we would be hitting the rev limiter earlier. However, from our analysis, we discovered that a little bit more time on the rev limiter was offset by being able to accelerate faster up to that Vmax.'

In addition to the updated ratios, M-Sport also homologated a new driveshaft design, having seen some reliability issues with the units on the R2 car. These were introduced using a reliability joker and, for once, are bespoke rather than production parts.

On its higher end cars (R5 and WRC) M-Sport works with supplier Brembo for brakes, but the Rally4 (and R2 before it) use Alcon calipers and discs at the front, with AP Racing rear discs.

'It is a mix and match that provides the best compromise in performance and price.' To switch between tarmac and gravel specification, the same calipers are used but in conjunction with larger front discs, coupled with pads that have greater initial bite and a higher operating temperature.

Brake cooling is always an issue, particularly on dirty gravel stages, and more so given the constraints on bodywork modifications in Rally4. All that is permitted is a 100mm diameter duct for cooling each caliper. Here, Woda makes an interesting observation on how different drivers tax the brakes. 'We still find some drivers will cook the brakes. It is good having the Junior WRC category [which runs just Fiestas] because across the spread of drivers, in the same car in the same conditions, the consumption of brake pads is entirely different. Sometimes we see drivers get to the end of a rally with minimal usage and they will be in the top three times, while others will not be as quick and will have used a lot more of the pads.'

Engine update

Central to the 2019 R2 upgrade and, latterly, the Rally4 was a significant engine update. 'The key elements [for the 2019 R2] were a different turbocharger, new pistons and new spark plugs that all improved the performance and reliability,' summarises Woda. These were followed on the Rally4 with a new exhaust, revised inlet plumbing and another specification of spark plugs.

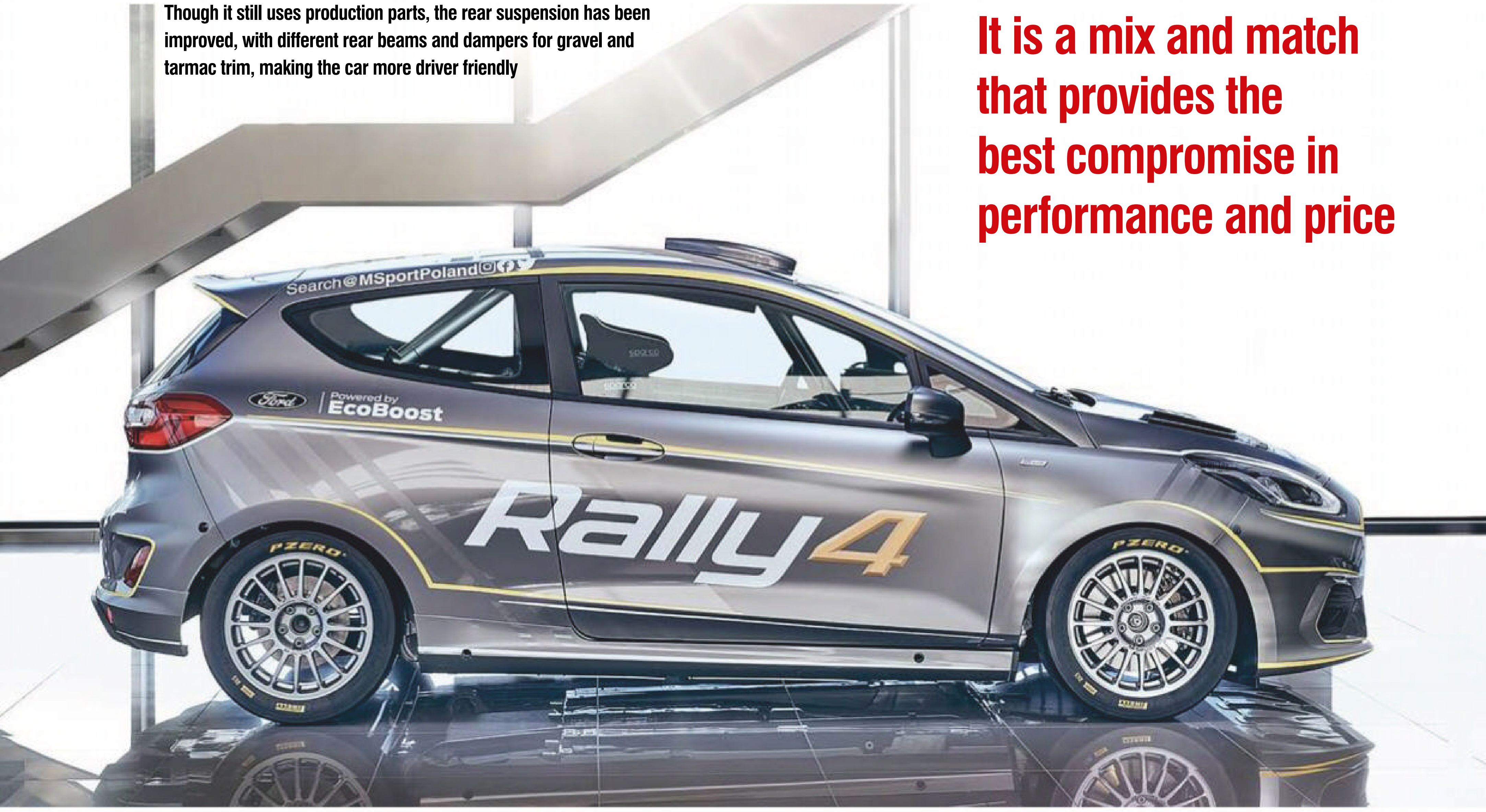
'Throughout the development, we were very cautious with the cost of everything as we did not want the price to go up too much. In real terms, the 2019 R2 car was the same price as the one we launched in 2015.'

The base engine is also markedly different to that used in the first iterations of the 1.0-litre Fiesta. The first R2 version of the 1.0-litre engine was called Fox, and the newest version is called Fox Upgrade. The most significant difference between them is the orientation of the cylinder head. On the first-generation engine, the exhaust exits the cylinder head towards the front of the car, while in Fox Upgrade the exhaust exits the cylinder head towards the back of the car.

These updates, coupled with the tweaks performed by M-Sport, have transformed the engine: 'The difference in performance from the two versions of the engine is enormous. The shape of the power and torque curves are entirely different. That is mostly down to the use of a different turbocharger.'

Additionally, in the Rally4 car, issues surrounding piston and ring reliability were addressed. The new spark plug specification was also reliability related, with M-Sport working with supplier NGK to cure a problem with plugs cracking, something Woda says is now solved.

The increase in performance from the first R2 to the Rally4 is substantial. The first generation R2 had 170bhp, while the Rally4 car has 210bhp. The power has also shifted further up the rev range. 'It drives a little bit more like a normally-aspirated engine. We have not developed the performance specifically to make it drive like



Though it still uses production parts, the rear suspension has been improved, with different rear beams and dampers for gravel and tarmac trim, making the car more driver friendly

It is a mix and match that provides the best compromise in performance and price

The difference in performance from the two versions of the engine is enormous. The power and torque curves are entirely different

that, but we wanted to make sure the torque was linear and very driveable.

'With a front-wheel-drive car, you do not want a massive amount of torque arriving in one moment. That was one of the downsides of the previous generation R2 car. There was a lot of turbo lag and so, when the torque arrived, it would saturate the tyres, losing grip.'

The introduction of new gear ratios went hand in hand with this development, helping further increase the linearity of power delivery through the gears.

On the subject of the updated turbo, the main difference from its predecessor is the size. '[The OEM unit] was pushed over the limit and, with a narrow throat, was not able to deliver enough air to the engine. That turbocharger in the first generation was only designed to provide performance up to 140bhp for the road car, and it was also designed to be emissions compliant. That is not what we were looking for in motorsport.'

Of course, a larger turbo means the potential for greater lag, and Rally4 regulations limit the types of anti-lag strategies that can be deployed, as Woda explains: 'We are not allowed to have any recirculation systems between the fresh air and the exhaust side of the engine.'

Therefore, the Rally4 car's system relies on injection timing and retarding the spark, with a careful balance between the two needing to be struck for optimum performance.

'You are fighting against the pressure on the two sides of the engine. You have the spark delay, which is trying to spin the turbocharger in the exhaust side, you have your throttle closed and the turbocharger trying to compress the air on the intake side adding pressure to the plenum. You always have to find a compromise so that when the car is off the throttle, the turbocharger continues to spin, but it doesn't cause too much engine braking. And, at the same time, when you get back on the throttle the car responds straight away.'

Strong foundations

Despite the current uncertain economic conditions, M-Sport is hopeful the new Rally4 class will be as successful as R2 and, part of its business plan is to further increase the number of complete cars it sells, as opposed to kits. This is a process it began with the last generation R2, and Woda explains the logic behind this approach: 'The first high profile customer car M-Sport produced was the Fiesta S2000. R2 was always a small brother of that car. M-Sport could not afford to provide loads of complete cars at an attractive price as it was not a profitable project [hence it just supplied kits].

'When we started to develop the R2 car in Poland, we looked at how best and cost-effectively we could sell them as a complete car, rather than as a kit. That helps us to keep the high level of quality and makes sure all the cars are identical, built to the right standards, and as good as they can be. Selling the R2 as a complete car made more business sense to us.'

Out of the 120 R2 kits sold in 2019, 70 rolled out of M-Sport as complete cars. When one factors in that many existing Fiesta owners will want to update their R2-specification cars to Rally4, and that car has always been at the front of its class, there is no reason to doubt M-Sport will see continued success.

KEY SUPPLIERS

Bodyshell	M-Sport
Dampers	Reiger
Springs	Eibach
Transmission	Sadev
Brakes	Alcon / AP Racing
Wheels	OZ Racing

Sandbagging is to BoP racing what spy shots are to a racecar engineer. Tempting as hell, not a necessity, but almost everyone feels the need to indulge

By Scott Raymond

Manipulating performance

In series where car performance is carefully controlled to ensure parity and good racing, sandbagging can be irksome to both sanctioning bodies and those trying to balance the performance, but if that balance is right, it shouldn't be necessary at all. Or should it?

In *RE* V29N12 we looked at the basics of Balance of Performance (BoP), and what things make it easy and difficult to implement. Under the heading 'Difficult for BoP' there is one topic that is the hardest of all to manage, and that is sandbagging. In that first feature, I alluded to this warranting a separate article unto itself, so here it is.

Simply put, sandbagging means masking one's performance capabilities to hide your true potential. Who might you be hiding from? Typically, competitors and sanctioning bodies, but the reasons for hiding performance from each are quite different.

Personally, I prefer to use the term 'performance management' as opposed to 'sandbagging'. The latter has a terribly negative connotation in my mind, as it implies deliberately choosing to do something nefarious. Performance management sounds a lot more boring, admittedly, but it more explicitly defines what this concept actually does. It also takes some of the negative impression away because there are always times in racing when managing performance is a necessity.

Sandbag strategy

Why sandbag? Well, because managing one's performance can also be considered a legitimate strategy in the development cycle.

Let us consider a marathon runner training for the Olympics. He, or she, has one goal in mind: winning a gold medal. Perhaps the athlete might also want to set a world record while they're at it, just to ensure everyone knows who is the best marathon runner in the world. In that case, preparing for the gold medal race, the athlete will train to achieve the goal of breaking a world record. Is this marathon runner going to want the competitors to know how fast they are capable of running before the race itself? My guess is absolutely not. They want to keep the competitors guessing so they are surprised (unprepared even) for what the athlete is capable of on race day.

Now, to set that world record the runner has to commit to it right from the start. In a running competition, you cannot decide half way through the race to go for the world record because at that point it is too late.

Keeping your competitors guessing is a strategy in itself. You hope to not tip anyone off that they need to prepare differently, or better prior to the race. With this strategy, you hope your level of preparation is better than that of your competitors, even if it doesn't appear to be from the outside. This strategy may be employed for a single race event, or over an entire season of racing.

Does this mean I condone performance management in motorsports? Unfortunately, that is a complicated question to answer. And to do so, first we need to distinguish between BoP racing and non-BoP racing.

In a spec racing series where BoP is not a factor, or in an open series such as Formula 1, I think managing performance is a winning strategy and completely justified. In a spec series like IndyCar, there is no need to show your true performance potential until it really counts, such as in the qualifying session. In doing this, your hope is that when it comes time to qualify, your competitors don't have enough time to react to your sudden increase in speed. How many times have we seen the fastest qualifying time set on the final lap of the session by the driver of the last car out on track?

In an open racing series such as Formula 1 we often hear the term sandbagging tossed around to describe the performance of various cars during pre-season testing. Again, the whole idea is not giving competitors time to react to any true performance gaps until after the season starts. Hence why we frequently see significant changes to Formula 1 entries between the cars presented at pre-season testing and the ones that line up on the grid for the first race.

Fine line

However, in race series where all things are not equal, we attempt to use Balance of Performance to level the playing field. But in BoP racing there is a fine line between strategically managing your performance to keep competitors guessing and deliberately hiding performance to keep the sanctioning body guessing. Balance of Performance is meant to equalise the machinery part of the playing field, to ensure all competitors have an equal opportunity to stand on the top step of the podium when the race is over.

In BoP racing, I want all races to be decided by execution, not by some vehicle having an unfair advantage that was hitherto unknown. When I say execution, I mean it to cover everything, including selecting the best driver(s), having the best strategist, being the best prepared, training your mechanics to perform the best pit stops, having the best plan and executing that plan successfully. I know all manufacturers who participate in BoP racing want the same thing as I do because they have told me so.

My personal target for balancing lap times between different manufacturer cars is less than 0.3 per cent. What that means is I want all cars to be able to complete a lap time within 0.3 seconds of each other on a 100-second lap. This is literally the same time it takes you to blink. To put that into perspective, open the stopwatch app on your Smartphone and try to repeatedly get 0.3-second laps. Now imagine 10 different cars representing 10 different manufacturers all crossing the start / finish line in that timeframe. So, if my target is to keep the cars within 0.3 per cent of each other, it does not take much 'performance manipulation' to make a car appear too slow in my eyes.

My personal target for balancing lap times between different manufacturer cars is less than 0.3 per cent

Sandbagging, or managing performance, isn't always a bad thing, it can also be considered a legitimate race strategy

For the remainder of this article, I will focus on performance management and how it pertains to BoP racing. Specifically, I will discuss performance management from the perspective of the sanctioning body. In addition, I will highlight some of the features of ORCA Engineering's Performance Analysis Application to show how a sanctioning body can detect it.

The first thing to note is a car cannot sandbag by itself. It takes people to do so. Be it drivers, engineers, team owners or manufacturers, it requires someone to make a conscious decision to deliberately manipulate the apparent performance of a car. Some of the techniques are easy for a sanctioning body to detect; others are sophisticated and difficult for a sanctioning body to detect. So, let's look at the ways people can manipulate performance.

1. Driver performance management

The primary person intrinsically linked to the demonstrated performance of a vehicle is the driver. A good professional driver can hit any target lap time asked of him or her. Think about the inputs the driver has to the car, throttle, brake, steering, gear selection, brake bias and adjustable components like anti-roll bars. A good driver can manipulate any of these inputs to make the car appear artificially slow.

Blatant tricks

The simplest, and most amateur, method is to lift off the throttle pedal at the end of longer straights. This slows lap time and makes it appear the car is down on top speed. I have seen this trick used many, many times but it is blatantly obvious to detect from logged vehicle data. A more subtle way to use the throttle is to apply the throttle late and / or slowly on corner exit. This will make the car look like it is slower out of the corners or slow on initial acceleration.

Under braking, the driver has several options. The simplest is to brake too early, or brake too hard, which over-slows the car on corner entry. Something that is difficult to detect is if the driver manipulates the brake bias to be less than optimal. For example, if the driver were to dial in a bit too much front brake bias, the car will likely pick up a corner entry understeer. It is difficult for a sanctioning body to determine if a car is being deliberately slowed when this is the only evidence, as it could be a legitimate set-up deficiency, rather than a deliberate manipulation of car performance.

Gearing is another area that is easy for a driver to manipulate to hide performance potential. The driver can upshift early, making the car appear to have reduced acceleration potential and possibly a lower top speed. In addition, the driver could select the wrong gear for a corner, which will impact cornering speed and lateral acceleration potential.

Inside the cockpit, the driver may have other mechanically-adjustable components at his disposal, which can be used to make the car artificially slower. Take, for example,

driver-adjustable anti-roll bars. Going one step too stiff on the front anti-roll bar has a similar effect as a forward brake bias mentioned earlier. Except, the understeer balance will be apparent throughout the entire corner this time. Once again, this is exceedingly difficult for a sanctioning body to distinguish. The only real indication is the car will appear to lack lateral acceleration capability when compared to one with proper mechanical balance.

A little extra

In addition, the driver may have control of electronically-adjustable components such as a fuel map, or an ECU map. Running lean on the fuel mixture would make the car appear down on power, manifesting in a lack of longitudinal acceleration potential. Another option the driver may have available is to turn off the air conditioning to get a little boost in power when required. This option falls into a category of having a little extra when you need it, though, rather than deliberately hiding performance.

Finally, the driver can simply not pilot the car at his or her true potential. In this case the driver could simply take a slightly wrong line through an important corner, miss a few apexes around the circuit, or generally drive a little bit untidily. One thing I always find frustrating is when drivers pit at the end of a fast lap. You will be watching the timing and scoring and see that a driver is going fast on a particular lap when they suddenly enter pit lane to complete the lap. This is another blatantly obvious technique.

2. Car performance management

There is an indescribable number of things an engineer can do to slightly downgrade the performance of a car. Remember that we are only looking for a few tenths of a second, and there are many ways to achieve that target. Imagine all the inputs the engineer has with

[OPAA] takes all the data from cars participating in an event and quickly summarises it into easily digestible performance metrics

From tyres to fuel maps to traction control settings and wing angles, all can be used to artificially slow a car, often a very nominal amount, either to sneak up on competitors or to hide performance from a sanctioning body

regard to set-up alone that can be used to offset a car's balance and slow it by a couple of tenths of a second. The following is by no means an exhaustive list, but it should help give you an idea of some of the things that can be done to falsely indicate a car's performance potential.

Let us start with the tyres, the most important components on the car and an area in which the store cupboard of choices is well stocked. The engineer can set the car with incorrect camber, toe or cold pressure to shift the balance slightly. Further to this, tyre compounds can be used to hide some performance. As an example, at the Nürburgring 24 hour race teams have multiple choices for tyre compounds. Once they find the compound that works best for the car, they save them and will only use them during the race, or perhaps in qualifying. The rest of the time they are running around on sub-optimal compounds knowing full well they have something left in reserve.

There is an indescribable number of things an engineer can do to slightly downgrade the performance of a car

Overall ride height and rake angle can have a profound effect on the performance of a vehicle because ride height has a dual impact on c of g height and aerodynamic performance. An engineer may choose to run the car slightly higher than optimal, or with a raised front ride height to reduce rake. These changes will reduce overall downforce, raise the c of g and shift the aerodynamic balance to the rear of the car. End result? Lateral acceleration performance will be hampered.

Continuing with aerodynamic set-up, it is exceptionally easy to mask performance with wing settings. On many occasions I have seen cars running too much rear wing to mask straight-line performance. In this case, the car appears deficient on longitudinal acceleration and top speed. Fortunately, a sanctioning body can compare the lateral and longitudinal accelerations in this case and look for a car with a lower top speed but a higher lateral acceleration capacity – a typical indicator of a car running too much wing angle.

There are so many things that can be done with a car's suspension or damping characteristics it is best to cover it with one blanket statement: any slight change in suspension set-up can be used to mask the overall performance characteristics of a car. Again, by introducing a suspension deficiency, the car will appear to be lacking lateral acceleration performance.

3. Engine performance management

In BoP racing, engine specification and ECU configuration are homologated items. They are not supposed to be modified in any way. That said, think about all the inputs the manufacturer has available to mess with an ECU. This may be considered blatant cheating, but sometimes manufacturers feel the risk is worth the reward.

A major function of the ECU is to control the timing of the engine cycle. Manufacturers may introduce a small change to the various timing controls – ignition timing (ignition angle), fuel injection timing, valve timing and cam timing – to reduce overall horsepower by just a few per cent. This reduction in power can easily cause the car to be a few tenths of a second slower, at least until the race when the optimal timing will be re-programmed into the ECU. To prevent this, sanctioning bodies usually require cars to be fitted with standalone sensors for many of these parameters, which feed into a series data logger so the signals cannot be manipulated by teams.

The rpm limiter can be used to mask performance as well. The simplest way to do this is to program the shift lights for the driver to indicate he or she should shift earlier than optimal. The ECU can also be programmed to physically implement an rpm limit earlier than normal. Thankfully, this type of change is relatively easy for a sanctioning body to detect.

A boosted engine can be manipulated by running the boost pressure below allowable limits or playing with the wastegate control. Again, this would have the effect of lowering the overall power of the car and is also reasonably easy to detect.

The traction control strategy on many racecars these days is very sophisticated and dependent on several input signals. A manufacturer can easily de-tune settings, which can negatively impact corner exit acceleration. In addition, there may be a driver-adjustable switch for selecting traction control settings. Neither are easy to detect if being used to manipulate overall performance.

Fuel maps are used by teams as part of their fuel strategy in the race, but I've seen it used to deliberately reduce overall power and hide performance. Fortunately, again this is reasonably straightforward to pick up.

The general idea behind all of the above is to give the impression a car is either down on power or down on cornering performance, relative to the rest of the field.

The above discussion highlights the myriad ways teams and manufacturers attempt to mask a car's true performance potential from a sanctioning body, in the hope it might prompt an increase in power level or reduction in overall mass for that manufacturer car model. That, of course, then leads to the car having relatively too much power, or too much cornering potential when running at its optimum setting.

As noted, some sandbagging methods are easy to detect, but many of the techniques used are challenging to pick up in the logged vehicle data, which is where ORCA Performance Analysis Application (OPAA) comes into play.

Metrics analysis

I have mentioned previously that my company, ORCA Engineering, has written software called ORCA Performance Analysis Application (OPAA) that is used to analyse massive amounts of vehicle data efficiently. The software takes all the data from cars participating in an event and quickly summarises it into easily digestible performance metrics. The primary benefit being it eliminates the need to manually dig through every lap for every car to understand the relative performance levels for all cars.

Any slight change in suspension set-up can be used to mask the overall performance characteristics of a racecar

The metrics are separated into categories including driver, car and engine to attempt to determine the source of any sandbagging. The software is also capable of generating metrics that can be used to detect and quantify performance management.

The driver performance metrics are used to evaluate how hard a driver is pushing, and how consistent the driver is at setting lap and segment times. The standard deviation of lateral acceleration has been found to correlate directly with lap and segment times. A higher standard deviation corresponds to a reduced lap or segment time. If you think about this for a second, it should make sense. When a driver is pushing hard, he or she will most likely have more movement in the steering while searching for the limits of grip in each corner. More movement equals more standard deviation, so the performance metric uses this concept to quantify how hard the driver is pushing. The driver metrics also express how much the driver is on or off the throttle and brake pedals as the percentage of lap distance, and can show if a driver is lifting at the end of straights or braking too much for corners.

The car performance metrics are focussed on quantifying the acceleration performance and speed of the vehicle. These are not directly used to detect performance management, but rather to compare expected values to measured values. When the measured values for accelerations and speed are lower than expected, it prompts an investigation to determine why. The analysis then becomes a matter of understanding if the acceleration is truly deficient or if the performance is being managed in some way.

OPAA uses a very sophisticated algorithm to quantify and compare engine performance. At the heart of this algorithm is a set of engine models, unique for each manufacturer car model. These models have approximately a dozen distinct degrees of freedom and are created using historical logged vehicle data. At a race event, the current engine performance is compared to the historical engine model to look for changes in parameters such as ignition angles, fuel lambdas etc. The engine models are adaptive and smart enough to account for changes in ambient conditions. The output from the engine model comparisons is a table of outlier data, which highlights any values that do not reflect expected engine performance. This technique allows the sanctioning body to quickly and efficiently look for any engine performance management.

A necessary evil?

This leads me to a final question: is performance management, of the sandbagging kind, really necessary? Ask any manufacturer and they will probably say it is. In my opinion, though, if there is enough trust between a sanctioning body and the participating manufacturers it should not be necessary to hide performance. Sandbagging detracts from the spectacle of racing, so it is the duty of the sanctioning body to create an environment of trust by being open, honest, and transparent.

If there is enough trust between a sanctioning body and the participating manufacturers it should not be necessary to hide performance

As I have stated my target for balancing cars is 0.3 per cent. My experience is that when this target is actually achieved, the amount of sandbagging seems to drop away significantly. Teams and manufacturers can no longer sandbag because the margins are too close, so they need to perform at their best to stay in touch with the rest of the field. It is satisfying to achieve this level of competitiveness because it automatically instills that level of trust a sanctioning body is looking for.

Whether you want to call it sandbagging or performance management, there is no question the job of the sanctioning body is made more difficult by its presence but, thanks to innovative software, a sanctioning body at least stands a chance of detecting it.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‘You can now go and win Le Mans with probably ten times less budget than 2014’

David Floury, ORECA technical director

New order

The ACO and IMSA recently released the regulation set that will govern the global platform top class prototype, and it has proven popular

By Andrew Cotton

Earlier this year, the ACO and IMSA announced they had completed their assessment into the global platform prototype and early in May unveiled the first details of the programme.

Labelled at Daytona in January as 'LMDh' for Le Mans Daytona… (the h has yet to be defined), the minimum weight has been fixed at 1,030kg and maximum power output defined at 500kW. These two parameters ran hand in hand earlier in the process, so it was natural to keep them in step. The hybrid system for the LMDh category appears to be relatively tame, housed on the rear axle only, although the effect on overall lap time is anything but tame. Offer any racing team an extra 30kW of power for the full lap and they will gladly accept it.

These details have taken a long time to arrive, and the path to this conclusion has been anything but straightforward, due to complications introduced by the FIA mid-negotiation that skewed the pitch and left manufacturers and technical working groups in total disarray as plan after plan was introduced.

World in motion

The original concept was that the ACO, FIA and IMSA organisations produce a global platform car that could compete in the key races of the US-based IMSA series, including Daytona, Sebring, Watkins Glen and the Petit Le Mans, as well as the key race from the FIA World Endurance Championship; the 24 Hours of Le Mans. Such a programme would offer a huge return on investment for both teams and manufacturers and would have allowed manufacturers to make a solid case to their board members to build cars. Things were progressing nicely until, inexplicably, the ACO, along with its partner, the FIA, veered off course and headed down the road of Hypercar.

ACO representatives had turned up at Daytona in January 2018 and explained the low-cost concept, as covered in *RE* V28N4. The idea was for a rear axle-only hybrid, perhaps a maximum of 4MJ storage capacity, and lower power delivery for a longer period of time than the short, sharp delivery of the current LMP1 hybrids.

The reasoning behind it was sound. The move away from four-wheel drive (removing KERS from the front axle), high-power hybrids was logical cost saving. Having a low-power hybrid system would also interest the US teams more than a high-power one and the manufacturers involved, including Mazda, Acura and Cadillac, accepted that hybridisation was a necessary technology to tempt in more manufacturers such as Ford and BMW.

Come March of that year, however, the FIA and ACO arrived in Sebring and announced they were sticking with high-power hybrid systems, four-wheel drive and a targeted €30m (approx. US$32.6m) price tag. Following a presentation of the rules at Château Élan in Sebring, the paddock was stunned and IMSA vowed to press on with what it considered the right way forward on its own path.

Hyper ventilate

The Hypercar regulations catered to the highest possible technology at a time when, particularly in the US, manufacturers had already reached the conclusion that the hybrid era was too expensive for endurance racing and the technology could be outdated. Hypercar was for extreme cars that were capable of achieving a target lap time at Le Mans of 3m15s. To the

The move away from four-wheel drive, high-power hybrids was logical cost saving

From left: FIA WEC Championship promoter Gerard Neveu, Pierre Fillon (seated), IMSA president John Doonan, NASCAR CEO Jim France (seated) and IMSA CEO Ed Bennett

FIA this seemed modest. Estimated budgets for Audi and Porsche were closer to €200 million (approx. US$217.2m) at the height of the hybrid war, but to the American teams and manufacturers these figures were far higher than they could afford, and significantly more than they were spending to compete currently.

There was a chasm between the two rule sets, but IMSA had to tread carefully as the basis of its top class was the ACO and FIA's LMP2 chassis, and it relied on the GTE regulations for its GTLM class, so could not afford a falling out.

Toyota committed to the Hypercar early, the Japanese manufacturer clearly seeing the benefit of racing at Le Mans, and was one of the leading voices in the move to retain the more efficient front-axle hybrid energy recovery system. However, there was no one else willing to join the party under these regulations. Aston Martin, McLaren, Ferrari, Porsche, Ford and others were all at the table at various stages of the process and none of them wanted this technology. Some wanted to go non-hybrid, some wanted a road car base, some wanted mild hybridisation. As a result, the ACO and FIA caved and allowed all concepts: hybrid prototype; non-hybrid prototype; hybrid road car and non-hybrid road car.

Glickenhaus and ByKolles announced their participation in Hypercar alongside Toyota, but the Holy Grail was a new manufacturer, and in Aston Martin they had it. The Valkyrie programme was confirmed at Le Mans in 2019 and it seemed to put the FIA and ACO back into a powerful position in their ongoing battle for supremacy to create the global car.

In November 2018, the ACO and FIA's position was further strengthened by the announcement that Peugeot would also join Hypercar. The announcement from the French came just a week before it announced it was withdrawing from the World Rally Championship. The two announcements were clearly linked, but even the FIA admitted Peugeot's announcement was a surprise.

Game changer

Aston Martin then suspended its Hypercar programme earlier this year. This was not a surprise, but it weakened the FIA's hand. That hand was further weakened when, at the opening round of the IMSA series at Daytona, the US organisation announced its next generation prototype would be labelled LMDh, and its cars would be allowed to race in the top category at Le Mans. This was a game changer.

> **'It was not easy to find a balanced working point between the US and Europe'**
>
> *David Floury*

This is a global platform car, continues to be based on the LMP2 chassis with manufacturer engine installation, aero and styling and will continue to be a cheap form of motorsport.

Le Mans was the cherry on the cake. Shortly after the first details of the LMDh regulations were confirmed in the media in May, the FIA announced that it would bring its Hypercar parameters into line with the US rules. Weight will be reduced from 1,100kg to 1,030kg, and power dropped from 585kW to 500kW.

Power up

The FIA's announcement in mid-May of this year signalled the third change in engine regulations for Hypercar. Its original concept was for around 600bhp, plus a powerful hybrid system, but with the Valkyrie road car producing more than 1,000bhp, reducing its output to fall in line with the others was not viable. Toyota, Glickenhaus and ByKolles all agreed to increase their ICE power output to more than 700bhp.

Toyota was rumoured to have been working on a four-cylinder engine, but abandoned that idea in order to reach the higher power output required to compete with the Aston Martin. Likewise, Glickenhaus abandoned his plan to modify a Ferrari 488 engine and instead went with Pipo Moteurs to produce a twin turbo V8, essentially two four-cylinder inline engines mated. These decisions were taken before the announcement of LMDh in January.

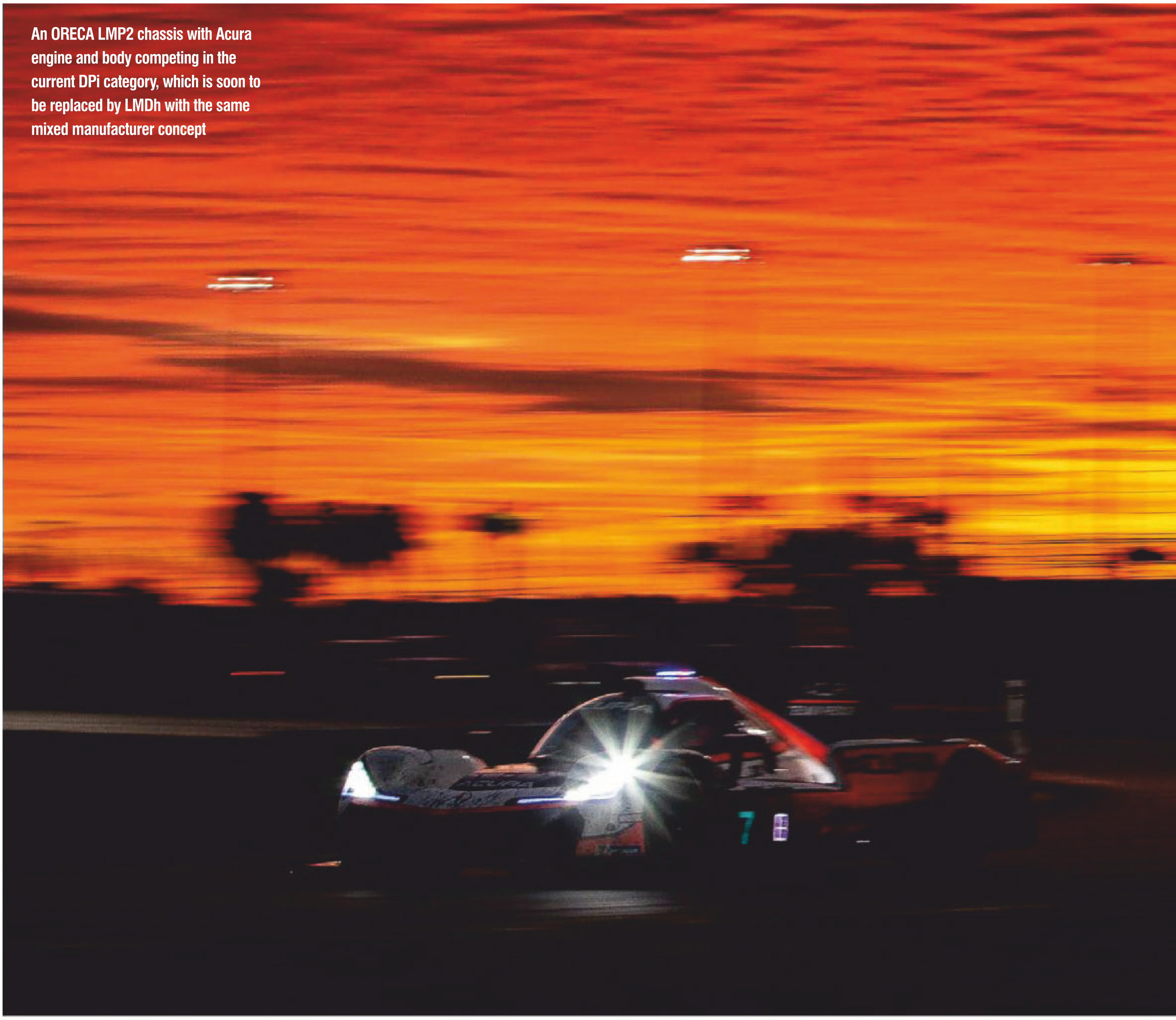
The LMDh plan retained the power output target of 600bhp engines as there was no need to change. The plans were largely driven by the manufacturers already involved in IMSA while others including Hyundai were also believed to be at the table with a view to joining the US series regulations. Ferrari, Porsche and Lamborghini are all closely eyeing the finalised LMDh regulations, and at least Porsche has confirmed its board has already ordered a concept study based upon them.

On the Hypercar table sits Toyota with Peugeot, Glickenhaus and ByKolles, plus other as yet un-named manufacturers, but thought to include Mercedes and Honda. Ferrari is also looking at these regulations closely as it wants to build its own chassis, as well as engine, although may have to go for the low-cost LMDh option if it goes at all.

At 600bhp, it seems highly likely the current US engine manufacturers will not need to build entirely new power units, although there are still some final details to be finalised before they push the green button.

The impact of LMDh on Hypercar was already large but, when Aston Martin stopped the development of its Valkyrie competition car, the regulations took on even more importance. Here was the chance to have a car on a low budget and, if performance balancing could be agreed upon, one that could race at Le Mans.

This set of regulations were supposed to have been released at Sebring in March, but


An ORECA LMP2 chassis with Acura engine and body competing in the current DPi category, which is soon to be replaced by LMDh with the same mixed manufacturer concept

the coronavirus scuppered that plan. Virtual meetings replaced those that were planned face-to-face and the regulations have now been distributed to manufacturers.

The choices are stark for the manufacturers: take an existing chassis, gearbox, electronics and hybrid system, fit your own engine and develop an aero kit from there, or build a ground-up prototype to your exact specification. Both concepts will be performance balanced and both will compete at the key races around the world.

Power down

The LMDh hybrid power output is the topic of contention, with a very low figure compared to the monster systems developed for Porsche, Toyota and Audi. The old LMP1 hybrid systems had a power output artificially limited to 300kW and incredible energy recovery systems were created, both KERS and exhaust driven.

Under the new regulations, power output will be limited to one tenth of that figure, just 30kW but, rather than spend all the power in one go on acceleration, it will be distributed around the lap more liberally.

The hybrid system will come from a single supplier, yet to be named, and few other details are available. It has been unofficially confirmed that the system will be high voltage, of the order of 600-800V to help keep its weight down.

'If you look at it, it is not such a mild hybrid,' says ORECA's technical director, David Floury. 'It looks like it is because its power output seems low if you compare it to a current system, but that boosts at 300kW only for a fraction of time at the exit of the corner and then you are only on the IC. Here, the hybrid system is going to boost all around the lap as soon as you have full throttle. It is a different situation. At the end of the day, the MGU will be capable of much more power capacity because of the regen' side.

'The battery and [energy] saving of the MGU is still quite high, but the idea is the IC power is limited to more or less what is in DPi [Daytona Prototype international] to limit the cost on this side. The hybrid system is a top up of the IC. A low-voltage system would have been 30kW but only for five seconds or so, and it would have been mild. This is boosting all the time.'

Clearly, there will have been a major discussion with Toyota that has developed another powerful hybrid system. Regenerating energy from the front axle is, argued Toyota, the most efficient method of doing so, and certainly large amounts of energy can be collected from a front-mounted KERS. However, power delivery back to the front axle, and the resultant occasional four-wheel-drive capability, is more complicated and expensive than a rear-mounted system only.

Before Aston Martin committed to the regulations, an agreement was reached

The LMDh chassis will be designed with compromises as it is primarily a customer-based chassis

whereby an old rule resurfaced. Hybrid power can only be delivered to the front wheels over 120km/h in the dry, and at a higher speed in the wet. Performance balancing is going to be a headache for the governing bodies.

Production identity

The performance balancing system has long been clearly defined, although the details have taken time to confirm, and again it is IMSA that has led the way with designing its process. Drag and power limits are placed on the basic car and tested in the wind tunnel and on the dyno. Cars are then balanced, which means the road-car styling departments can have limited impact on aero performance. What comes out in the final product is a prototype that is identifiable to its production car cousins.

Engine characteristics have proven harder to manage, particularly in the case of Cadillac and its large capacity V8 engine that has led IMSA to delve even into the length of its gears to reduce performance, allowing Acura and Mazda to compete without having to out-spend their American rivals.

The cars are based on the next generation LMP2 cars, which are due for introduction into the WEC in 2023. LMDh cars will therefore come first, but at least the four chosen manufacturers – Ligier, Multimatic, Dallara and ORECA – are able to start design work on the new cars. 'It will be a completely new car with different dimensions,' says Floury. 'Obviously you need to accommodate for the hybrid system.'

The road to these regulations has been rather simpler than others. Although Ford was known to have wanted a larger hybrid system and was driving the hybrid route in IMSA, there was consensus that the US teams and series did not want the complexity or costs.

The current DPi regulations are based on the existing LMP2 regulations and there was no reason to change that concept. Key elements of the car are fixed, such as the gearbox, braking system, clutch and chassis. They are homologated for five years and there is currently no plan to change that process.

IMSA will have this platform as its main category, but the organisation has accepted that Hypercars can race at its key race, the Daytona 24-hours, in January 2022. This measure is understood to have come from Glickenhaus, who wants to race his Hypercar on home soil. Further tracks will accept the Hypercars once the BoP has been established.

Here to stay

As yet, there is no clear reason why manufacturers cannot mix and match their cars. Ferrari could, for example, build its own chassis, engine and body, while taking IMSA's hybrid system and reduce the need for expensive development in this area. This possibility will increase the attractiveness of Hypercar to a manufacturer, although costs will certainly be different between the two.

'There will be a difference, but it is difficult to know the gap between the two,' says ORECA managing director, Hugues de Chaunac. 'I don't know the budget of Hypercar, but there will be a big gap. When a car manufacturer is spending money, they always spend more than a private team. It is difficult to say for the moment because the cost to have a competitive car, and to have a top-level car, in Hypercar [is high]. To have [a Hypercar] is one thing but to have a top car with everything free on the hybrid system, for instance, it can cost a [lot]. This is defined in the LMDh. You cannot spend a lot on each component.'

Car architecture

The LMDh chassis will be designed with compromises as it is primarily a customer-based chassis. 'You should be in a position to accommodate all types of engines, so you have to make provision for a non-stressed engine,' confirms Floury, who will now start work on the ORECA LMDh / LMP2 car. 'We are designing the spine and the car architecture, doing some simulation work and working on the aero. We don't have all the styling input from the OEMs, but it is good to prepare for the future. At the moment we are more in a conceptual stage than fine-tuning stage.'

Deals have been struck with Michelin for both series. IMSA is near the start of a 10-year deal for its series in the US, the WEC signed its deal with Michelin after succumbing to pressure from its partner manufacturers. One tyre will be for the four-wheel-drive Hypercar, a second option will be available for the two-wheel-drive Hypercar, as well as for the LMDh cars, reducing the amount of development and cost for the teams and the tyre partner.

Costs are aimed low enough that customer teams can afford to represent manufacturers in both series. A common figure for the current privateer LMP1 cars were around €4-6million (approx. US$4.35-6.52m) per car, while the manufacturer budgets were far higher. This is widely accepted as a common cost for manufacturers in IMSA, while the privateers run on less money, although are finding it increasingly difficult to raise funds.

'It has been a very efficient process, all credit to the ACO and IMSA,' says Floury. 'It was not easy to find a balanced working point between the US and Europe and, at the end of the day, it is successful and good for the sport because LMDh is good value for money and a good way to reduce the budget. You can now go and win Le Mans with probably ten times less budget than 2014, and this is quite efficient with a global platform. And [with] the same development, you can race in the US, Europe and at Le Mans, which is brilliant. In the post-COVID situation, this a good package.'

Logical step

'As these technical regulations will attest, LMDh is a logical and appropriate next step to follow the successful Daytona Prototype international (DPi) in the IMSA WeatherTech SportsCar Championship,' commented IMSA president, John Doonan. 'The LMDh will retain many attributes that led to the success of DPi, but the addition of relevant technologies and the convergence of regulations with the ACO opens the door for more manufacturers to participate in the future. We could not be more proud of the instrumental role our IMSA technical team played alongside their counterparts at the ACO to deliver these regulations.'

There are further details that have to be thrashed out in the final set of regulations that are intended for publication in September at Le Mans. Until then, the signs are positive for the global platform car.

'[With] the same development, you can race in the US, Europe and at Le Mans'

David Floury

Wayne Taylor's WTR team has consistently represented Cadillac's prototype racing brand at the highest level, winning the Daytona 24 hours three times and the title in 2017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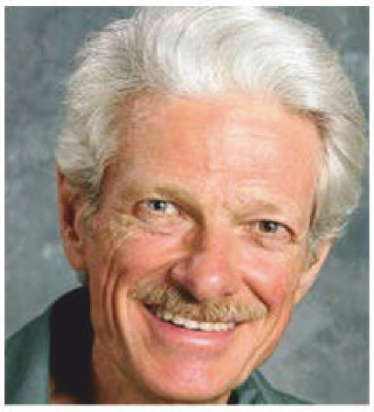

Further diff-essentials

Deliberately introducing friction into the equation

By MARK ORTIZ

In *RE* V30N5 we considered the various types of differentials, in their 'open' form. We noted a differential is a gear mechanism that splits the power from one input shaft between two output shafts, providing a fixed torque split while allowing free variation of the output shaft speeds with respect to each other.

This property can create a problem when the distribution of available traction at individual wheels is different to the distribution of torque provided by the differential. In such situations, one or more wheels will spin prematurely and the traction of others will not be fully utilised.

Methods of modifying the differential's characteristics to reduce this tendency generally involve introducing some form of friction, usually within the differential itself, though sometimes through the use of a brake. It is also possible in some applications to drive two output shafts from a single input shaft with devices that are not properly differentials.

The parts that make up a viscous coupling type differential from Ricardo

Friction within the differential can be provided by clutches, by gear design, by some form of viscous coupling or by a combination of these. The friction can be constant, torque dependent, speed dependent or controlled electronically, either by a computer or by a manually-operated control.

Clutch packs

The most popular approach is to use either one or two multi-disc clutch packs within the differential unit. These introduce friction between the carrier and one or both output shafts. It is sufficient to have this on only one output shaft, because the mean rotational velocity of the two shafts has to equal the input velocity, and therefore restricting the speed difference between one output shaft and the carrier also restricts the speed difference between the other output shaft and the carrier, and restricts the speed difference between the two output shafts.

The clutch pack(s) will generally have a preload, and also some provision to increase the clamping load on the discs as input torque increases. The simplest way to do this is to use the spreading force on the side gears. All gears try to separate when transmitting torque, and whatever locates them has to resist this force. The spreading force will depend on the pressure angle of the spider and side gear teeth. This will have to fall within fairly narrow limits – typically around 20 degrees – and will generally be the same on the drive side and coast side of the teeth, although it doesn't necessarily have to be.

The unit can then be tuned mainly by varying preload. It's hard to change the rate of locking friction gain with respect to applied torque. Also, the side gears cannot be allowed to spread very far, as this will compromise their proper meshing with the pinion gears.

If we are willing to accept some added complexity, we can make the locking friction gain greater, and also make it adjustable via substitution of components. This involves not having the spider gear shafts attach directly to the carrier, but instead having the carrier torque transmitted to the spider gear shafts through a pair of ring-shaped cams. The side gears nest inside these. The cams are splined to the carrier on their outer diameter, so are locked to the carrier rotationally but are free to slide axially. The outer face of each cam bears on a clutch pack, some of whose discs are splined to the carrier and some to the output shaft. The inner face of the cam has angled ramps that mate with flats on the ends of the spider gear shafts. When the cams transmit torque to the spider gear shafts, the ramps induce a spreading force on the cams, which loads the clutch packs. The magnitude of the spreading force, and in turn the locking friction gain, can be varied by using different ramp angles. If desired, these can be made different for the drive and coast sides.

Gears as friction

It is also possible to use gears themselves as frictional elements. This involves making them worm gears, or giving them such extreme helix angles that they approximate worm gears. It wouldn't be impossible to make a conventional spider gear differential that way, using spiral bevel spider and side gears, but parallel-pinion epicyclic differentials really lend themselves to this approach. The parallel pinion gears are made worm gears.

Such differentials have a very smooth action, but also have some drawbacks. One is that they either have no preload or, if the gears are preloaded against each other, the preload is generally very wear sensitive.

Another drawback is that large axial forces are induced in the pinion gears. These can actually split the carrier apart in extreme cases,

The friction can be constant, torque dependent, speed dependent or controlled electronically

or cause a lot of wear on the pinion gear thrust washers or bearings.

One untried possibility that suggests itself would be to use this spreading force to load clutch packs, which could be preloaded with springs, as in other clutch pack differentials. The friction gain here could be varied by changing the pinion gears' helix angle.

I'm not sure this is more attractive than existing clutch pack designs for ordinary 50 / 50 torque split applications. For one thing, it would be harder to get different friction gains for drive and deceleration. However, high helix angle, parallel-pinion epicyclic differentials, with or without clutch packs, offer interesting potential for inter-axle differentials because they are more easily designed to provide any desired unequal baseline torque distribution.

Friction types

Another alternative is to use viscous friction, generally provided by silicone fluid.

At this point, we should probably briefly discuss the difference between Coulomb friction and viscous friction. Coulomb friction is friction between smooth, hard, dry surfaces, loaded short of the point of catastrophic failure from either load or heat. It is dependent on the substances involved and the normal force pressing them together, and nothing else. It does not vary with macroscopic (apparent) contact area, or relative velocity of the surfaces.

Viscous friction occurs between smooth, hard surfaces held apart by a layer of lubricant, loaded lightly enough so they do not penetrate the lubricant and make contact. Viscous friction varies with the first power of macroscopic contact area and the square of relative linear velocity at the interface, and does not vary with normal force. It does not depend on the nature of the surfaces, but it does depend on the viscosity of the fluid separating them, and also the thickness of the lubricating layer.

For typical situations, friction varies inversely with the first power of the lubricating layer thickness, or clearance in the case of, say, a journal bearing.

Any viscous liquid will provide viscous friction, but silicone fluids are preferred because their viscosity does not decrease significantly with temperature. Some silicone fluids can exhibit viscosity increases with temperature. Silicone fluids can provide decent lubricity but, compared to good lubricating oils, provide poor extreme pressure wear resistance. Therefore, we can't use them alone as rear end lubricant. It is possible to use them only inside the differential carrier, and have this sealed. Viscous friction is created by the gears churning the fluid. Ability to get away with this will depend on the unit design, operating conditions and what wear rate is acceptable.

A more prudent approach is to use a sealed multi-plate viscous clutch. This has plates a bit like other multi-plate clutches, but these don't

Friction varies inversely with the first power of the lubricating layer thickness, or clearance

have friction material on them and are not pressed against each other. They are merely in close proximity, and the shearing of the viscous fluid between them generates the friction.

Any wet clutch that isn't totally locked exhibits some viscous friction, but basically they are Coulomb friction devices. This means the friction is largely independent of velocity (ie output shaft rpm difference) and is pretty much a linear function of applied torque, plus some initial value due to preload.

Recall that an open diff splits input torque between two output shafts in a fixed proportion. That normally means the wheels driven by those shafts see torque in the same proportion. However, if we apply the brake on just one of those wheels, that changes. Similarly, if we apply the brakes on both wheels, but with unequal force. This is how the trick of using the parking brake to free a car with just one rear wheel spinning works.

One might suppose applying the parking brake affects both rear wheels equally, so it wouldn't help. However, if the rear brakes, or just the parking brakes at the rear, are drum brakes, generally those are self-energising to at least some degree. In which case at least one shoe – often both – are leading shoes. The rotation of the drum against the shoe induces an added apply force. That causes the brake on the spinning wheel to be applied harder than the other. In combination with added power application, this gives us more torque to the wheel with traction, which may move the car.

In tractors, it is common to have rear brakes only, with individual control of the right and left. Individual right and left-hand brakes are also common in other off-road vehicles, where they are sometimes called tractor brakes.

Locked differentials

There are also some other ways of driving two output shafts from one input that are not differentials. The simplest is a spool. This drives the two output shafts at the same speed all the time. Torque distribution depends on circumstances. Quite often one wheel will retard the vehicle while the other is propelling it, particularly when travelling in a curved path.

Another option is a locker, which is a dog clutch device that allows one output shaft, but not both at once, to overrun the input shaft or ring gear, and drives the other output shaft at ring gear speed. When both output shafts are engaged, the unit acts like a spool, turning both output shafts at the same speed. Torque distribution in this case depends on relative traction or resistance. When one shaft disengages and overruns, all torque goes to the one that remains engaged.

Now, what characteristics do we want? Arguably, we generally want to allow small differences in rpm with minimal resistance, and have resistance build as rpm difference increases. A viscous differential provides that. The friction force varies roughly with the square of the rpm difference, and in some cases can also increase a bit if the fluid thickens as it heats.

One possible problem is a viscous differential only generates significant locking friction when there is some wheelspin. It limits it, but it has to allow some. This can present a problem with electronic engine control that will cut spark or fuel under such conditions.

Car control

Clutch pack and worm gear differentials don't have this problem, but they either promote quasi-locked-axle understeer due to clutch preload, or have inadequate locking torque when one wheel has very little traction: no torque, no lock; no lock, no torque.

Applying brakes to control wheelspin is as good as whatever controls this. It does have the disadvantage of directly sapping power, much more than inter-shaft friction does.

All these methods have implications for car control. An open differential provides equal thrust from both drive wheels. If we give more power to the wheel with greater traction, by whatever means, that creates a yaw moment and steers the car. For this reason, tractor brakes are also known as steering brakes or cutting brakes. There is therefore an inherent trade-off between forward thrust and directional stability when traction is unequal on the right and left sides of the car.

With inter-axle differentials, we usually want at least a slight excess of power to the rear so we can use the throttle to position the car and preserve steering control at the front wheels. None of this means limited-slip differentials are bad, but it does mean we need to pay attention to their interaction with the rest of the car and their effects on car control.

CONTACT

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The right balance is critical in racecar set-up, but varies depending on category. A rally car, for example, might be set up to oversteer (above), or neutral steer (top) through the turns. Understeer (below) is rarely a desirable handling trait in any racecar. All conditions induce a reduction in lateral acceleration

Photos: XPB

Handle with care

A qualitative approach to implementing vehicle dynamic set-up changes on a racecar

By Dejan Ninic

The handling of a racecar is one of the primary areas of research and development in the pursuit of peak performance of the car in a diverse set of conditions and environments. The handling is the communication of the car's motion to the driver so, if the handling has limitations, the performance will be compromised.

The academic research of handling is referred to as vehicle dynamics, and its aim is to predict the resulting motion of the car due to the forces acting upon it. Whilst propulsion and aerodynamic improvements may be applied to the car, the potential gains are only realised if the chassis is configured correctly to transmit those forces through the tyres.

There have been numerous publications written on the topic but, without a post-graduate degree in engineering, most racecar engineers lack a clear strategy for optimising a vehicle's handling. In this piece, we look at the Vehicle Handling Model (VHM), a simple tool that provides a process to bring the engineer's knowledge of the car's set-up to effectively address its handling limitations.

Solution variance

The first, and most important, question to answer is how much time do you have to make a change? If you have three minutes in pit lane, three hours in the garage or three weeks at the workshop, the solution for the same problem could vary significantly. Suggesting a change in scrub radius may be impossible to implement during a pit stop in a four-hour endurance race, for example, yet on some single seaters changing camber may be easier, and quicker, than changing a wheel.

Understanding the tools, timing and available set-up changes on any particular racecar is a task best done at the workshop, though, surprisingly, is often only done thoroughly by the most committed teams.

The first, and most important, question to answer is how much time do you have to make a change?

We can summarise any vehicle handling issue in four basic categories: stability, response, balance and grip

Imagine a one-make series car such as a Porsche 911 GT3 Cup car, or Audi R8 LMS Cup – the team that masters the operation of the car will find advantages in opportunities others are not prepared for. This is the secret to success in one-make categories.

A typical list of set-up changes could include adjustment of tyre pressure, wing position, ride height, damper adjusters, spring rate, camber, toe angle, caster, roll-centre position, cross-weight, ballast location, bump rubber type, packer height and anti-roll bar settings. While making set-up changes during a session, you must consider the time it takes to raise the car and remove wheels, keeping in mind that parts on a racecar will be hot enough to give second-degree burns if touched by exposed skin.

Second-order effects

The set-up recipe book is what aspiring junior race engineers often learn first so they have solutions for the car's handling eg to reduce understeer, soften front anti-roll bar, and so on. The limitation with this method is that second-order effects of each set-up change are not considered in advance. However, the equation must be solved inversely. Understanding how to trade a handling strength to improve a weakness is key to making forward, not sideways steps with each set-up change.

To do this, the handling of the racecar must be clearly defined. Only then can its handling strengths be used as a source for solving other weaknesses. Thankfully, vehicle dynamics can be simplified for this task.

We can summarise any vehicle handling issue in one of four basic categories: stability, response, balance and grip. These are mathematically represented as the four boundaries in the graphical representation of a theoretical vehicle dynamic model, often termed the force moment analysis, or yaw moment method. These identical mathematical models aim to predict the car's instantaneous turning rate (yaw acceleration) created by the relative forces experienced at each contact patch, which create the yaw moment, or vice versa.

The aim is to understand the dynamic state of the car as a function of the applied forces and furthermore, predict how the dynamic state then varies due to the feedback loop of forces and response.

Whilst the mathematical model may seem complex, the governing fundamentals are simple, and their relationships natural to most people who have driven a car aggressively enough to find a limit of handling. **Figure 1**, below, displays the relative orientation of yaw and lateral acceleration.

Now let's look at each category individually. **Stability** is the ability of the car to maintain its general heading with little or no driver correction due to changes in forces on the tyres and body. The forces acting upon it could be wind, road banking, impact with another car or simply the driver turning the steering wheel or pushing the brake pedal. Unstable handling means the driver or car driver aids do not have the tools to regain control of its heading without spinning off the road, or being forced to reduce speed significantly.

Some drivers enjoy being on the edge of stability, but most need stability to have confidence to push the car to its limit of performance. Due to the severe outcome when it is lost, stability must always be addressed first.

Response is the change in heading rate (yaw acceleration) that occurs due to changes in the applied forces. It can be measured relative to time or a driver input, such as steering angle. Excessive response may lead to instability, and insufficient response could render the car incapable of navigating the environment (consider, for example, the difference in the range of steering angle required at Indianapolis Speedway compared to Monaco GP circuit).

The car's set-up and build specification will define the response behaviour, but it will also vary dynamically when the car is in motion,

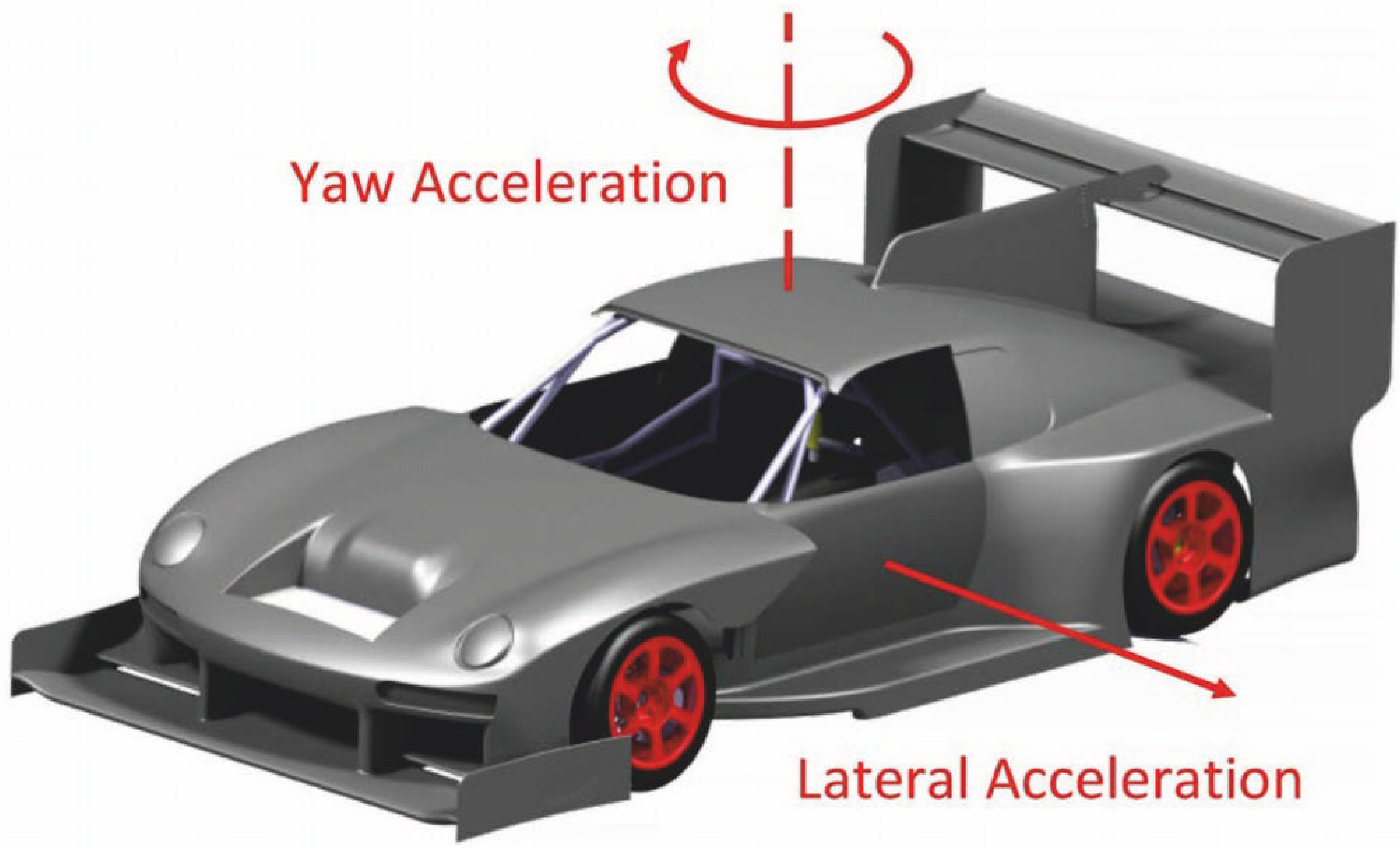
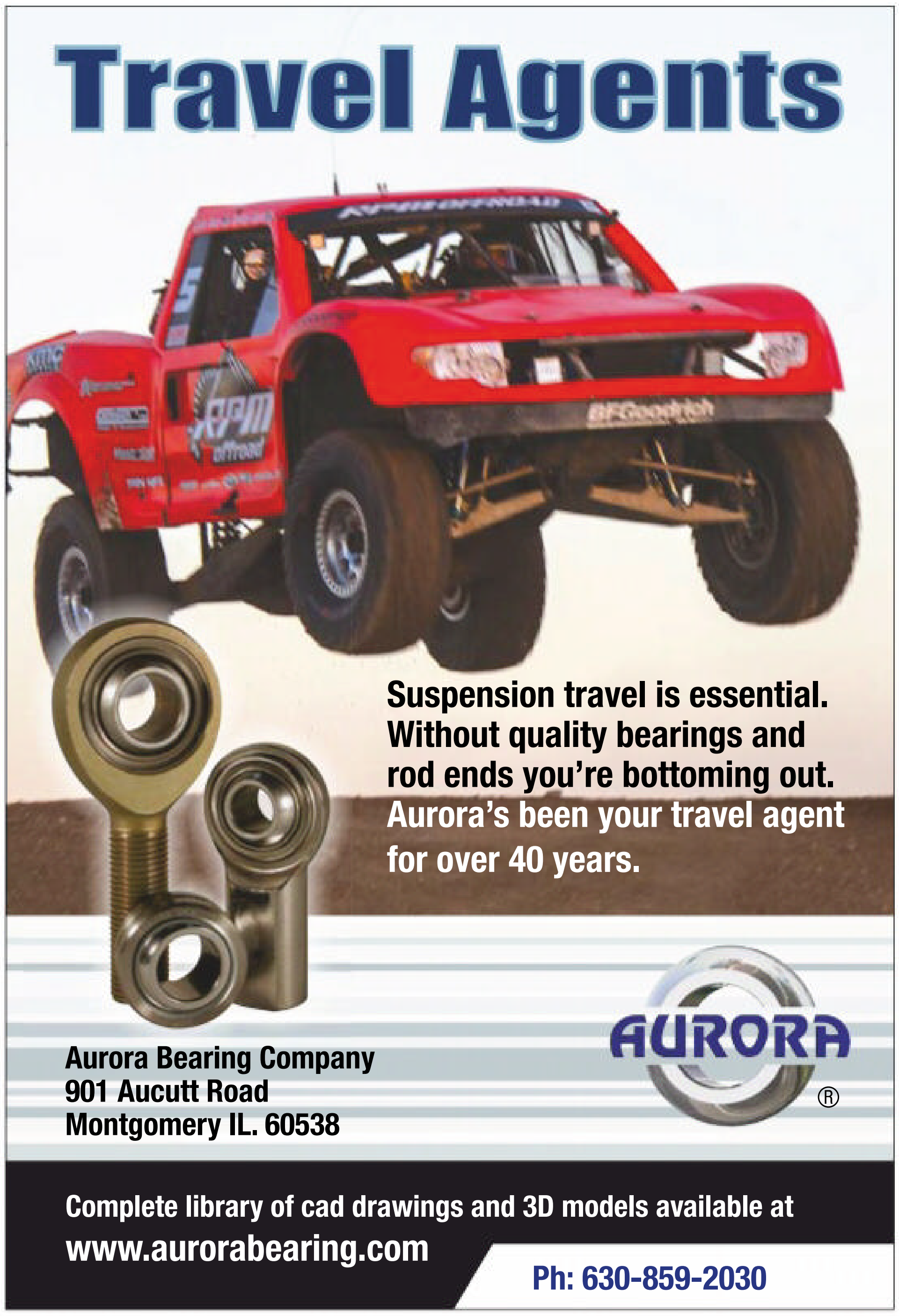


Figure 1: Yaw acceleration and lateral acceleration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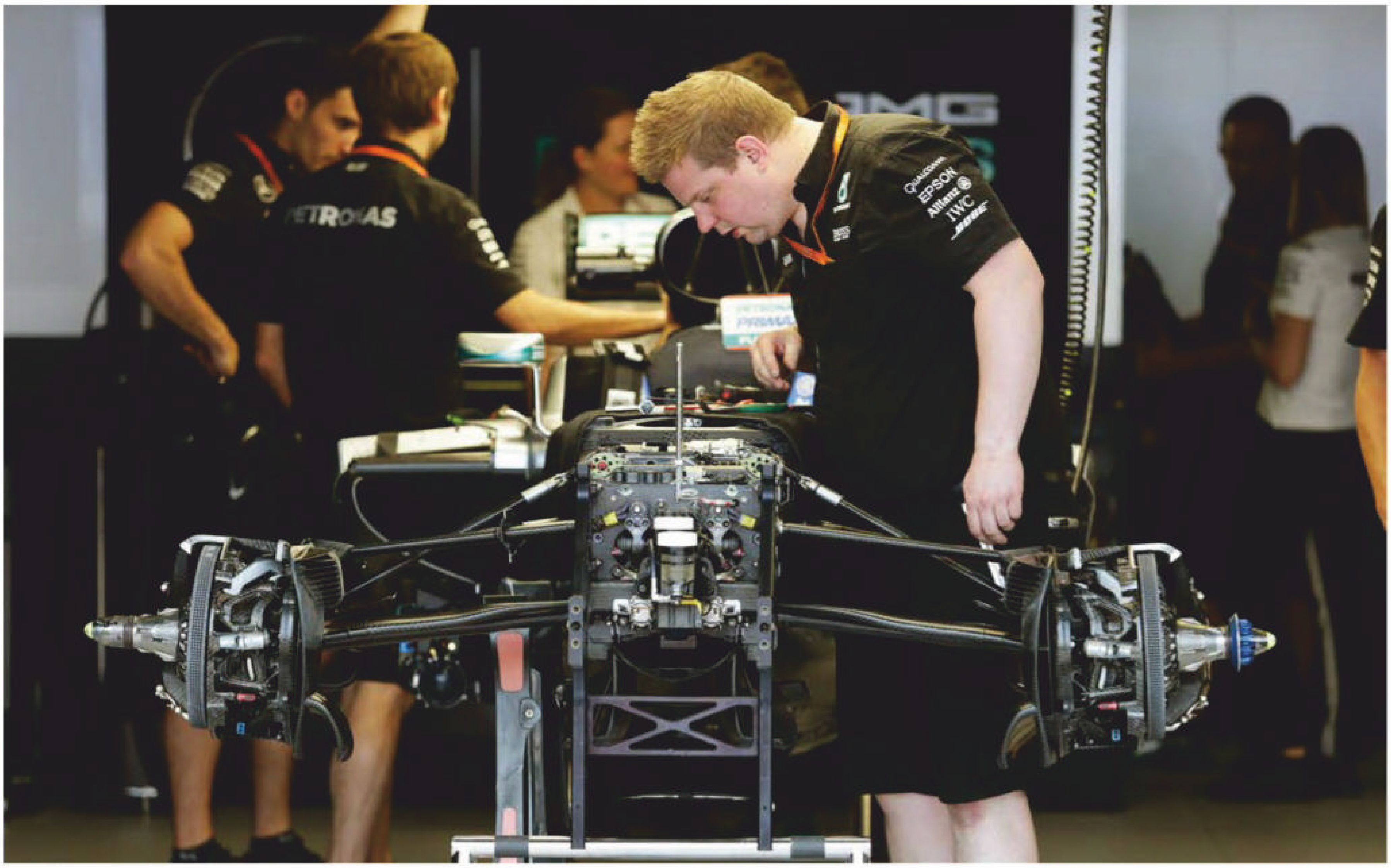


Understanding how to trade a handling strength to improve a weakness is key to making forward, not sideways, steps with each set-up change

and is not a constant for any given set-up configuration. Most drivers refer to response as the car's ability to rotate towards the chosen apex at a desired rate and steering angle, and so we can also refer to response as control. There is no maximum or minimum value for response and drivers have their own preferences.

Balance is simply explained as the conditions understeer, neutral steer or oversteer, when the car is close to its maximum lateral acceleration during a turn. During understeer, the car experiences a decrease in lateral acceleration with its front wheels sliding out onto a larger turn radius. In oversteer the car also experiences a decrease in lateral acceleration, this time with the rear wheels sliding out onto a larger turn radius. Neutral steer is the condition when both the front and rear of the car reach a limit and the whole car slides out to a larger turning radius.

It is important to understand that once the car has achieved a limit in balance, the lateral acceleration *always* reduces, and the car diverges to a larger radius of turn. When oversteer exceeds its limit a car spins out of control and, when the ensuing slide cannot be regained, it's actually a lack of stability. Similarly, a lack of turn entry rotation is often referred to as 'turn-in understeer', whilst this is more correctly defined as a lack of response.

To make it simpler, only when the car has near zero yaw acceleration ie during the mid-corner phase can it be assessed for balance. In most cases, balance issues result in a decrease in lateral acceleration, whilst a response or stability issue results in a change in yaw acceleration.

Maximising grip may not always produce a car that has the desired response or stability

Grip is the maximum achievable acceleration for the given conditions and, in this context, relates to the car globally rather than each contact patch. Maximising grip may not always produce a car that has the desired response or stability, but the aim is to cover distance in the shortest time possible, a condition related to magnitude and duration of the peak accelerations at the limit conditions of braking, accelerating and turning. Better grip is often the consequence of improvements in stability, response and balance.

Figure 2 represents the Vehicle Handling Model model in a visual format.

The diamond shape is modelled off the typical theoretical graphical output of the yaw moment diagram. In this context, it serves to display the strong interaction between adjacent categories and the loose connection to categories on opposing sides. Whilst some may consider the relative interactions a compromise, it is these that guide the choice of intervention. Therefore, it is better considered a trade-off.

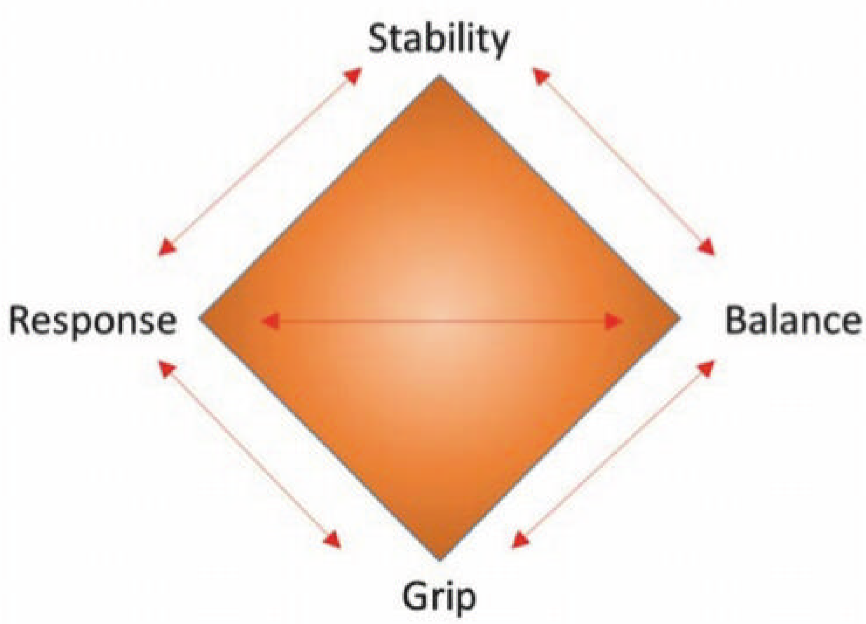


Figure 2: The Vehicle Handling Model

The Vehicle Handling Model summarises complex mathematical vehicle dynamics models into a qualitative approach

To be specific, a stable car can trade some stability in return for corner-entry response, while a car that is unstable in high-speed corners can trade its low-speed neutral balance for understeer. In most cases, it's not desirable to trade grip for anything, but changes that aim to improve stability by improving chassis (platform) control, such as damper stiffness, may indirectly reduce wheel control for the sake of body control and consequently cause a reduction in mechanical grip.

Transient or steady state

To add further to the definitions of the handling categories, we can specify their significance to transient state or steady state. Stability and response are considered transient, meaning they are issues that occur when yaw acceleration is high but lateral acceleration is low, such as corner entry / exit.

Balance and grip are considered steady state as yaw acceleration is low and acceleration is high, in situations such as mid-corner or straight-line braking. Despite this simplification, it is very likely that during a near steady-state condition a change in any of the forces may result in a switch to a transient condition, such as a car cornering at near peak lateral acceleration receiving an impact from another car, or a wheel hitting an inside kerb.

With a specific understanding of car set-up and the individual effects of the four categories on the car, it is possible to define the process using the model as follows:

1 Determine the time available to make a set-up change. Use as much time as reasonable to gather information and promote discussion.
2 Determine the handling strengths and relate them to the VHM.
3 Determine the handling issues and relate them to the VHM.
4 Prioritise issues of stability and response over balance and grip.
5 Determine which set-up change(s) would affect the strength and improve the issue, considering the time available to make the changes.
6 Propose to the driver the most likely trade-off and, time permitting, propose a second possible option.
7 If there are numerous solutions and sufficient time, apply and test each change in sequence to evaluate individually.
8 Always give the driver confidence that the changes are specific to the information they have given, and within the limitations of the situation / car.
9 Review and reflect on the changes and always consider other possible solutions, even if they are with the benefit of hindsight.

As an example, consider a gravel rally car in a midday service, with five minutes available to make set-up changes. The driver reports the car has good grip with maybe a small amount of understeer through slow corners, but at high speed it's really hard to rotate the car and hit the desired apex. The car doesn't feel unstable and has never 'stepped-out' suddenly.

The strengths here are stability and grip, the issues are response and some potential understeer. In this situation, we can reasonably trade some stability for response, and aim to reduce the understeer. Typically, to achieve this we stiffen the suspension to improve response, and we can stiffen the rear suspension to reduce understeer. Five minutes isn't enough time to change the springs, so we suggest a firmer setting of the rear anti-roll bar during service and ask the navigator to increase stiffness in low-speed compression of the rear dampers after they have had a change to evaluate the first setting.

Understanding the effects of each set-up change to the car's handling is still critical. However, relating how each change affects the car in handling makes finding trade-offs possible in what seems like a vast array of coupled set-up variables.

The Vehicle Handling Model summarises complex mathematical vehicle dynamics models into a qualitative approach of choosing the direction and significance of set-up changes to improve overall handling. The VHM is a tool to align practical car set-up knowledge with basic set-up handling relationships to a common goal with reasonable trade-offs. For readers with less experience in the effects of set-up changes, we will discuss these and how they can be used and traded using the Vehicle Handling Model in our next article.

Response is the change in yaw acceleration that occurs due to changes in applied forces. Excessive or insufficient response may lead to instability and embarrassment

Occupational therapy

Or how to keep your engineering mind active while you are locked down at home

By DANNY NOWLAN

Unless you have been living under a rock for the last couple of months, it's pretty obvious that Covid-19 has brought the world to a shattering halt. However, just because you are stuck at home doesn't mean your race and performance engineering has to stop. Quite the contrary; this is a heaven-sent opportunity to do some analysis work that you usually don't have time to do.

In this article I'm going to show you how to combine data analysis and simulation to fill in the blanks on two grey areas of vehicle dynamics; tyres and aerodynamics.

With regard to tyres, the first technique I'm going to show you is one I developed about four years ago that has since been widely adopted by the ChassisSim community. This technique revolves around the second order traction circle radius vs normal load fit, as presented in **Equation 1**. Some typical values for this are presented in **Table 1**.

Plot this out and you will have something that looks like **Figure 1**.

Where things become interesting is the relationship between the initial coefficient of friction and the peak tyre load that produces the most force. If we take the derivative of **Equation 1** with respect to load and set it to zero we get **Equation 2** where Lp is the load where the maximum value of the traction circle radius will occur. Doing a little bit more manipulation of **Equations 1** and **2**, the maximum possible value of the traction circle radius is shown in **Equation 3**.

This is best illustrated graphically, and this is shown in **Figure 2**.

What this shows is that the maximum force of a tyre can be described by its peak load and initial coefficient of friction. A spin on this curve is that as the peak load decreases, the shape of **Figure 2** becomes more compressed. This shape tells you some useful information about where to go with the set-up.

For example, if the difference between the peak loads you see on circuit and the peak load of the tyre is within 20-30 per cent, it tells you to run the car soft. Conversely, if it is over 50 per cent, it is dictating low roll centre and high spring, bar and damper rates.

Static load balance

Where this comes out to play is when you use **Equations 1** and **3** for a simple static load balance. All you are doing is taking your roll centres, springs, bars and front and rear track and aero information to determine your tyre loads for a given lateral acceleration and speed. Both your front and rear cornering speeds can then be determined by **Equation 4** and believe it or not, these equations are the basis of pseudo static simulation.

The pay off is that you can combine this into a simple set-up sheet and start to use it to predict cornering speeds. A screen shot of this is shown in **Figure 3**.

This is the worksheet I use for calculating load transfer distribution, and I've expanded it to include tyre forces and cornering speed predictions. While this is not going to win any

Figure 1: Second order plot of the traction circle vs load characteristic

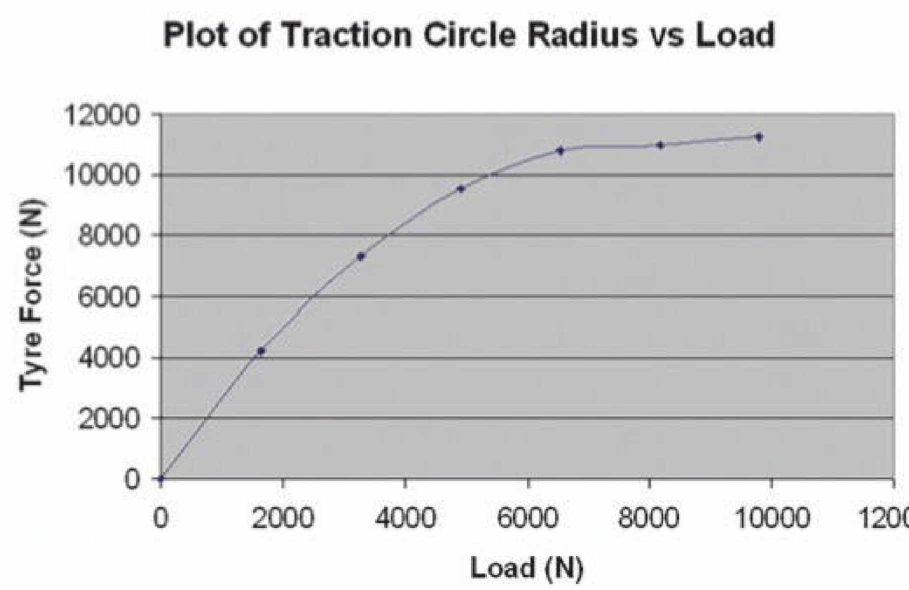
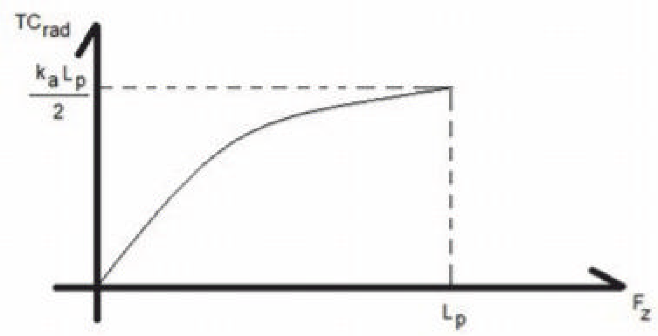


Table 1: Typical open wheeler numbers for maximum tyre force with the coefficient of friction dropping off linearly with load

Parameter	Value
k_a	2
k_b	5.0 e-5 (1/N)

Figure 2: Graphical illustration of the peak load and traction circle radius values



EQUATIONS

EQUATION 1

$$TC_{RAD} = k_a(1 - k_b \cdot F_z) \cdot F_z$$

Where:
TC_{RAD} = traction circle radius (N)
k_a = initial coefficient of friction
k_b = coefficient drop off with load
F_z = load on the tyre (N)

EQUATION 2

$$L_p = \frac{1}{2 \cdot k_b}$$

EQUATION 3

$$TC_{RAD\_MAX} = \frac{k_a \cdot L_p}{2}$$

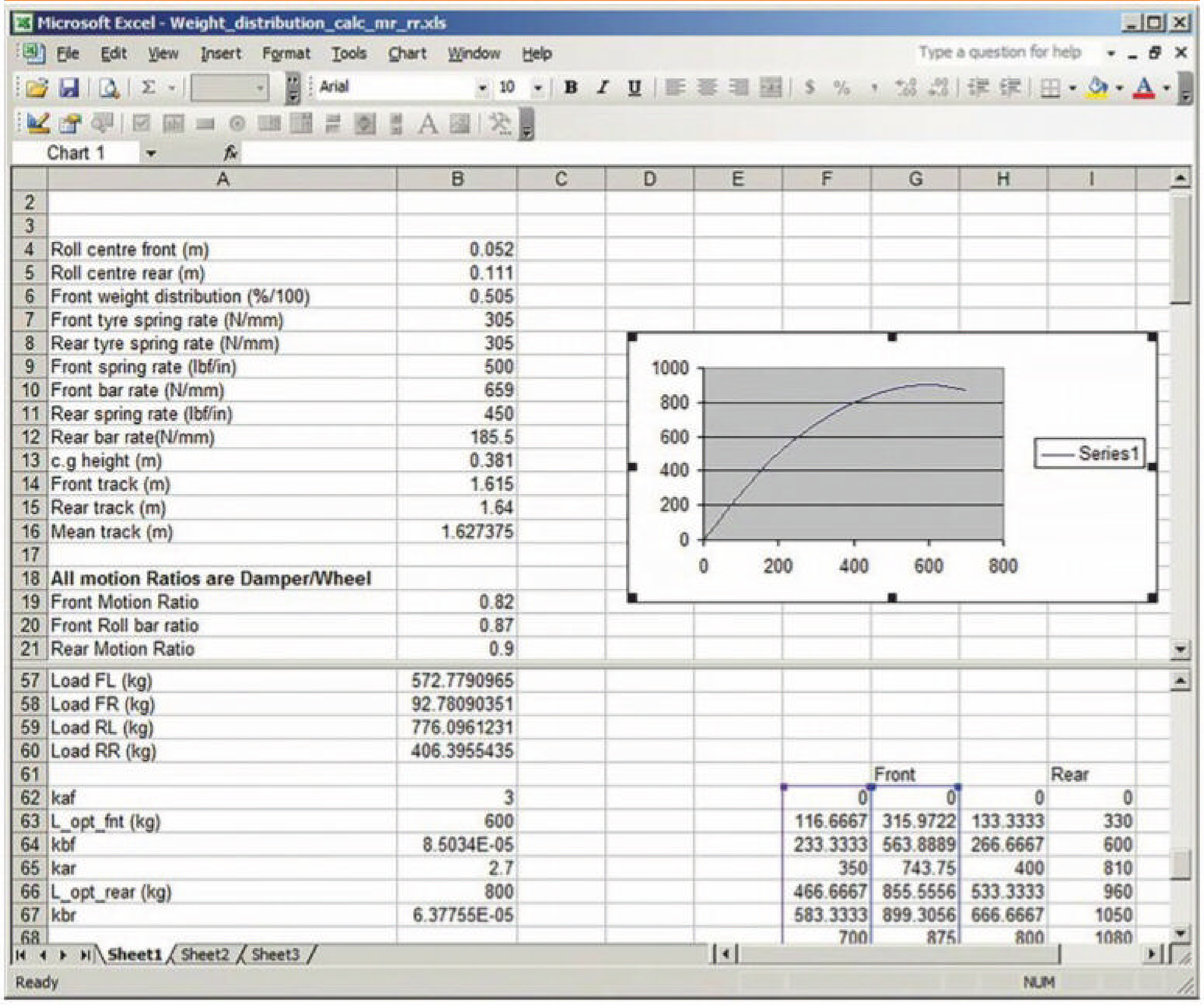
EQUATION 4

$$F_{yf} = wdf \cdot m_t \cdot iR \cdot V_x^2$$

$$F_{yr} = (1 - wdf) \cdot m_t \cdot iR \cdot V_x^2$$

Where:
F_{yf} = front lateral force deduced by plugging the front loads into equation 1
F_{yr} = rear lateral force deduced by plugging the rear loads into equation 1
wdf = front weight distribution (per cent / 100)
m_t = total car mass (kg)
iR = peak corner curvature (1/m)
V_x = cornering speed (m/s)

Figure 3: Excel worksheet for predicting tyre forces and cornering speeds



	A	B	C	D	E	F	G	H	I
2									
3									
4	Roll centre front (m)	0.052							
5	Roll centre rear (m)	0.111							
6	Front weight distribution (%/100)	0.505							
7	Front tyre spring rate (N/mm)	305							
8	Rear tyre spring rate (N/mm)	305							
9	Front spring rate (lbf/in)	500							
10	Front bar rate (N/mm)	659							
11	Rear spring rate (lbf/in)	450							
12	Rear bar rate(N/mm)	185.5							
13	c.g height (m)	0.381							
14	Front track (m)	1.615							
15	Rear track (m)	1.64							
16	Mean track (m)	1.627375							
17									
18	**All motion Ratios are Damper/Wheel**								
19	Front Motion Ratio	0.82							
20	Front Roll bar ratio	0.87							
21	Rear Motion Ratio	0.9							
57	Load FL (kg)	572.7790965							
58	Load FR (kg)	92.78090351							
59	Load RL (kg)	776.0961231							
60	Load RR (kg)	406.3955435							
61							Front		Rear
62	kaf	3				0	0	0	0
63	L_opt_fnt (kg)	600				116.6667	315.9722	133.3333	330
64	kbf	8.5034E-05				233.3333	563.8889	266.6667	600
65	kar	2.7				350	743.75	400	810
66	L_opt_rear (kg)	800				466.6667	855.5556	533.3333	960
67	kbr	6.37755E-05				583.3333	899.3056	666.6667	1050
68						700	875	800	1080

If the difference between the peak loads you see on circuit and the peak load of the tyre is within 20-30 per cent, it tells you to run the car soft

beauty awards, it is a powerful tool because in an instant you can adjust your initial coefficient of friction and peak tyre load to estimate what your cornering speed should be for a given speed and peak curvature (this you can take from logged data).

Then you can change the set-up parameters to see how sensitive either end is to set-up changes. This method actually started life as a sanity check for what ChassisSim would output, and has since proven to be very useful.

Peak tyre loads

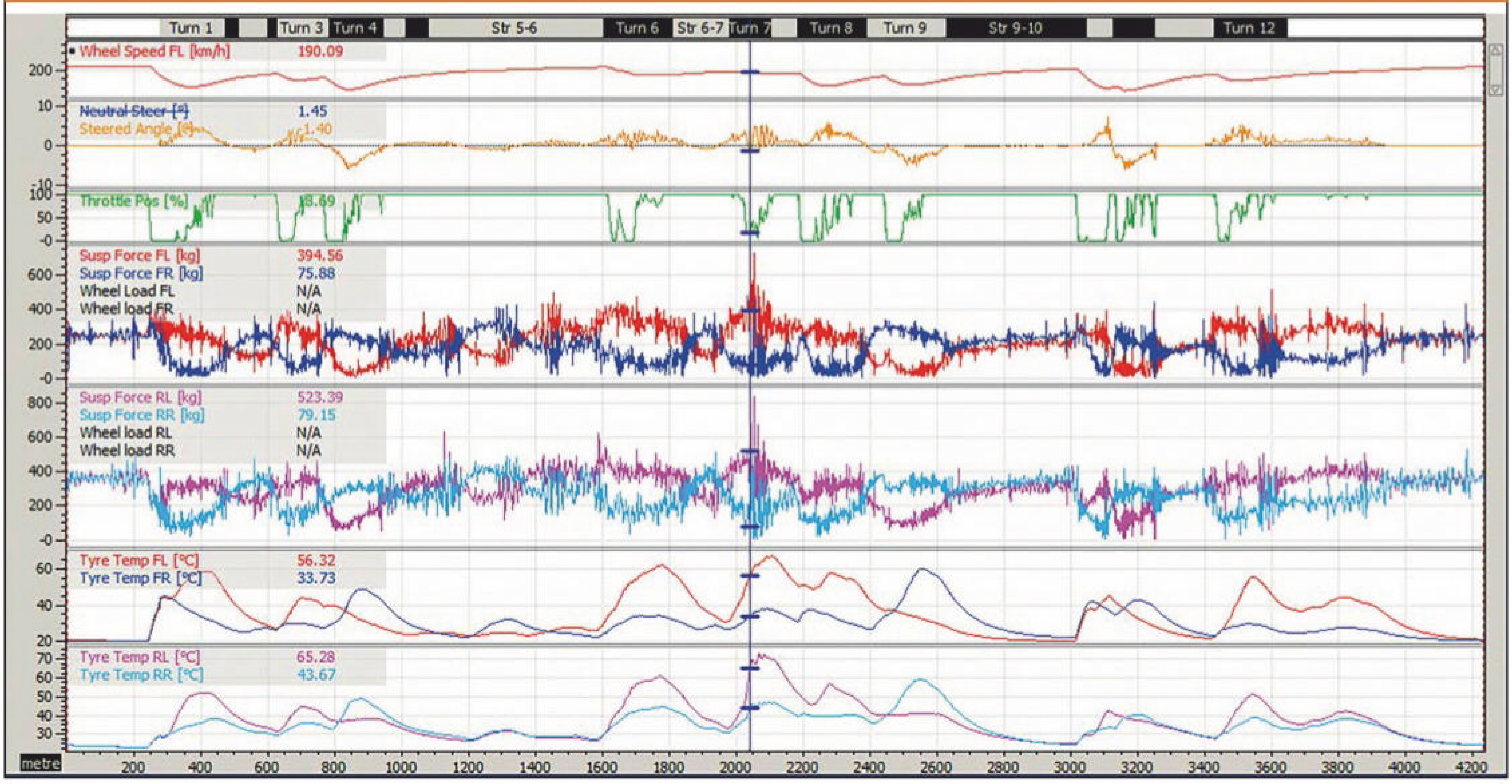
The next step in this process is to estimate the peak tyre loads. You can do this with either simulated or actual data. This is illustrated in **Figure 4**.

The peak load in this case was about 400kgf at the front and 500kgf at the rear. As a rough rule of thumb, you add about 20 per cent as a start point for the peak tyre load and this is what you plug into the Excel sheet we illustrated in **Figure 3**. I realise, given what we have just discussed, you have introduced a compromise, but we'll talk about this shortly.

Once you have this figure, you can play with the initial coefficient of friction to dial in your corner speeds and which end you want to oversteer or understeer. You do this by taking some values from the data from low, medium and high-speed corners, and then play primarily with the initial coefficient of friction to tweak the peak load and dial in the results.

When this is completed, you then enter the numbers into ChassisSim, or whatever simulation package you are using. In ChassisSim speak, you reset the tyre load axis to correspond with the peak load you

Figure 4: A plot of tyre loads for a given lap



determined in **Figures 3** and **4**. You then use the tyre model quick start to enter the tyre curve you determined in the Excel sheet in **Figure 3**. An example of this functionality is shown in **Figure 5**. You then run the simulation and tweak the global grip factors.

I cannot speak for other simulation packages, but the final step in this process is to use the ChassisSim tyre force modelling toolbox to fill in the details.

Sensitivity traps

Now, there are a few traps with this technique you need to be aware of. Firstly, a lot of the set-up sensitivity we have discussed will revolve around the peak load you choose. Taking my initial suggestion of starting at a delta of 20 per cent for peak load, run it through the ChassisSim tyre force optimisation toolbox and then repeat the process for 40 per cent. Then try some set-up sweeps. Do this and you'll figure out pretty quickly which is the way to go.

It's worth the effort, though, as the end results are stunning. **Figure 6** is an overlay I did using this technique that I ask students of the ChassisSim bootcamp to do.

As always, actual is coloured and simulated is black. Now ChassisSim is faster into the turn and the steering lock mid-corner is less then the actual car. This is the simulated data, remember, and so is to be expected. However, the cornering speeds are spot on, and I get the students on camp to work through this in a rapid 30-minute session after lunch!

Closing the loop on this discussion you might ask if you can obtain a useable tyre model by just studying one set of data? The answer to this is that while a single data set will get you started, you'll need about three or four iterations to build a full tyre model.

Although in my opinion the ChassisSim tyre force modelling toolbox is fit for purpose, at this point you might choose to re-visit the method we have discussed because different circuits will load the tyre in different ways.

Aero modelling

The second thing to discuss is aero modelling, and in particular constructing the pitch sensitivity map. I've discussed on a number of previous occasions how, in order to build a pitch sensitivity map you need data from multiple runs. This is because when you extract data from a run you obtain a single line from the aero surface map, and the bottom line is you can fit a surface to a line.

If you have a problem with that, I would suggest taking it up with your supernatural deity of choice.

So, in order to do this accurately, you need to look at a number of runs. This situation is illustrated in **Figure 7**.

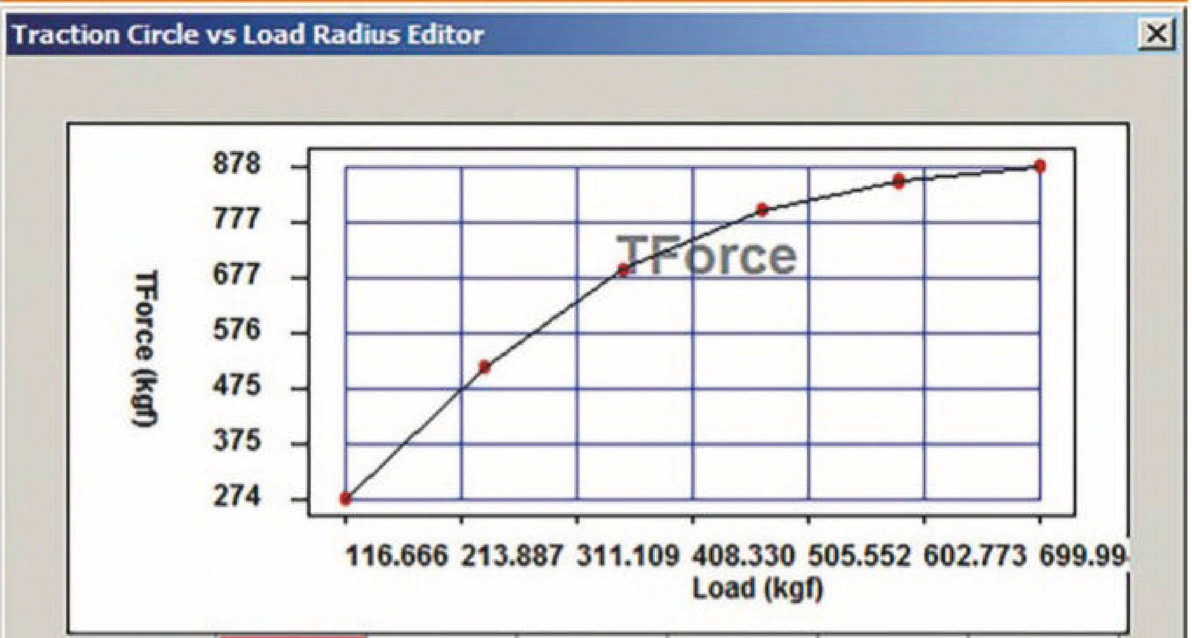
Each of these lines represents a sliver of data. By collecting as big a spread as you can, you can now construct a reliable pitch sensitivity map. And using the technique I'm about to show you, it's remarkably easy.

Firstly, enter a set-up into ChassisSim and export a monster file from a set of data with a known wing configuration. **Figure 8** shows what the aero modelling toolbox looks like.

The outputs of this will be an ascii file with the following format:

- Columns 1 and 2 are ride heights in m
- Column 3 is CLA

Figure 5: Example of the tyre force quick start



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

OK Cancel

Figure 6: Tyre modelling correlation using the second order TC radius fit method

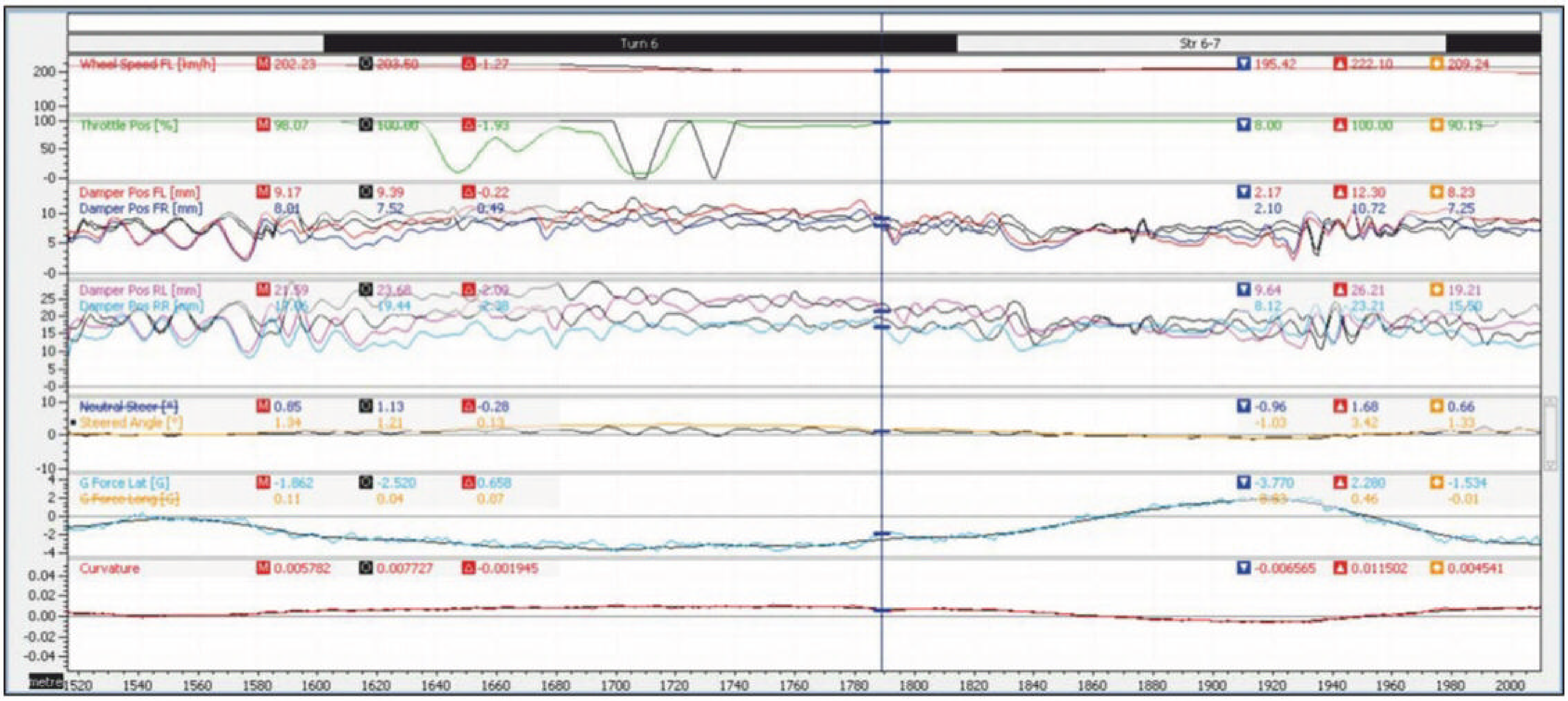
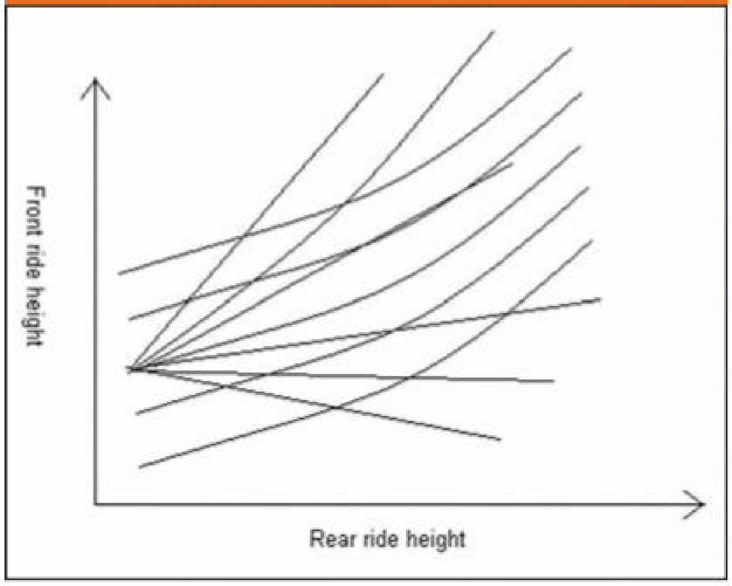


Figure 7: RH envelope from multiple runs



- Column 4 is CDA
- Column 5 is aero balance at the front scaled between 0 and 1

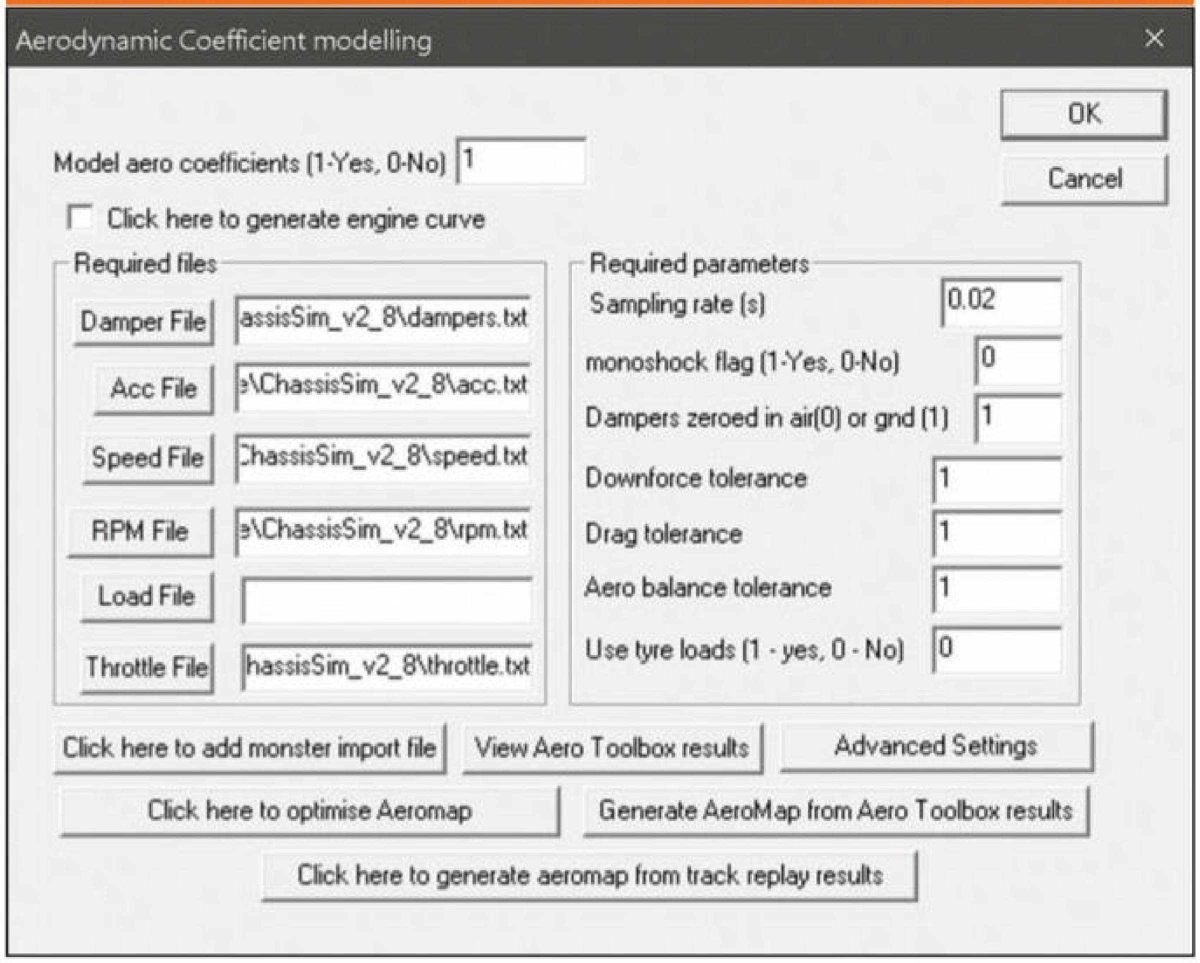
At this point you might be thinking this is all well and good but from multiple runs I'm going to have different wing settings, so how do I cope with this? All you need to do is to import this into Excel and scale the CLA and CDA by a known global value. I suggest taking the maximum possible value.

But what about aero balance? One suggestion is choose a baseline configuration and hand calculate the aero balance offset difference. You can then modify that in Excel.

At this point all you have to do is to bring all these different files together into a big file and curve fit this. You can do this in Matlab, Excel and ChassisSim has some tools you can use for this endeavour. Then multiply by your global values of CLA and CDA and wallop, you have a pitch sensitivity map you can then tune.

The final step is to adjust the rear wing CLA and CDA values in ChassisSim to fine tune the results. While this analysis method isn't perfect, it will get the job done.

Figure 8: ChassisSim aero modelling toolbox



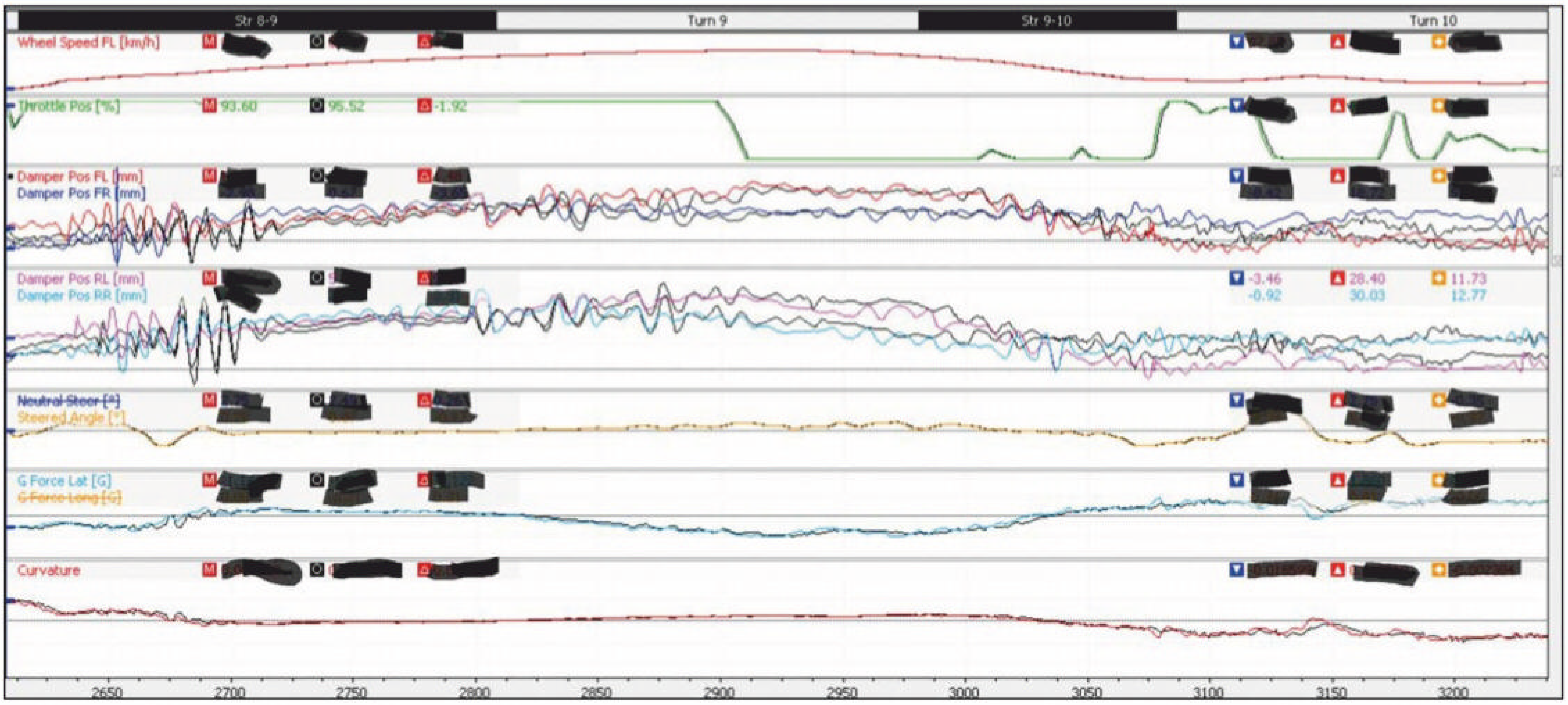
This is the time to delve deep into your data

Figure 9 is an example of some Time Attack aero map curve fitting I did when I was under the pump. As always, coloured is actual and simulated black. Since this is an open loop / track replay simulation, the inputs are identical. However, the money shots are in the third and fourth traces, which are the damper positions. The correlation speaks for itself.

In closing then, just because motor racing is in enforced hiatus due to the coronavirus epidemic, it doesn't mean your racecar engineering needs to stop. As we have just discussed, this is the time to delve deep into your data to better understand what your racecar is doing.

With the examples of tyres and aero we have discussed here, this is a great showcase of how you can use both data and simulation to learn more about these critical elements of car performance. Do this, and when we return after hibernation, you will be in a position to hit the ground running.

Figure 9: Open loop simulation of actual vs simulated data



Crisis talks

Racecar asks FIA President and UN Special Envoy for Road Safety his views on the future of motorsport after Covid-19

By DIETER RENCKEN

Frenchman Jean Todt (74) reaches the end of the final of three terms as FIA President in December 2021, not least because the former world champion rally co-driver and record-setting team boss of Peugeot (rally, Sportscar and Raid) and Ferrari (Formula 1) will have served the maximum number of permitted mandates allowed by the body, and be beyond the under-75 age limit prescribed by FIA statutes.

Generally considered the pre-eminent motorsport manager of his generation, arguably of all time, his CV boasts eight constructor F1 World Championships, a WSC title, two Le Mans victories, two WRC crowns and four and two Dakar and Pikes Peak wins respectively.

Consider that this 25-year roll call is sandwiched by a successful WRC career and three FIA presidential mandates, and the extent of Todt's achievements in motorsport are clear.

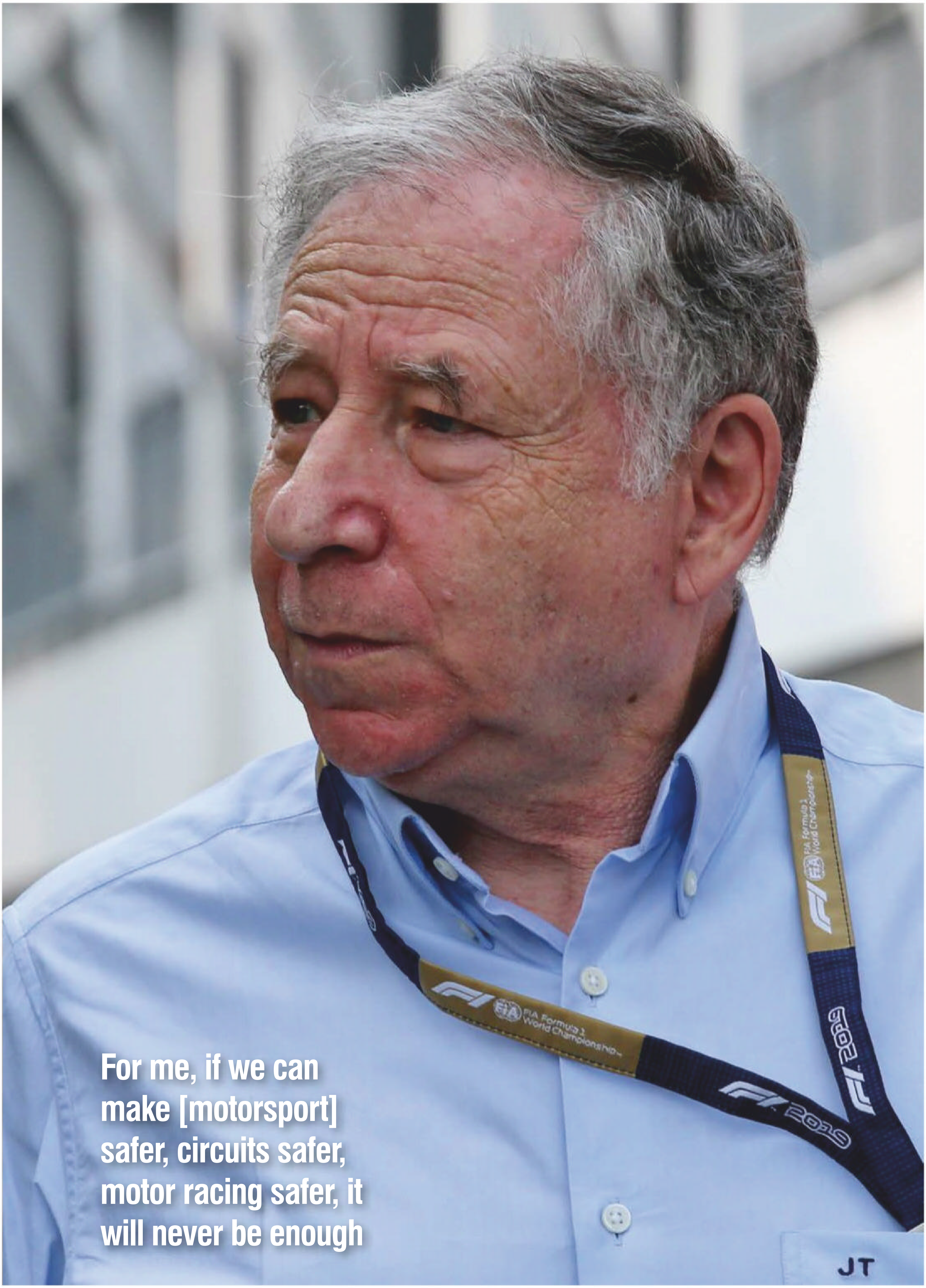
Hands on

This career, combined with his (seconded) role as UN Special Envoy for Road Safety uniquely equips him to comment incisively on global motorsport – from safety and technical matters, through driver and human factors to governance issues and political wrangles – through the prism of participation, combined with a variety of hands-on leadership roles.

As is his wont, Todt's pending departure from FIA office was meticulously planned. The incoming 2021 F1 and WEC regulations would have been in place for a year before his exit, enabling any issues to be resolved prior to handover to his successor, whoever that may be. The election process lies in the gift of the FIA's global membership, and Todt will not be drawn on a preferred successor, even if he has one.

However, Covid-19 has complicated such plans, given that in the wake of the pathogen's decimation of the sport, Formula 1 has elected to delay introduction of its 'new era' regulations by a year. As such, my opener to Todt, appearing relaxed and dressed casually as he speaks to *Racecar Engineering* from his home office outside Chartres, south west of Paris, is would he consider remaining in office for an extra year?

Todt has had an impressive career with multiple victories in F1, WSC, Le Mans, WRC, Dakar and Pikes Peak, as well as three terms as FIA president



For me, if we can make [motorsport] safer, circuits safer, motor racing safer, it will never be enough

It's not the moment to give up, it's the moment to be more energetic and more ambitious

The answer is typical Todt. In that it appears to answer the question, yet leaves an opening:

'I've been doing three mandates, and it has taken quite a lot of my time, of my energy, and of my commitment. My mandate is ending by December '21.'

True, but what about another year given Covid-19? It makes perfect sense, for global motorsport is on hold even if, as hoped, events are staged later this season. A year (at least) has therefore been lost, just as major changes are scheduled. Apart from F1 and WEC's radical Hypercar class, WRX is pushing ahead with Projekt E and Formula E is in the throes of sorting its Next Generation 2022 car. In other words, all major FIA series face change.

'It's not something I was planning at all. I must confess I was not planning this Covid-19 either. It's not a priority.'

Typical Todt ambiguity that leaves the door open for an extension, but only if asked to remain for another year.

The Covid effect

Which neatly leads us to the next topic: how has Covid-19 affected the FIA operationally and financially, and how readily has he, inveterate traveller that he is with a schedule that makes the Formula 1 community look homebound, adapted to remote working?

'First, we will reduce travelling, for obvious reasons, but not only us. You know, this Zoom video conferencing [also, coincidentally, our interview platform] **is clearly something new and very efficient, so we learn out of that,'** adding that the FIA has also taken the opportunity to agree a partnership with the International Red Cross, which extends beyond the current crisis.

'They will be our partners to [assist] the people who will participate in motor racing in future. The head of the medical department of the FIA is in discussions with them. We are engaging in programmes also to support [member] countries.'

And his personal adaptation?

'You know, I will be very honest, finally I became more lazy!' he says with a slow smile. **'I am fortunate to be in a comfortable, nice place, which I have been enjoying very much.**

'I could stay here more, if it were not [for] the situation. So if I travel so much, it is because I am the president of the FIA, because of the UN Secretary General's Special Envoy for Road Safety. My responsibilities make me travel. I'm a committed person. I do it more by commitment than by enjoyment.'

Covid-19 has ravaged businesses across the world, and the obvious question is whether the FIA has been affected, given that income is derived largely from member clubs (funded by their members) and driver and team licence fees. A decade ago, before Todt assumed office, finances were said to be under pressure. Can the FIA survive this crisis?

'We are a non-profit organisation, and fortunately we have stable finances. In all our plans we have some reserves, which will allow us to go through such a crisis.

'Even if we were not expecting the crisis, we were [anticipating] that it was important to have some reserves for the future.'

While Todt is confident the FIA is financially secure, the same cannot be said of a number of F1, and other, teams. Indeed, in the latest *AUTO*, the FIA's in-house magazine, he voices concerns: 'I don't think the priority now for a manufacturer

After a successful career as a co-driver in world rallying, Todt went on to become Peugeot Talbot Sport's director and gave the French manufacturer four World Rally Championship titles and four Paris-Dakar wins

is to secure continuity in motor racing. I'm sure some teams, suppliers and manufacturers may have to review their programmes.'

'I hope team owners and sponsors will keep the motivation. We must encourage them to feel they still like it and need it. On that, we have a responsibility. That's why we should listen to everybody.'

During this interview, Todt repeated those fears when it is put to him that current agreements commit F1 teams only through to end-2020, and that Covid may trigger a mass exodus, as occurred in 2009 – tellingly, as he took office for the first time.

'The world is different, and will be different, after the crisis. The economy has been devastated, we know that. But saying that, I feel in such circumstances you must always be even more aggressive, more on the case. So it's not the moment to give up, it's the moment to be more energetic and more ambitious.'

Surely, then, the answer is to have in place a mechanism to attract incoming teams, whether to F1 or other series?

'We must be optimistic. We must be positive. And it's also for them to be interested. We have tried to create the most exciting post-2020 Formula 1 championship. We have agreed to delay what we feel are very good regulations to 2022 due to the situation, which was for me a rational, logical decision, and a decision that was supported by everybody. The future looks good.'

Under pressure

A major coup in 2019 was to persuade the top F1 teams to accept annual budget caps of \$175m (with certain exceptions) from 2021, but Covid-19 has placed pressure on the FIA and F1 to further reduce that level, with a three-year (2021 / '22 / '23) glide path of \$145m / \$135m / \$130m up for a team vote as this is written.

Todt won't be drawn on the chance of success, saying only, **'I cannot go into specific detail because at the moment it's a work in process. But it's a question of days.**

'We also made one emergency article in our statues, the International Sporting Code, in order to be able to adapt new rules with a 60 per cent majority.'

Previously unanimity was required for changes less than 12 months hence, which invariably bogged down processes. This measure points to Todt's determination to break

[Obsolete] technology should be forgotten and excluded

the stranglehold of F1's major teams, and hence a belief in F1 circles that he will prevail.

'Clearly, this pandemic has reinforced our wish, our energy, to make more drastic decisions for the future. And in a way to resist even more the resistance that was occurring from certain teams.'

A clear dig at the Ferrari / Mercedes / Red Bull axis, which is aligned against stringent caps.

Pioneering spirit

One of the, some say 'unfortunate', side effects of cost saving is that standardisation of components, and even entire championships, has come to the fore. Is the president concerned that motorsport is gradually losing some of its pioneering engineering spirit?

'I would say no. Engineering is fortunately increasing every year, because there's more technology available.'

Then, after a pause, there's a direct reference to the current crisis:

'The fascinating thing, there is so much technology, but unfortunately not enough technology to understand the human being. The crisis, which is not understood – hence we're talking – is destroying the world.'

Then, leaving philosophical comment about Covid-19 behind, he's back on track, so to speak:

'The consequences of what we do in motor racing to the environment [are clear], even more now. I think we had the vision when we decided on Formula E, we had the vision when we decided on hybrid engines in F1.

'You know, when in the past some people said, "But I like the noise," it cannot be acceptable now. So you have different kinds of technology, technology which is close to the environment, to saving pollution, and all that is essential. [Obsolete] technology should be forgotten and excluded.'

There is no denying, though, that the ranks of racecar manufacturers has fallen dramatically over the past two decades. *The A-Z of Formula Racing Cars 1945-1990*, authored by David Hodges (1998), lists almost 1,000 chassis manufacturers. True, some only produced one-offs, or specials, but the likes of Lola, Lotus March and Reynard are listed as customer racecar brands. Today, only a handful remain as specification series suppliers. Is this a healthy state of affairs?

'I will say the most stable, the most healthy organisations will remain. Clearly, the healthiest – both financially and structurally – will remain, but they will suffer. That's why it's very important also for us to make the right decisions.'

Todt (left) with Pierre Fillon, president of the ACO (middle) and Chase Carey, chief executive officer of the Formula One Group (right)

In 1993, Todt moved to an ailing Scuderia Ferrari as general manager of the manufacturer's racing division. The first non-Italian in the role, he went on to lead the team to 14 F1 World Championship titles

We are also pushing like hell on green fuel, clean fuel, biofuel. We are investing in that [and] we will invest more

It was Todt, of course, who presciently pushed for an electric racing series a decade ago now, at a time when Tesla was just a novelty, peddling only a single, limited-edition model based on adapted Lotus Elise architecture. And there are perceptions in some quarters the current president is pushing an electric agenda now, particularly as Formula E outranks Formula 1's motor manufacturer count by a ratio of nine to four, and mutated into a fully-fledged World Championship in just six seasons. I asked the question; is there any truth in that belief?

'I was with Peter Bayer [FIA Secretary General for Sport] on the 'phone [earlier],' he scoffs with a smile, accompanied by a shake of head, **'and I was saying we must investigate more into hydrogen, fuel cell…'**

So is there a chance we could see the birth of, say, a Formula H championship in the not too distant future?

'I speak with our experts. I understand from them that there are limitations. We are also pushing like hell on green fuel, clean fuel, biofuel. We are investing in that [and] will invest more. So we must be open and creative.'

Todt's period of office to date is epitomised by three diverse sporting pedestals, if one excludes the road safety and touring matters that form part of the FIA's portfolio and are still very much on his radar. These are: cost saving, safety and new (or rejuvenated) motorsport categories such as FE (2014), WEC (reintroduced 2012) and WRX (2016).

Under his watch, the FIA Serious Accident Study Group was formed, tellingly chaired by Todt and including all FIA Commission presidents as members. It meets regularly to discuss actions from all serious and fatal accidents around the world and across all disciplines, and it is clear how he personally ranks the three components:

'For me, if we can make [motorsport] safer, circuits safer, motor racing safer, it will never be enough. Maybe the difference is we must optimise more motor racing, not only on safety but on technology as well, to have some repercussions on mobility. Road safety, road cars, whatever.

'I don't think now even manufacturers can afford to move into motor racing if it is not linked with other considerations. Clearly, the cost, because it is essential [to reduce that], there has been too much inflation. And it's come to a certain limit where it's simply not sustainable [to continue].

'So you have to be [resolute] and to make decisions, and to demonstrate strong leadership on that, even if you don't get full support from everybody. Even sometimes you are disappointed, because it's so full of good sense, but you should explain that support to everybody. But it's not always good sense that prevails in our world.'

On hypercar

Todt is indelibly linked to the Ferrari / Michael Schumacher 2000s hegemony, but his first on-track racing successes came via WSC (the '90's equivalent of WEC), so where does Sportscar racing fit into future plans? Is 'hypercar' the future of WEC, particularly given the series' internecine squabbles?

'In 1991 / '92 I was leading the group to save the Sportscar championship, the World Endurance Championship, and unfortunately it did not work [so] in 1993 [we were] without the championship.'

'Then a few weeks after I was elected president of the FIA [in 2009] I had a meeting with [motor manufacturer] management and the president of the ACO to re-open discussions. And from there we decided to create the WEC.'

Indeed, and after that Sportscar racing enjoyed a resurgence and some bumper seasons, with Audi, Porsche, Peugeot, Nissan and Toyota all entering 'works' teams, yet gradually they exited stage left. Today, Toyota is the sole brand in the top class, while there is much bickering over the future 'hypercar' category. WEC, therefore, currently stands before a major crossroads. Does it have a future?

'I feel that this kind of hypercar is the right way to go. Fortunately, whatever we say, people still dream [about] beautiful cars. We have too many manufacturers involved in producing some hypercars, so of course what is happening is not helping. But clearly, in a way, it's like rationalising the Group B at the time of rallying.'

Clearly, Todt is referring to both Group B's global success and associated political wrangles (not that he, as Peugeot's motorsport director at the time, unsuccessfully sued the FIA after the category was dumped due to a run of tragedies). Perhaps best to leave that there.

Todt's tenure as president of the FIA will come to an end but there is no hint of who he would back as his successor

The next steps

Another Todt initiative was the formation of the FIA Women in Motorsport Commission, ably presided over by Michelle Mouton, the only women to win a WRC round and a member of Todt's Peugeot roster. Is W-Series only the beginning of a dedicated female championship, or is there more to come?

'There are two topics I want to push. Engage more women, and engage more youth in the leadership (of motorsport). Those are two things that are very dear to me.

My penultimate question is slightly leftfield. Given the increasing environmental and social pressures being brought to bear on all of motorsport, would it not make sense to have some form of structured co-operation with the FIA's motorcycling equivalent, FIM?

It seems the FIA is ahead of our question: **'We are working very closely together. I invited [FIM president] Jorge Viegas in our High-Level Panel. And [FIA medical commission president] Gérard Saillant is working on many commissions that could be combined [between] FIA and FIM. So we are working very closely together. We are also working on developing a homologated cheap helmet for mobility, for motorbike riders.'**

There are two topics I want to push. Engage more women, and engage more youth in the leadership (of motorsport)

'If you take the FIA High-Level Panel [an FIA think tank created by Todt, with some serious heavyweights to call upon]**, we have the UN Secretary General Special Envoy, we have the Secretary General of the Scout movement, so it's very important. So both [women and youth] are for me essential.**

'You will see the diversity of people we have in our panel is quite spectacular.

'I must commend also the work which has been done with Michelle Mouton. It's the first time the FIA had a women's commission. We have started to have some women in both motorsport and mobility world councils, to have women in the Senate. So we want to have more women engaged in motorsport.

'We are working with WEC [and] all our other championships to create more.'

Finally then, when you – the only man in motorsport history to have led world championship-winning teams in rally, cross-country, endurance racing and Formula 1 – eventually step down, whether it's at the end of 2021, or even 2022, what legacy would you like to leave the sport you initially embraced as a hobby, but then ended up dedicating your entire working life to?

'Not an easy question!' he replies with a gentle smile. **'Honestly? Just to make all forms of motor racing as safe as possible. And also as large as possible. Of course popular, too.**

'We've [now] got pyramids in the single-seater [series], and we want to build pyramids in rallying, off-road... We want a strong motorsport, starting from grassroots, all the way through to the pinnacle.'

The International Journal of Motorsport Technology
Racecar engineering

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Subscriptions
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Subscription rates
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ROW (12 issues) £100
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News distribution
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Tel +44 (0) 20 7429 4000
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Email info@seymour.co.uk

Printed by William Gibbons
Printed in England
ISSN No 0961-1096
USPS No 007-969

THE CHELSEA MAGAZINE COMPANY LTD

www.racecar-engineering.com

Feats of endurance

The year was 2001 and the Bentley EXP Speed 8 programme was about to go to Le Mans for the first time in 70 years. Martin Brundle was one of the lead drivers and I interviewed him over the phone. I asked why he thought Sportscar racing had never taken off. His answer then is, unfortunately, as relevant as now: 'Because it hasn't had one single person like Bernie Ecclestone steering it in one direction and maximising what they have got.

'If there was [just] one Sportscar world championship with some key players and manufacturers... it hasn't given itself a stable base and understandable championships. I don't understand the differences between the ALMS, the ELMS, the FIA GT Championship. They have got to build a brand.

'When I won the Championship in 1988 it was the World Sportscar Championship, or was it the World Sports Prototype Championship? What the hell does it all mean? They haven't built a secure platform and therefore haven't attracted worldwide exposure and kept the manufacturers on board.'

Today, we have the FIA World Endurance Championship, IMSA and the Intercontinental GT Challenge as international endurance racing series, and each has sub-categories of either prototype or GT cars, be they LMP1, LMP2, GTE (also known in the US as GTLM) or GT3 (GTD). That's before you get to the GT World series, or Creventic.

The announcement of the LMDh regulations in January then further muddied the waters. These are the regulations that comprise one part of the top class at Le Mans. That is the easy explanation, but not the full one. They primarily govern the top class of the IMSA WeatherTech Sportscar Championship that incorporates races such as the Daytona 24 hours, Sebring 12 hours and Petit Le Mans. LMDh cars will also be able to race at Le Mans.

H for, er, well…

So just what does the 'h' stand for? At the press conference at Daytona, the members of IMSA and the ACO were asked and each had a different opinion. Was it hybrid or Hypercar?

Trying to explain the difference between an LMDh car and a Hypercar is time consuming. By the time you get past 'LMP2 chassis' and 'balance of performance' you have lost your audience. We need it to be called 'Global Prototype' and be done with it. As both Hypercars and LMDh will race in the same category, at the same races, will have the same power output and the same weight, they should fall under the same name. If one has an original chassis and own-developed parts while another does not, so be it.

We need it to be called 'Global Prototype' and be done with it

Yet no one is willing to back down. In these pages FIA president, Jean Todt, talks of his belief in Hypercar, and so he would. These were the FIA's regulations. Rumour has it he was closely involved in all aspects of the regulations, including pressurising Aston Martin to join. That may or may not be true.

Brundle's comments regarding the single player still carry some gravitas. In a recent interview by Jim Holder of *Autocar*, Bernie Ecclestone was asked about Formula E, replying: 'I would have buried it. It would have saved all the arguments. It wouldn't have happened if I had been there. But now everyone is talking about electric cars, so it would be a bit of a courageous thing now to go against it.'

Bounce back

Bernie's single-minded approach has done a fair bit of harm to racing outside Formula 1, and series that would otherwise have thrived were no doubt killed off. Sportscar racing fought through in the early '90s, only to have a 3.5-litre formula imposed upon it. Once that failed in 1993 and the likes of Mercedes and Peugeot moved to F1, it was clear F1 was the FIA's sole priority and it took years to bounce back.

The latest chapter has been written under Jean Todt's presidency. The FIA World Endurance Championship has run since 2012 and has seen some incredible racing and the most stunning technology. On the way, Todt killed off the FIA GT1 World Championship of Stéphane Ratel, but let's put that down to Bernie-style leadership. The WEC has gone through some glorious years, that cannot be denied, but now it is time for a change and here again you need strong leadership. The LMDh category is a cheap way of going endurance racing and I hope that, following the pandemic that has claimed thousands of lives and rather put motor racing into perspective, car manufacturers still find a value in such competition.

There is no doubt racing will face a tough time getting back on its feet and, already with an eye on the freshly oiled gallows, internal combustion engine racing has never had a more uncertain future. Will Hypercar really be that much more expensive? Fans want brands to support, competition departments want racing and board members want victory.

However, after 20 years in which there have been a multitude of natural and unnatural disasters, endurance racing continues to make the same mistakes and still exists. There must be something it is doing right.

ANDREW COTTON Editor

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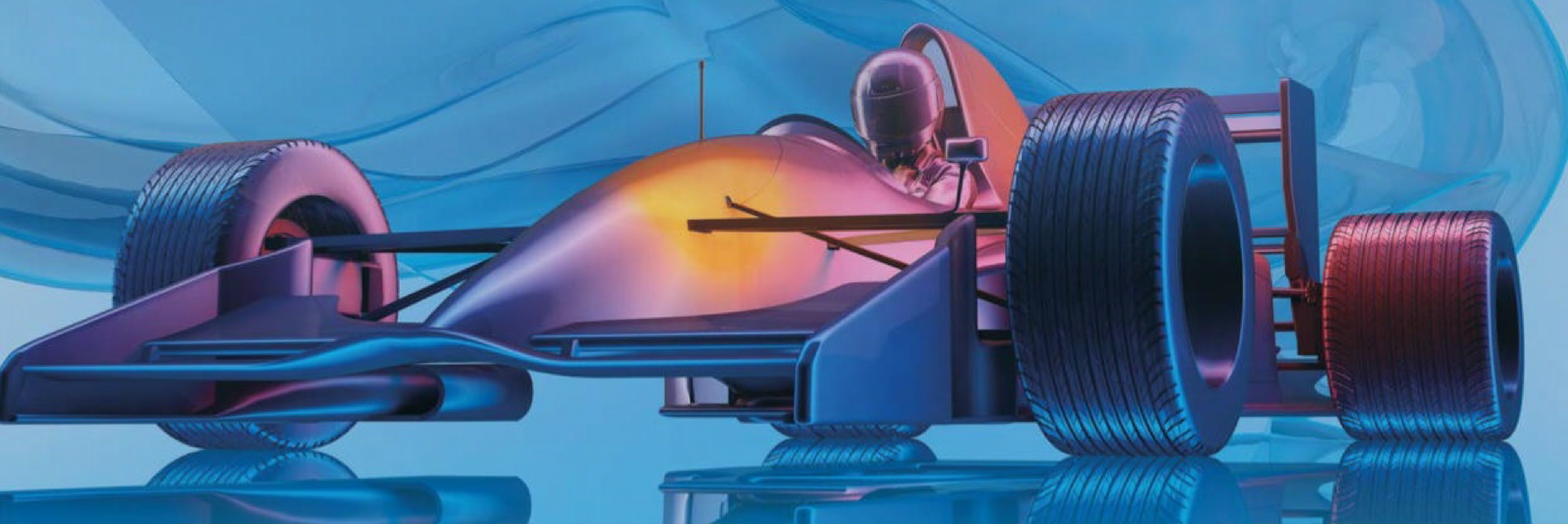

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