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NASCAR enters its Next Generation

Aero chief Eric Jacuzzi reveals the new car's development process

F1 2022

What teams can expect from the new aero rules

HONDA'S BOX OF TRICKS

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ELECTRIC TOURING CAR

New ETCR series under the spotlight

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Cadillac took the title in the 2021 IMSA WeatherTech series and the next season will be underway at Daytona in less than two months

Jake Galstad

Through the letterbox

There's no doubt safety has improved, but at the expense of visibility?

Having been critical of the seeming inability of drivers competing in the FIA's 'road to F1' single-seater championships – including in the premier category itself – to stay within track limits, onboard footage recently from Alpine F1 driver, Fernando Alonso's, helmet camera actually shocked me. Reclined so low in the monocoque, with the high side protection and bulky halo strut immediately in front, it was akin to looking through a letterbox. At 200+ mph.

Valentino Rossi made the same observation when he swapped car and bike with Lewis Hamilton in a recent TV feature. Previous video from cameras mounted on the roll hoop structure revealed no such limitation on sighting the car into and through high-speed corners.

It's reasonable to assume this 'handicap' applies to F2, F3 etc as well. However, as drivers have not been complaining, it must be that they soon become acclimatised.

Despite this letterbox view, drivers do finally manage to stay within specified boundaries (whatever they may be, different track to track and seemingly-day to day sometimes!) after receiving warnings and penalties, so clearly it is possible. Nonetheless, my respect for them and their abilities has increased.

Restricted view

Interestingly, following simulator work, Pierre Gasly has reported negatively concerning the front tyre air deflectors (which look rather like cut-down mudguards) that feature in the 2022 regulations. Apparently, they *further* restrict view of the front wheels, and hence accurate placing the car. That also makes it harder for a driver to see a lock-up under braking in the wet, when there is no tyre smoke visible.

In an age past, the maestro Juan-Manuel Fangio always performed at his best in open-wheel cars, which he said he preferred because he could steer them so precisely. And so I wondered, during an idle traffic queue moment, whether today's drivers might be able to achieve better lap times if seated higher and without the obstructions mentioned above?

Pointless thinking, of course, due to the safety regulations, raised c of g and aerodynamic compromises that would be involved.

Not such pointless thinking is that, ideally, two more F1 teams are needed on the grid, partly to reward the achievements of a number of outstanding drivers coming through the ranks of F3 and F2. Otherwise, this talent is lost to IndyCar, Formula E, Sportscar and GT racing or, worse still, from motorsport altogether.

There should also be the possibility for very successful teams from other major motorsport disciplines to aspire to grand prix racing. This would provide the backstop that may be needed if existing team-owning billionaires should pull their support at some point in the future.

Unfortunately, the barriers to this happening are very high. Any new entry is discouraged formally by the F1 governance until the new PU regulations are implemented, reinforced by a $200m 'dowry' to be shared among current teams.

What would Bruce McLaren make of rumours his eponymous team could come under German rule?

This, of course, is on top of the enormous up-front capital costs of setting up a team from scratch, and the difficulty of reaching agreement with an engine supplier.

I can understand why adding even one team without compensation for the existing players creates opposition from them, especially those who have fought long and hard to get where they are and stay there. It dilutes TV and other revenues, just when the cost cap and greater corporate awareness of F1 look as if team 'franchises' are accelerating in value, with the potential of becoming bottom-line profitable, with the stability that brings.

There are also the practical aspects of extra garage and paddock spaces, and the myriad logistical, administration, management and other requirements. It's nothing that couldn't be solved, but I suppose self-protection is inevitable.

Gene Haas was the most recent to take the plunge (before the dowry) and set up from scratch through an innovative approach, but – because of this strategy, perhaps – the team has struggled after a praiseworthy first season. Nonetheless, it has been important to have his eponymous team on the grid, and only partly because it's American. It may just be making up the numbers at present, but it is providing valuable seat time for Schumacher and Mazepin.

Depending on whether or not Alfa-Romeo (Sauber) move up the grid progressively in future, it may be a shame that the proposed Andretti Autosport takeover failed at the 11th hour. It would be positive to have another non-European outfit in what is, after all, a *World* Championship. Maybe Haas F1 will be Andretti's next target, although its structure, plus the Uralkali involvement, would doubtless be a complication.

The rumour mill

As I write, there are news stories emerging that Audi and BMW are vying to buy McLaren – a big surprise to most outside the inner circles, I imagine. If the rumours are true, and eventual disappearance of the famous name should be a consequence, this would greatly disappoint the host of McLaren followers and fans.

The positive aspect is it indicates the renewed strength and appeal of F1. However, I think it more likely that some kind of partnership is under consideration, particularly on the PU front.

The problem is that takeovers do not bring in additional teams. Much better if the aforementioned German manufacturers – or any other serious entrants – were to establish new F1 entities. It's harder than buying into an existing outfit, but with the cost cap and the potential self-funding model Mercedes has apparently achieved via financial and technology partnerships, they can afford it.

With third-party assistance, Audi (and Porsche) were able to very successfully produce and operate extremely sophisticated LMP racecars employing similar PU technical challenges as F1. Therefore, it should not take them as long to become competitive as it did for Mercedes and Honda, for examples. Plus, there are numbers of experienced personnel available as a result of the mandated cost cutting. Surely, 24 cars straining to be launched as the lights flash green seems about right?

Surely, 24 cars straining to be launched as the lights flash green seems about right?

Graduation day

Those involved in the aero development of the NASCAR Next Generation racecar see it not so much as the birth of a new era, but more like the completion of a study course

By DR ERIC JACUZZI

A once-in-a-lifetime project for most of us involved, who may never see another project quite as revolutionary to an ecosystem as this

The NASCAR Next Generation vehicle has taken to the track in earnest in late 2021, beginning the final team tests prior to its debut at the Busch Light Clash at the Coliseum, an exhibition race that starts the 2022 season.

Its development has spanned several years, thousands of hours of design and testing work, numerous suppliers and, of course, one global pandemic. The following is a small part of the story of its development from an aerodynamic standpoint, as told by managing director of aerodynamics for NASCAR, Dr Eric Jacuzzi.

NASCAR's current generation vehicle, the Generation 6, or Gen 6 as it's known, was introduced in 2013. With its forward emphasis on manufacturer identity, it was a breakthrough for the sport. It was the first time in many years that the entirety of the vehicle, from nose to tail, was unique to each

Perhaps the greatest departure of the Next Gen vehicle from the Gen 6 is the move to a coupe-like roof line, and the symmetry of the rear of the vehicle

The evocative, 'retro' styling of popular cars like GM's Camaro and Ford's Mustang don't lend themselves to the traditional three-box NASCAR silhouette, so the Next Generation body has moved more toward a coupe appearance

The new body style, and change to a symmetrical shape, meant all the aero development done to ensure the Gen 6 cars remain on the ground in yaw on high-speed ovals had to be re-visited

manufacturer (within certain parameters), harking back to the fiercely competitive manufacturer racing days of old. After eight years of racing, though, it was time to update the look of NASCAR's top series to more closely resemble their roadgoing counterparts, which too had evolved over that time period.

Couping the roof

Perhaps the greatest departure of the Next Gen vehicle from the Gen 6 is the move to a coupe-like roof line, and the symmetry of the rear of the vehicle. The Gen 6 was designed around a sedan greenhouse profile, which at the time was more relevant to the manufacturers' vehicle mix. However, the introduction of evocative coupes such as the Ford Mustang and Chevrolet Camaro meant fitting the production body style onto that sedan greenhouse proved challenging.

The side profile of the Next Gen vehicle is therefore a blend of the lines of the Camaro, Mustang and TRD Camry, featuring a lower roof line and swooping back glass design that works well for all three cars. With the greenhouse decided, the next step was to move to another stylistic sore point, the tail.

The Gen 6 was optimised to race on left-turning, high-banked ovals, generating stability in yaw via a large rear overhang and a 2.5in offset to the right. This offset generates rear side force, resulting in a restorative, positive yawing moment to the car. It also allows the car to 'correct' itself when the driver oversteps the bounds of traction at the rear.

The lower roof line and swooping rear window suits all three of the main manufacturer models, as does the much shorter rear deck section. The result is all three retain a strong brand identity

However, achieving all that presented significant aesthetic challenges for manufacturers and NASCAR, since car designs not only had to be stretched at the rear, but also have different shapes on the left and right sides. This leads to various interpretations of what is acceptable, and often lengthy lists of revisions from NASCAR in terms of qualitative styling, as compared to the production vehicle.

Spitting image

Introducing a symmetric body eliminated most of these issues and presented a car that is a near spitting image of its street counterpart. Another factor in moving toward a symmetric body was the evolution of the NASCAR racing calendar. The introduction of more road courses and short tracks reduces the need for the car's design to focus on high-speed ovals, and more toward a shape that can do it all including ovals, road courses and short tracks.

Speaking of the tail, another key feature of NASCAR vehicles is the spoiler. It's a blunt instrument, but a historical element that completes the stock racecar look. It is also a very effective device from a sanctioning body perspective for controlling top speeds, which is critical for both fan and driver safety due to the proximity of both to the walls and fencing at most of the oval tracks.

Another element that influenced vehicle styling was the decision to duct cooling air out of the car once it passed through the radiator. This concept is not new to vehicles in general but, for all previous NASCAR designs, the radiator simply emptied into the under-bonnet (hood) region like a production car. The counter incentive this created was less radiator cooling flow, which resulted in more front downforce and less drag. This added up to extremely hot engine temperatures.

NASCAR previously investigated ducting radiator air out of the engine bay area of the cars at the 2019 All Star Race at Charlotte, and it was decided to implement this feature on the Next Generation cars in an effort to promote longer engine life spans and reduce in-car temperatures. Two zones were opened up for OEMs to place their radiator exits, with the majority of the underlying radiator ducting common. Either louvred or open designs were permitted, based on the styling desires of the manufacturers, which is apparent when comparing the different design paths of the three vehicles.

Cowl induction at the base of the windscreen has been a mainstay of NASCAR competition cars for decades, but is not compatible with heated radiator air exiting out of the bonnet just ahead of that zone. It was therefore decided to take the engine air from the front side of the radiator core rather than create an additional opening in the front fascia for stylistic reasons.

One development was ducting hot air from the engine bay to prolong engine life. This had a knock-on effect with air induction paths

With these elements settled, the OEM aero teams and design studios went to work on what would become their 2022 challengers.

Carbon underbody

One of the largest departures of the Next Gen car, aerodynamically speaking, is the lack of side skirts. While skirts are effective at generating downforce in a simple manner, they give the appearance of the cars being sealed to the track, along with the inevitable – and undesirable – wrinkling and deformation they experience during competition.

The Next Gen car is the first NASCAR vehicle to feature a full carbon fibre, aerodynamically-driven underbody. That said, the Generation 6 cars had become substantially developed to take advantage of the high-speed undercar flows. The difference is that one is purposefully built, the other had to 'pretend' to be for other reasons.

Introducing a symmetric body… presented a car that is a near spitting image of its street counterpart

Development of the underwing was done in parallel with the common elements development on the body. The process was primarily undertaken in CFD, with over 2000 runs dedicated to underwing development for both performance and lift-off safety testing.

Side skirts have gone, and the Next Gen cars have a full-length, aerodynamically-driven, carbon-fibre underbody, plus 18-inch rims

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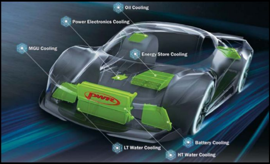

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Since the original introduction of the Next Gen was slated for 2021, it was decided that the only viable path to making the timeline was to go from CFD straight to full-scale testing. Scale model options were evaluated as well, but with confidence in the simulation work and world class local wind tunnel facilities, it was decided to move ahead and target only four development tests of 20 hours each to finalise the underwing.

NASCAR has always placed a premium on safety for both drivers and fans in all instances, so it was important to establish early in the process that no design decisions would adversely affect the lift-off speed of the car. It was also decided to use a 14-point CFD ride height map, which included front and rear ride height, yaw and pitch sweeps to characterise as fully as possible the performance of the vehicle and any impact changes had. This map was later used in wind tunnel testing at Windshear wind tunnel in Concord, North Carolina.

Aero goals

Early in the process, the goal was to match the relative aero performance of the Gen 6 vehicle, primarily in terms of total downforce and balance. Because the Gen 6 car had a restorative yawing moment due to the rear asymmetry, teams were able to run very high front downforce percentages, often exceeding 50 per cent. It was understood early in the process that the reduction of rear side force due to body symmetry would impact the useable aero balance, but initially it was something of a guessing game, although not entirely without value.

Early aero development focused on matching the evenly distributed downforce number. The thing about aero development in general is that it's much easier to make front downforce than it is to generate rear downforce. Minor improvements in shapes, fit and finish yield greater results at the front of the car, where the highest energy air is found.

As that air loses energy toward the rear of the car, it becomes much more difficult to generate downforce. Add in the fact that the ability of the rear of a car to generate downforce is hampered by the mass in front of it means, basically, that the front of any car has the first choice on making downforce.

After reviewing ride height data from early tests and determining where the drivers felt comfortable after the car was adjusted, it was easy to identify that it correlated with a downforce distribution of approximately 30 per cent front. This meant moving the downforce balance rearward by 12-14 per cent, which was a significant departure from the existing Gen 6 architecture. This is where the front downforce-generating exercise paid dividends – by knowing what could reverse the front downforce gains.

In achieving the goal of matching the downforce and aero balance of the outgoing Gen 6 car, the front splitter played a crucial part

At the front of the car, one of the most substantial downforce-generating characteristics, aside from ground effect, is the outwash of the front splitter in front of the tyres. The outward sweep of the splitter footplate, which is a wear limiting device for track contact, proved to be a very significant generator of downforce. Reducing the balance required reversing this original development. One of the advantages of this, however, was that the change funnelled some of the previously ejected high energy air towards the rear of the car.

Diffuser evolution

At the rear of the car, the diffuser also underwent an evolution at the same time as the front splitter when the balance change was implemented. The original diffuser was relatively simple in its design so wind tunnel testing could begin and provide an early opportunity for validation against the CFD model. With confidence in the CFD predictions and a need to attain more rear downforce, a multi-week CFD study began to refine the diffuser for the Next Generation car. It was decided to keep its kick line (the most forward edge) as far toward the centre of the car as possible.

This meant moving the downforce balance rearward by 12-14 per cent, a significant departure from the existing Gen 6 architecture

It was evident as well that the outer tunnels were ingesting the front tyre wakes. In an effort to draw in higher energy air from the outside of the floor, the rear of the rocker boxes is ramped upward and the diffuser outer tunnels feature a double hump design. This pushed the initial outer tunnel ramp forward and outward. To accommodate the maximum suspension droop, these outer tunnels then move back downwards before resuming an upward trajectory.

Rear downforce performance is largely constant over a range of ride heights, and floor pressures are very consistent across a range of ride heights.

Lift-off safety

On the lift-off safety front, NASCAR evaluated the vehicle in CFD before testing at the Automotive Center for Excellence (ACE) in Oshawa, Canada and the Chrysler Technical Center's Aero Acoustic wind tunnel in Auburn Hills, Michigan. The Next Gen features the passively deployed bonnet (hood) and roof flaps use in all NASCAR's vehicles, but the diffuser presented an opportunity to add another safety device; a diffuser flap. This is held in place at the centre of the diffuser and, when deployed, releases downward to block the central tunnel of the diffuser. This creates low pressure behind the flap and increases the lift-off speed of the car when nearly backward by 10-20 percent. The flap was originally designed to operate via a pressure based deployment system, but it was found to be more effective to deploy via a mechanical release connected to the right-side roof flap by a cable. Overall, the path of development for the underwing was aggressive but successful, thanks to the correlation between CFD and wind tunnel.

After nearly nine months of private development testing, all three OEMs submitted their vehicles at the end of August

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for three gruelling days at the Aerodyn wind tunnel in Mooresville, North Carolina. The advent of a new vehicle allowed NASCAR and the OEM aero teams to further refine an already tight Gen 6 submission process.

Aside from qualitative and quantitative CAD reviews, the wind tunnel performance of the body is the most critical component. To ensure the most accurate and repeatable testing environment possible, NASCAR uses a dedicated submission vehicle capable of having different OEM body panels mounted to it. Because of the enormous time demands of three manufacturers wind tunnel testing in the same period, three clones of the submission vehicle were produced for the OEMs to use in their private testing efforts.

The submission process itself consists of two distinct components. The test opens with NASCAR setting the performance targets using its generic body, with several repeated runs at the start of the test. The OEM vehicle(s) must pass the first gate with no radiator flow, which must be worse in lift and drag than the generic body. With the radiator flow open, the OEM body must have a radiator velocity ratio (VR) within +/ 0.005 of the NASCAR generic body, which also occupies the centre of a lift / drag box with tolerances in each direction. The body must fall within this box, or the test is considered a failure.

Configuration changes

OEMs are allowed up to five different design attempts per shift though, practically speaking, it is difficult to get through more than three configurations. The submitted OEM bodies are scanned in the wind tunnel and compared to the submitted CAD for each design, with strict tolerances enforced to ensure each test article is representative of the design intent. Testament to all three of the manufacturer aero teams is they all passed their submission tests on the first attempt.

With the bodies submitted and approved, work began on converting the bodies into composite components. The body uses flanges and a common mounting system to attach to the chassis, with adjustment built in of up to 0.15in in each direction to accommodate manufacturing tolerances.

Body inspection at the track will still be conducted by NASCAR's Optical Scanning Station, which compares a rapid photo scan of the car to the approved CAD surface of the vehicle. This scan is located off targets on the chassis and has a tolerance of +/- 0.15in for the body, which presents challenges to the teams to build to that tolerance but also keeps the competition on a level playing field.

As production parts began to arrive in early 2021, the first major test of team cars occurred at Daytona International Speedway. Over two sweltering hot and humid days it

Early on-track testing showed unacceptable heat ingress into the cockpits, so a raft of change were made to improve driver cooling

became readily apparent the production cars were much hotter than either of the test cars NASCAR had previously utilised. Some of this was attributable to inadequate insulation and material changes in production, but a great deal was due to the ingestion of hot radiator air into the cockpit, and inadequate evacuation of air from the cockpit.

These issues had not arisen during single vehicle testing, due to some seemingly minor design differences between the prototype vehicles and production. One example was the use of Kevlar composites to form the seals between the exhaust and the cockpit, which appear to have resulted in greater conduction into the steel chassis of the car since no heat is dissipated from the composite surfaces. Another was at the rear of the car, where the production wheel tubs further closed off the rear of the boot (trunk) area, sealing in hot air from the transaxle cooler.

Thermal modelling

After Daytona, the NASCAR R&D aerodynamics team embarked on a month-long extensive study of the problem, thermally modelling the entire vehicle in much more detail than it had previously.

This resulted in a laundry list of changes that were implemented at the Charlotte Roval test in mid-September, which included windscreen driver cooling ducts, slotted rear glass, a full right-side door window, the elimination of left-side NACA ducts into the cockpit, a NACA duct in the floor and opening up the rear to evacuate the transaxle heat.

The path of development for the underwing was aggressive but successful, thanks to the strong correlation between CFD and the wind tunnel

These changes yielded substantial gains in the instrumented cars at the test.

Overall, the Next Gen car has been a once-in-a-lifetime project for most of us involved, who may never see another project quite as revolutionary to an ecosystem as this. Its significance to the sport cannot be understated, and its promise has already yielded gains with increased team charter values and new team ownership entering.

While there certainly will be teething issues and uncertainty as teams adapt and learn at different rates, the Next Gen is a platform for the 21st century for both current and future new manufacturers in the sport.

For the men and women of NASCAR R&D, Dallara, and the industry involved in making the Next Generation car a reality, the start of the regular season in Daytona will be not so much the birth of a new era, but more like a college graduation. A well-prepared student entering a world of possibility and excitement, with a proud group of invested parents standing behind it, wishing it every success for the future.

The idea was to transfer [the TCR] model across to the electric realm, making EV racing considerably more accessible than it is currently

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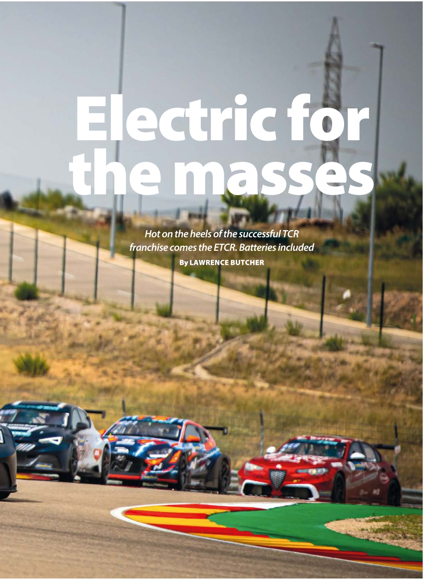


Electric for the masses

Hot on the heels of the successful TCR franchise comes the ETCR. Batteries included

By LAWRENCE BUTCHER

Until now, Formula E has been the only pure EV racing series in the upper echelons of motorsport. Though cheap compared to Formula 1, it is still the preserve of those with sizeable budgets, has a niche fanbase and isn't exactly a relatable product for the average car buyer.

However, 2021 saw the launch of a rules formula that has the potential to bring EV racing to the masses. Electric TCR (ETCR) comes from the stable of WSC (World Sporting Consultants), owners and originators of the phenomenally successful TCR Touring Car specification, which has been licensed across the globe.

TCR championships run on almost every continent, and the rules create a cost-effective solution for tin-top racing (vehicles cost in the region of €100-150,000, approx. $113,300-$170,000), with development frozen and performance balanced. The result is close racing and cars that are affordable, at both a regional and national level.

Manufacturer interest is also high, with many of the major OEMs' motorsport departments offering customer cars. The idea of the ETCR regulations was to transfer this model across to the electric realm, making EV racing considerably more accessible than it currently is.

Straight to electric

As Marcello Lotti, president of the WSC Group and driving force behind the formulation of ETCR explains: 'We started to think about making a fully electric set of TCR technical regulations at the beginning of 2017. There was discussion at the time about going with a hybrid, but for me, it was important to start with something that was completely electric. I'm not against hybrid, but the vision was to go pure electric.'

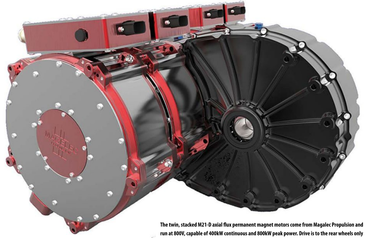
According to Lotti, there were some key requirements that the rules had to meet to ensure they attracted the interest of manufacturers in the same way conventional TCR has. 'We wanted something that was not overly complicated in terms of technical regulation,' he says. 'We also wanted regulations that were easy to adapt to a production car with an ICE.' It's important to bear in mind that, in 2017, most manufacturers had very few EVs in their ranges.

However, the rules were also forward looking, recognising the fact a lot more EVs were soon to be coming.

'We had to make sure that if someone wanted to start with an EV production car, which tend to be a little bit different, a bit higher for example,

XPB

The new series is the brainchild of Marcello Lotti, president of World Sporting Consultants, the group behind TCR



ETCR

The twin, stacked M21-D axial flux permanent magnet motors come from Magalec Propulsion and run at 800V, capable of 400kW continuous and 800kW peak power. Drive is to the rear wheels only

ETCR

SEAT's sub brand, Cupra, was first to sign up, but now Hyundai and Alfa Romeo (the latter as Romeo Ferrari) are on board, too

'We wanted something that was not overly complicated… We also wanted technical regulations that were easy to adapt to a production car with an ICE'

Marcello Lotti, president at WSC Group

they could,' adds Lotti. 'We wanted to make a performance racecar in terms of chassis, and that was the first step.'

Of course, there is no getting around the fact that high performance EV powertrains are expensive, especially the battery systems, particularly when compared to the relatively bargain price of IC TCR engines. Lotti acknowledges that ETCR will be more expensive than TCR. 'We worked progressively towards something that was affordable, or at least fairly affordable,' he says. 'We wanted to create something that in future, regional and national championships could consider, with affordable running costs.'

The rules also set out to create cars that had similar performance to IC-engine TCR machines, though Lotti notes that, due to its unique race format, this year's Pure ETCR series (see sidebar on p22) does not necessarily show this. However, he asserts that the cars should be capable of similar race lengths to current TCR events at a comparable pace.

With a set of regulations thrashed out by the end of 2017, WSC needed a company to take on the production of a prototype and found what it was looking for in SEAT sub-brand, Cupra. The prototype hit the track in July 2018, having been revealed at that year's Geneva Motor Show. Development then progressed throughout 2019 and into 2020, ahead of Pure ETCR commencing its debut season in 2021 (the original target was 2020, but Covid put paid to that ambition).

Packing a punch

The powertrain devised for ETCR is a spec system supplied by Williams Advanced Engineering (WAE), which builds the batteries, and Magelec Propulsion, provider of the motors and transmission. The latter is a specialist in the development of axial flux motors and is part of Omni Powertrain Technologies, which has been producing powertrain components since 1960.

The battery has a nominal capacity of 65kWh, with a useable capacity of 62.5kWh.

Williams Advanced Engineering

Williams Advanced Engineering is supplying the batteries for the powertrain. The packs have a nominal capacity of 65kWh and are made up from the company's proven Generation 1 modules

It is built up from what the company calls its Generation 1 (Gen 1) modules, which have been developed for use across a range of different projects. WAE technical director, Paul McNamara, explains: 'Each module has 32 21700 cells in it. They have been used in three or four of our programmes to date and the module is sort of "off the shelf", in that we have it available internally to roll out and use.'

Hi-tech solution

Though intended to be a more cost-effective solution than some of WAE's motorsport battery solutions, it's not low tech. 'There's a lot of tech in the module,' notes McNamara. 'You've got to encapsulate [the cells] lightly but you also must think about propagation, which is where if one cell decides to have a thermal runaway you must stop that spreading to the others.

'You've then got to manage your welding and your processes, because one of the problems with these packs is that you have thousands of welds [linking the cells] and you have to make sure the quality is consistent.'

A big benefit of the using the Gen 1 modules was they were already validated, so the main task facing WAE was forming them into a pack to suit ETCR's requirements. This it achieved in seven months, having been given the green light in May 2019 by WSC, and was manufacturing packs by that December ready for testing.

The pack operates at 798V and has a peak output of 500kW, though continuous power is rated at 300kW. Charging from 10-90 per cent capacity can be achieved in an hour using fast chargers. The individual weight of the battery pack has not been revealed, but the combined powertrain weight, including motors, inverters and transmission is 500kg.

'It should end up as a big volume market, with the technology cascading down through to different national series'

Paul McNamara, technical director at Williams Advanced Engineering

In addition to the battery pack, WAE also supplies the vehicle control unit (VCU), which runs dual ARM Cortex A9 processors and an FPGA (Field Programmable Gate Array) to ensure the inverters and battery play nicely together and allow mapping of the torque delivery.

For McNamara, ETCR represented quite a different challenge to some of its other projects, such as Formula E and Extreme E.

'It is interesting, because it should end up as a big volume market, with the technology cascading down through to different national series,' he remarks. 'We're expecting it to take off and give a lot of people exposure to electric racing. It's a slightly more mass-market approach [than WAE's other projects], which is why we used the Generation 1 module, because that is a robust, manufacturable in quantity system. Also, as production volumes go up, the costs will go down.'

Motive power is provided by a pair of Magelec's M21-D axial flux permanent magnet motors driving the rear wheels, with each unit consisting of two motors stacked together. Running at 800V, these are capable of 400kW continuous and 800kW peak power, but are limited by the battery's 500kW maximum output. Under normal race conditions, power is limited to 300kW, but drivers have a boost function available giving the full 500kW.

Lotti says the powertrain is deliberately over specified because, 'You never know what might happen tomorrow with new generations of battery.'

Cooling is via a water-glycol mix, which is also used for the inverters, two per motor unit (four in total) that use silicon carbide MOSFETS. Drive is then transferred though a single-speed transmission, also built by Magelec, that relies on VCU-controlled torque vectoring rather than a differential.

Conventional chassis

Beyond the electric powertrain, the rest of the car is relatively conventional, with McPherson strut suspension at the front, double wishbones at the rear and a chassis based around standard production 'shells with manufacturer-developed bodywork.

Under normal race conditions, power is limited to 300kW, but drivers have a boost function available giving the full 500kW

www.trenkler.photos

The SEAT Cupra prototype was first tested in July 2018 and then developed through 2019 / '20. Aside from the EV powertrain, the chassis is conventional, albeit with a secure battery compartment

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Pure ETCR

The ETCR concept's debut took the form of the Pure ETCR championship, run by Eurosport Events who are also responsible to the FIA World Touring Car Cup (WTCR). The season ran over five rounds in Europe, with entries from three manufacturers: Cupra, Hyundai and Alfa Romeo (built and operated by Romeo Ferraris).

The race format is quite different to a standard Touring Car event, having more in common with Rallycross. On the first day, the field of 12 is split by a draw into two pools. Each pool is then split into a pair of three-car 'Battles' for the first round. Winners face off in a second round with runners-up and third-place finishers doing likewise.

The final day consists of a flat-out time trial as a third round that sets the grid for the 'SuperFinals' that conclude the weekend. Points are awarded at all stages, bar the time trial, with the top scorer crowned King or Queen of the Weekend, and the Most Valuable Driver.

Rather than a grid, cars line up side-by-side for each Battle inside a giant starting gate, intended to be the centrepiece of the series. During the Battles, each driver has between 20 and 60 seconds' use of their 500kW boost, the duration dependent on circuit, while the time trial is run at full power.

Between heats, the cars are charged using a pair of hydrogen fuel cell generators from series partner, HTWO.

For series director, Xavier Gregory, coming up with a race format to suit the new cars was a challenge, but he's happy with the outcome: 'We seem to have gambled the right way because at the end of the day, it's working well.

'We had to adapt the sporting formats for the technology itself, but we also wanted something different from the WTCR, because it did not make sense to have two series with the same format.'

In terms of creating a format to suit the cars, 45-minute races weren't feasible, so short, sharp duels were considered the best option as, unlike Formula E, ETCR is about flat-out competition.

'What drove us was the fact we did not want to make any power management. The main goal of Pure ETCR is to show that you can have electric racing without any restriction in terms of power. You can go flat out from the beginning to the end of the race, and you can make the competition super exciting, and super intense.'

Nelson Silva

Like many forms of modern motorsport, plenty of attention has been paid to the show. The starting gate is a main feature

The main goal of Pure ETCR is to show that you can have electric racing without any restriction in terms of power

Xavier Gregory, series director

@World

Coupled to this was a desire to create a show with a TV and social media-friendly narrative. Hence gimmicks such as the starting gate and Battles (the series also deploys some nifty FPV drones to capture spectacular on-track footage).

The in-race boost, significant at 200kW, further adds to the show. 'It's very fun for the drivers,' says Gregory. 'When you have the time trial at 500kW, over one lap, you can see the drivers in pain, trying to control the car. You can see and feel that they are really enjoying themselves, but they are struggling at the same time with such power.'

Despite setbacks and delays due to Covid, Gregory is happy that the debut season has been a success. 'Now we can sit back after five events and look at what the data and statistics say. We can see that the cars last for way longer than I would have expected as a promoter. Maybe WSC will tell you that with the WAE batteries and so on the cars last for as long as they thought they would, but as a promoter we were extremely positively surprised. The cars have very good range and do not need lots of recharging, even when run flat out.'

The main modification, in addition to the rollcage, is a reinforced structure in the floor to house the battery. From a packaging and safety perspective, the battery is clearly the main concern and, to this end, it is tied in closely to the chassis and roll structure, with the entire assembly tested to withstand impact of up to 50*g*.

Overall car weight, due in no small part to the battery, is significantly higher than a conventional TCR machine at 1750kg (compared to between 1185 and 1315kg) and this is something Lotti is keen to address in the future.

'The development of the cars is definitely not yet finished and, over the winter and the first three months of next year, there are some components we will be improving. Frankly, we are happy with the end result and have several manufacturers interested in the project, so it is looking good.'

Popular choice

It remains to be seen how much of a foothold ETCR will gain but, given the rate at which manufacturers are rolling out EVs, and the historical success of Touring Cars from a win on Sunday, sell on Monday perspective, it should prove popular.

Lotti suggests 2024 would be a realistic point for the potential introduction of the cars at a national level. This is due to both the complexities of introducing new series and the fact that production of the cars will take some time to ramp up.

'Clearly, our road map is to build a pyramid, but we are conscious we will not do it as fast as we did with TCR. However, we have pre-agreements with different promotors and there is good interest.'

He also points out that as the ETCR matures, there is potential to move away from the spec nature of the powertrain and for manufacturers to supply their own, within the constraints of the performance balancing rules.

If anything is going to bring electric to the racing masses, it'll be Touring Cars.

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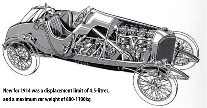
How Mercedes took the fight to the French in 1914, producing one of the world's greatest grand prix racecars in the process

By WOUTER MELISSEN

The Mercedes racers were remarkable for many things, not least the driver and co-pilot sitting within the enclosed bodywork, which had obvious aerodynamic forethought

Amidst rising political tensions in Europe, the Automobile Club de France staged what has gone into history as one of the greatest races of all time, the 1914 French Grand Prix. Appropriately enough, it was also won by one of the finest racecars ever produced; the Mercedes 18/100 Grand Prix.

Scheduled for 4 July 1914, the sixth French Grand Prix was held just one week after the Archduke Franz Ferdinand was assassinated. Racing in those days was a very nationalistic affair and these real-world events added to the tension for the entries in the most prestigious race of the year.

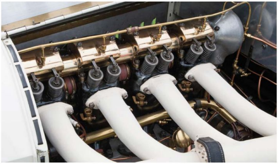


New for 1914 was a displacement limit of 4.5-litres, and a maximum car weight of 800-1100kg

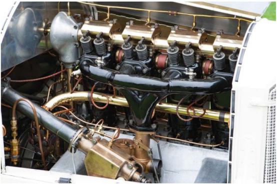
Each team was allowed to enter a maximum of five cars. Mercedes brought six, including one deemed a spare

At the end of the race, much to the annoyance of Peugeot and Delage, Mercedes finished one-two-three

In order to be competitive, an all-new, high-revving engine and a modern propellor-shaft drivetrain was needed.



Four valves per cylinder was a technological development borrowed from Peugeot, but Daimler engineers chose to use just one cam



The car's under square, four-cylinder engine has a displacement of 4493cc and produces 105bhp at 3100rpm

There was a record entry of 37 cars, purpose built by 13 manufacturers that represented the six countries competing, most of whom would be at arms before the end of the month. No privateer entries were permitted, and each manufacturer could enter a maximum of five cars.

Pre-race, all eyes were on defending champion, Peugeot, and the French manufacturer's main challenger, Mercedes.

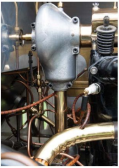
The 1914 French Grand Prix was also significant in that it was the first motor race run with a displacement limit, in this case 4.5-litres. Another major restriction was a set weight range of 800-1100kg, excluding fluids and tools.

The 1913 French GP-winning Peugeot was a hugely sophisticated and influential design that featured an engine with twin overhead camshafts and four valves per cylinder. Mercedes did not compete in the race that year, but had already started work on its new design for the following season. To better grasp what would be needed to win the big race in 1914, Mercedes competed in the much lower profile Coupe de la Sarthe at Le Mans with its first new grand prix car since the hugely successful car it had introduced in 1903. It was powered by a mighty, six-cylinder aircraft engine that powered the rear wheels through chains. Theodore Pilette was the best Mercedes driver in the 540km race in third, but finished six minutes down from the winning Delage.

Although the results were disappointing, the Le Mans race did make clear to Paul Daimler and his engineers that, in order to be competitive, an all-new, high-revving engine and a modern propellor-shaft drivetrain was needed.

Clean sheet

The Daimler-Motoren-Gesellschaft engineers could start with a clean sheet and quickly determined that a four-cylinder engine would suffice for the 4.5-litre displacement limit. Although purpose built for racing, the new engine was laid down by the same engineers that had created the Daimler aero engines. Accordingly, it was designed with redundancy in mind, and this was a trait that would later result in another major victory.



The single overhead cam was driven by a vertical shaft from the crank, mounted at the back of the engine

Like the aero engines, the 4483cc engine featured four separately machined cylinders, which were welded to the individual heads. This assembly was mounted on a two-piece, aluminium crankcase. Each cylinder boasted welded-on water jackets designed to directly cool critical areas like the cylinder hotspots. The engine was decisively under square with at 93mm bore with a massive 165mm stroke.

Placed at a 60-degree angle, each head was equipped with two intake and two exhaust valves. This was a first for Daimler. Whereas the Peugeot engines used twin overhead camshafts, here only a single cam was fitted. It was driven from the crankshaft by a vertical shaft at the rear of the engine. Per cylinder, there were three cams with the intake valves actuated by a single, forked, roller-type rocker arm and the exhaust valves by a rocker arm each. While the camshaft was enclosed, the valvetrain was exposed.

Running in five main bearings, the crankshaft was made of a single piece and carefully counterbalanced. However, initial testing proved the original design too fragile so new crankshafts were made using Austrian 'Aquila' steel. Although the Daimler engineers experimented with aluminium pistons, four of the five drivers entered in the French Grand Prix opted to run heavier, and sturdier, cast iron pots instead.

The oiling and ignition systems were typical of contemporary aero engine practice. Two adjacent oil pumps were fitted transversely at the back of the engine, driven from the crank by a transverse shaft. The two pumps fed oil from a massive oil tank to each of the five main bearings, and also pumped oil back from the bottom crankcase. An additional system was fitted that was operated by the driver through a foot pump. This separate system lubricated the cylinder walls, camshafts and rocker arms. It was designed as a total loss system and, as a result, the Mercedes grand prix cars were always followed by a plume of white smoke.

Twin Bosch magnetos were used for the three spark plugs per cylinder, two on the intake side and one on the exhaust. These were special Eisenmann spark plugs with platinum electrodes to withstand the unprecedented speeds the engine would be running at. There was no generator or battery as the engine relied on a starting crank to get going.

Fitted with a single piston, slide valve carburettor, the engine was reported to produce 105bhp at 3100rpm. With a 3200rpm red line, it was the first grand prix engine to rev over 3000rpm.

Incidentally, a later version of the same engine, equipped with aluminium pistons, could rev to 3600rpm.

Ladder and braces

For the rest of the new car's design, the Daimler engineers drew inspiration from the car the company had raced at Le Mans in 1913. The chassis was a conventional, pressed steel, ladder frame with an x-shaped cross brace just aft of the gearbox. At both ends, the chassis rails swooped up considerably to lower the ride height.

As was standard practice at the time, suspension was through semi-elliptic leaf springs. The cars were also equipped with Mercedes' proprietary friction dampers, and the Daimler engineers opted to fit brakes on the rear axle only. Mechanically actuated, the drum brakes were operated by a lever on the Rudge-Whitworth wire wheels, while an additional pedal actuated an external band brake on the transmission.

A crucial departure from the previous Mercedes competition car designs was the final drive, which was now through a shaft instead of chains. The gearbox was mounted separate from the engine and had four forward gears. A propellor shaft ran from the gearbox to the final drive inside a torque tube that was bolted to the cross brace. Combined with the universal joint that connected the propellor shaft to the gearbox, this set up allowed the shaft to move with the suspension.

With a 3200rpm redline, it was the first grand prix engine to rev over 3000rpm

The final drive was through ring gears, which allowed the halfshafts to be mounted at a slight angle to create positive camber.

Where the bodywork previously only served to protect the most crucial components, which usually did not include the drivers, the latest Mercedes competition design helped to reduce drag somewhat, too. The most obvious wind-cheating device was the v-shaped radiator. The bodywork was also full length, which meant the driver and his riding mechanic now actually sat in the car, as opposed to on it.

A further aerodynamic aid was a belly pan mounted underneath the car. Behind the compact passenger compartment, a pair of spare wheels was fitted, should a tyre puncture during one of the long laps.

Staying within the maximum weight limit, the new Mercedes 18/100 Grand Prix tipped the scales at 1082kg.

Walking the track

While the new racecar was developed at the Untertürkheim factory, Paul Daimler had already dispatched several of his aids to carefully inspect the newly proposed track for the 1914 French Grand Prix. Laid out on public roads just south of Lyon, the 37.6km lap proved quite a challenge. Among the track's features were a 12km long straight that included a steep, downhill s-bend. Somewhat worryingly, that section was nicknamed *la piège de la mort*, or the death trap. It was then followed by a tight hairpin.

All their findings were conveyed to the Daimler engineers back in Stuttgart, which allowed them to calculate optimal gear ratios, and also determine how much fuel and tyres the cars would use during the race.

A cynic may be quick to point out that the Automobile Club de France had imposed the new regulations to suit the French manufacturers. After all, both Peugeot and Delage had been dominant forces in the smaller *Voiturette* category. Peugeot brought a downsized version of its 1912 and

With no battery or generator onboard, the engine was started by hand

Suspension was standard (for the time) semi-elliptic leaf springs all round, assisted by Mercedes' proprietary friction dampers

A crucial departure from the previous Mercedes competition car designs was the final drive, which was now through a shaft instead of chains

1913-winning design, which featured brakes on all four wheels, as did Louis Delage's latest design, which also benefited from a five-speed gearbox.

Delage was clearly confident the French would come out on top, famously stating before the race: 'I have a 48 per cent chance of winning. Peugeot also has a 48 per cent chance, and Mercedes may account for the remaining four per cent.'

This was a bold statement as details of the new Mercedes contender had been a carefully kept secret. Even during the event, the engine covers rarely came off.

Leaving nothing to chance, the *Daimler-Motoren-Gesellschaft* fielded the maximum number of five cars, and brought a sixth as a spare. Among the drivers was 1908 French Grand Prix winner, Christian Lautenschlager, youngster Max Sailer and Belgian, Theodore Pilette, who was the only driver running aluminium pistons.

Following two brief, pre-dawn practice sessions, a week earlier, the race started at 8am on 4 July in front of a 300,000 strong crowd. The cars were released in pairs at 30-second intervals according to the start numbers, so the first to go were Ferenc Szisz in his Alda and Carl Jörns driving an Opel. The leading car on the road after the first lap was Peugeot's Georges Boillot, who had started at number five in the third batch. The actual leader, however, was young Max Sailer, who had thrown all caution to the wind and held an 18-second lead after the first of 20 laps.

By lap four, Sailer had a three-minute lead over Boillot, but two laps later it was all over for the enthusiastic youngster as he was forced to retire his Mercedes with a con rod failure. Pilette was also out on the same lap, suffering the after effects of over-revving his engine during practice.

In an early example of strategy, Daimler sent aides to the track before the race so the amount of fuel required could be calculated

Using rear brakes only may seem foolhardy, but it helped win the race as the all-wheel braking Peugeot wore its tyres much faster

Tortoise and hare

Sailer would later claim he was sent out as a hare in an attempt to push the competition to destruction, but he was alone in this view as the official Mercedes tactic had been to keep tabs on the leaders and pit at the half-way mark for fuel and tyres.

From that point onwards, a new tactic was formulated. Spearheading the Mercedes charge after the early retirements was Lautenschlager. After the lap 10 pit stops, he, and team mate Louis Wager, were in second and third positions. At that point, Boillot still held a two-to-three-minute advantage over his German rivals. However, with its four-wheel brakes, Boillot's Peugeot was much tougher on tyres, and he eventually ended up stopping six times compared to the single scheduled stop of the Mercedes cars.

By lap 17, the deficit had been cut to just 14 seconds, and then Lautenschlager took the lead from Boillot. His Peugeot had clearly taken a beating trying to keep with Sailer early in the race and he eventually retired on the penultimate lap with engine failure. This allowed Wagner to move up to second and Otto Salzer completed the one-two-three podium sweep for Mercedes.

Lautenschlager had completed the 20 laps in just over seven hours. The closest Peugeot driver, Jules Goux, was nine minutes down in fourth, while the best placed Delage driver was Arthur Duray in eighth position.

Neither Lautenschlager nor a distraught Boillot would ever race again. The German driver retired from motorsport and used the 25,000 Francs prize money he won at Lyon to build a new house. Boillot would serve in the war, first as the private driver of French commander-in-chief, Marshall Joseph Joffre, and later as a fighter pilot. In 1916, he was shot down over Verdun and killed.

'I have a 48 per cent chance of winning. Peugeot also has a 48 per cent chance, and Mercedes may account for the remaining four per cent'

Louis Delage

While the Mercedes 18/100s were shrouded in secrecy in the build up to the race, Daimler was quick to show off the technology onboard once the objective had been achieved. The two cars that had retired and the spare were dispatched to Mercedes distributors in London, Brussels and Paris to

After intensive research across three continents, this was formally identified as the sixth car, the one taken to the France as a spare. Though it didn't compete in the race, it has fine provenance

spread the word, and just a few days after the resounding victory a press release was published detailing the machines' cutting-edge technology.

And so to Indy

Keen to get his hands on one of the other cars, American racer Ralph DePalma travelled to Stuttgart immediately after the race. In 1912, he had come achingly close to winning the Indy 500 with a Mercedes. Having led 196 of the 200 laps, his challenge only came up short after a piston cracked. That was one of the reasons why he raced for Vauxhall instead in the 1914 French GP. Realising the error of his ways, he managed to convince Paul Daimler to sell him one of the dominant cars to give it another go at Indy in 1915.

With no racing expected in the foreseeable future, Daimler allowed DePalma to pick whichever car he liked of the three available. He was long believed to have chosen Wagner's second-placed example, but it appears more likely that he acquired the third-placed 18/100 of Salzer instead. The mechanicals were refurbished in less than a week before DePalma was advised to make his way quickly to the nearest port in France and leave the continent. With only a few days to spare, he made his way to Le Havre and boarded the SS Olympic.

Fresh off the boat, DePalma entered the Mercedes in the Chicago Auto Trophy Race and Elgin National Trophy Race on 21 and 22 August respectively. He won both races, setting a new track record in the process.

Over the winter, the car was rebuilt and slightly modified at the Packard factory. A revised body and a Packard carburettor was fitted to prepare the Mercedes for the 1915 Indy 500. Leading 132 of the 200 laps, this time DePalma snatched victory, fittingly beating the Peugeot of Dario Resta in the process. Ironically, one of the con rods broke in this engine too, but with just two laps to go the engine was strong enough to last the final five miles with a hole in the crankcase, undoubtedly helped by the redundancy built into the elaborate oiling system!

DePalma would score several further minor race wins but the car eventually disappeared from sight.

After the Armistice, Daimler dusted off the surviving racecars and they continued to be raced by various privateers for many more years. Thanks to later additions such as front-wheel brakes and supercharging, the cars remained competitive well into the 1920s. In 1922, for example, Count Giulio Masetti won the Targa Florio, and four years later Rudolph Caracciola won at Semmering behind the wheel of a supercharged 1914 Mercedes 18/100 Grand Prix.

The last known contemporary outings for these cars were in 1930.

Under the influence

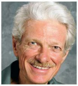
Dominant at its crucial first outing, and then both an Indy 500 and Targa Florio winner later in life, the 1914 Mercedes 18/100 Grand Prix is rightly considered one of the all-time great racecars. As it turns out, it was also a hugely influential one.

One W O Bentley is reported to have taken a very close look at the engine in the car that had been dispatched to London. A few years later, he introduced his very first production car, powered by a four-cylinder engine with a four-valve, single-overhead camshaft head. Coincidence?

One W O Bentley is reported to have taken a very close look at the engine in the car that had been dispatched to London

Of the six cars built, three are believed to have survived. One is in the Mercedes-Benz Museum collection in Germany and two are in private, American hands. Among them is the winning car of Lautenschlager, which has been part of George Wingard's fabulous collection of Edwardian competition cars for many years. As chronicled in Wingard's fascinating book, *Real Wolves in Sheep's Clothing*, the car was discovered in England in 1961, sporting a Berliet sports car body. Once the 'sheep's' body had been removed, it received a rudimentary restoration, but was then properly restored after it was acquired by Wingard.

All three surviving cars have been restored to their 1914 configuration and were brought together at the 2014 Pebble Beach Concours d'Elegance to celebrate the 100th anniversary of the one-two-three victory. Underlining the fact these are racecars, not just display pieces, Wingard also competed in his car at nearby Laguna Seca during the Monterey Motorsports Reunion during the same weekend.



New year's resolution

Sometimes approximation is as good as it gets

By MARK ORTIZ

Scott Mitchell

JEP/BTCC

Using the car's static loads and geometry, it is possible to work out the roll angle and wheel loads. Then, using an assumed ground plane force distribution gives us a 'first cut' of roll displacement

Q Regarding your resolution line method of assigning roll centre height, it makes sense to me that the resolution line location depends on the distribution of lateral ground plane forces (grip, basically, as I understand it), but I wonder how / when to apply that method since we never explicitly know these forces.

Don't you need to assume a tyre model and a given slip angle to find those? It does not seem like you can find the resolution line just by starting with mass, *g*-force and some suspension geometry.

THE CONSULTANT

A At least in my work, it is necessary to be able to work from a wide variety of inputs or knowns, to a wide variety of outputs or unknowns, with a wide variety of constraints amongst them.

In most cases, when estimating roll angle and wheel loads, we *do* use an estimated ground plane force distribution. We also use an assumed lateral acceleration and an estimated roll angle. We can take the car's static loads and geometry, and then work out roll angle and wheel loads from that, using any assumed ground plane force distribution. That gives us 'first cut' wheel loads and roll displacement. If we then consider total front and rear jacking forces, we also get a heave displacement.

Using these values and a geometry programme, or manual drafting, or shop floor measurements of the actual car, we can determine the suspension geometry and estimated wheel loads at the displaced condition. If the car has independent suspension, and this has asymmetries in any condition we are examining, then if we have a tyre model, that will give us some idea what the ground plane forces can be. Although, as the questioner notes, slip angles influence the ground plane forces, too.

Moreover, tyre modelling from tyre test rig measurements is primarily useful for comparing tyres. It is not possible to duplicate conditions at speed on a test rig for a wide range of loads, camber angles, slip angles and other variables, without altering the tyre's properties during the test.

It is also necessary to have a consistent surface on the drum, or belt, the tyre rolls on. This means the tyre is run at low speed, on a controlled surface as close as possible to an industry standard for surface texture and cleanliness. This is necessary for consistency, so we can at least achieve meaningful comparisons between one tyre and another.

However, the properties of a road or track surface the car is running on in real life may be very different, and the tyre itself may be different as well, due to effects of age, temperature and wear.

In most cases, when estimating roll angle and wheel loads, we *do* use an estimated ground plane force distribution. We also use an assumed lateral acceleration and an estimated roll angle

JEP

Some assumptions are perfectly reasonable. For an engine-over-drive-wheels car, for example, we know that the outside wheel at the non-driven end will take all, or nearly all, the load in a corner

If we are willing to do [iterations], and if we assign roll centres correctly, we *don't* need to start with an assumed, or estimated, ground plane force distribution

One recent development is instrumented road wheels that telemetrically communicate with data loggers. These offer the prospect of more realistic measurement of tyre properties under real-world conditions, but are currently still the preserve of very high-dollar operations, and I've never worked with anybody who has access to such hardware.

Close approximation

So, ground plane force distribution is just one of many things we estimate when analysing, modelling or designing a car. And there are ways we can get pretty close with the approximation. If we have a measured, or estimated, overall c of g location and a lateral acceleration, we can calculate the overall lateral load transfer. As a percentage of vehicle weight, this is simply lateral acceleration, in *g*s, times the ratio of c of g height to track, which for racecars is typically around .25.

As such, a car that corners at 1.0*g* and has a track width four times its c of g height has about 75 per cent of its weight on its outside tyres. This load transfer may or may not be equally distributed between the front and rear wheel pairs, but generally we will have some idea how severe the inequality will be. If the car has roughly even front-to-rear weight distribution and equal size tyres all round, we can be reasonably confident it will work well with approximately equal load transfer front and rear.

If it's an engine-over-drive-wheels car that essentially corners on three wheels, we know that at the non-driven end the outside wheel will have all, or nearly all, the load, and the load transfer at the driven end will be correspondingly reduced.

We also can be sure the ground force distribution will be a bit less lopsided than the normal force distribution, due to load sensitivity of the coefficient of friction. We don't know exactly, but we can achieve a reasonable estimate by reducing the outer wheel percentage by two or three points.

Therefore, as a default value to use when examining front-view suspension geometry without additional information, I suggest assuming 75 per cent of ground plane force on the outside wheel.

If we don't mind doing iterations, it is entirely possible to start with the car at static condition, apply lateral acceleration, calculate roll and load transfer, look at where the roll centres go to, and then iterate again with the new geometry and estimated ground plane forces. We will then realise a somewhat different roll angle and set of wheel loads, and slightly different roll centres again.

If we are willing to do this, and if we assign roll centres correctly, we *don't* need to start with an assumed, or estimated, ground plane force distribution.

However, if we only are doing one iteration, and if the system has a Mitchell index far from one, we are better off using roll centres based on an estimated roll angle and ground plane force distribution than doing one iteration based on static properties.

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Hard graft

Racecar *investigates the benefits of integrating hardware-in-the-loop into a driver-in-the-loop simulator*

By GEMMA HATTON

When the FIA cuts the number of test days, or shortens practice sessions, there is usually uproar amongst teams. Yet most engineers will breathe a secret sigh of relief, because trying to extract accurate data from track testing is an engineer's nightmare.

Changing weather conditions, track evolution and traffic make it nearly impossible to conduct representative back-to-back tests. While the vibrations and interference on a racecar disrupts sensors, so the data you record is often peppered with errors. By the time you've accounted for these, you're usually left with a few laps of data, from which you must decide how to make the car faster and more reliable.

Even if you're fortunate enough to experience optimum test conditions, it's still up to the driver, mechanics and yourself to execute the test perfectly. At which point the human condition comes into play.

Compare this to the almost clinical environment of a driver-in-the-loop (DIL) simulator, where you can choose a dry track, turn tyre degradation off and remove other cars. The driver can complete repeatable back-to-back testing in consistent conditions, giving the engineers endless laps of data to analyse. Given all that, it's no wonder race engineers and drivers now spend more time in the simulator then they do at the racetrack.

However, simulators cannot yet fully replicate the physical world, so final validation still must be completed at the track. But today's advanced motion platforms, coupled with faster running vehicle models, means that by applying the relevant correlation factors engineers can now get pretty close to simulating reality.

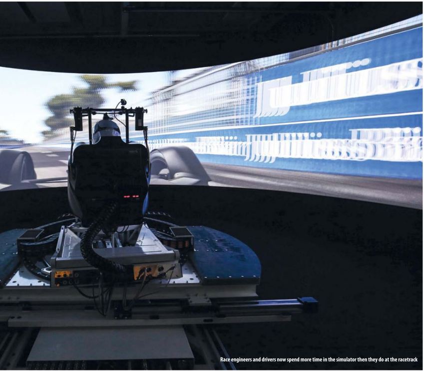
Hard data

One recent development that has bridged the gap further still between the virtual and physical worlds is hardware-in-the-loop (HIL). This is where real components from the physical car, such as ECUs, steering wheels and controllers are integrated into the simulator, allowing their functionality and performance to be extensively tested without being on the real car.

To achieve this, the hardware is connected to an electronic unit that contains a vehicle model. This simulates the relevant inputs into the hardware, tricking it into thinking it is attached to the real car. However, components such as ECUs run in hard real time

Real components from the physical car, such as ECUs, steering wheels and controllers are integrated into the simulator

To integrate hardware from the real car into the simulator, it needs to run on a hard real time system. This is a computer that guarantees certain processes will be completed within a particular time step



Race engineers and drivers now spend more time in the simulator then they do at the racetrack

and so the vehicle model must also run on a hard real time system. This is a computer that guarantees certain processes will be completed within a particular time step, usually one millisecond, or 1kHz.

There are three different ways in which race teams utilise HIL, which were explained in detail in *Racecar Engineering* V31N10. The most advanced set ups embed HIL within the simulator environment so, as the driver makes their way around the virtual track, information is passed through the ECU, in the same way it would on the real car.

In this case, the vehicle model provides hard real time inputs to the ECU and sends the necessary acceleration, torque and velocity information to the actuators of the simulator. The driver's responses are fed back into the simulator and ECU, which then outputs information back into the vehicle model and virtual environment.

Accurately managing all these interactions, whilst meeting the strict run time demands of testing, is an extremely complex task. In this article we will explore the best approach to integrating HIL into a simulator and the common pitfalls to avoid.

Hardware requirements

'I have a great deal of sympathy for anyone trying to set up a DIL simulator with a motion platform,' says Mark Catherall, co-founder of Canopy Simulations. 'In other areas of motorsport, you can go to a single supplier and they will do it for you, but the simulator world is a daunting landscape. You need a lot of components from different areas, so at every stage you have to make decisions on which components to get, and from which companies, and then figure out how they all fit together yourself.'

The first step is to identify the hardware you want to integrate, whether that's an ECU, steering wheel or damper. You then need to investigate the necessary input and output requirements of this hardware, which will determine the number and type of I/O (input/output) cards you need. I/O cards use digital and analogue channels to communicate with computers and are the interface between the hard real time system and the hardware being tested.

In an HIL rig, the hard real time system is essentially a series of rack PCs with I/O cards, as well as other types of processor boards, plugged into the back of it.

'The I/O of the hardware needs to be served by the HIL system, so you first need to know this specification,' explains Dr Klaus Lamberg, senior product manager HIL testing at dSPACE GmbH.

'When we're designing a HIL system for an ECU, for example, we first find out how many digital and analogue inputs and outputs there are, and what sensors the ECU is communicating with. We then look at the network technologies, such as the number of CAN buses required. Once we have all that information, we can design the configuration of the necessary network and I/O boards to interface accurately with the ECU.'

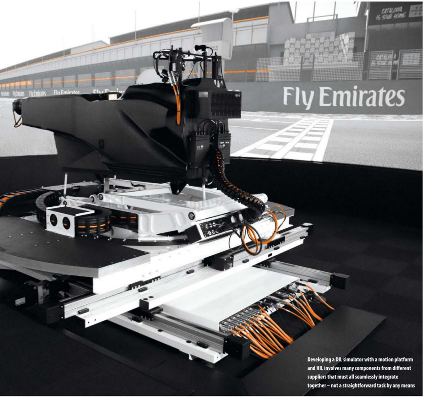
Vehicle model

Once you have an idea of the relevant inputs and outputs, the next stage is to choose a suitable vehicle model.

'This is really just a set of equations that tells you what the forces and accelerations on

I/O cards use digital and analogue channels to communicate with computers and are the interface between the hard real time system and the hardware being tested

As well as selecting the appropriate hardware, a suitable vehicle model must also be chosen. The difference here is the part of the model that simulates the hardware being tested is replaced with the actual piece of equipment



Developing a DIL simulator with a motion platform and HIL involves many components from different suppliers that must all seamlessly integrate together – not a straightforward task by any means

the car will be in any given position, with any given inputs,' explains Catherall.

'The model will define its current state, which, in the case of a DIL simulator, is generally the position and orientation of the main chassis body, the wheels, suspension, steering as well as things like fuel mass. This information is sent to the virtual world model on the simulator and the driver responds.

'Effectively, the model then takes those driver inputs, along with the information on its current state, and then calculates what the forces and accelerations on the wheels and chassis are.

'Using these accelerations, it calculates the resulting position and orientation of the vehicle one millisecond from now, which is then fed back into the world model. All that calculation necessarily must be done in less than one millisecond.

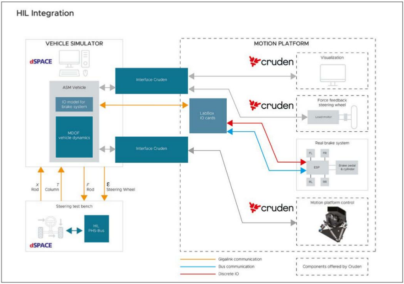
'The world model then draws a new picture of the car, one millisecond further down the road, which the driver sees and responds to, and the process repeats.'

This is how a vehicle model interacts with a conventional simulator. However, when incorporating HIL to test hardware such as an ECU, for example, the section of the model that would normally simulate the ECU is replaced by the actual component.

'In this instance, you essentially disconnect your ECU model, and then set all of your outputs out of the HIL rig to the ECU,' explains James Waters, simulator group specialist at Ansible Motion. 'Then all of the signals that would have come in from your model are now real signals from the hardware itself.'

Naturally, there is a whole spectrum of suitable vehicle models and suppliers to choose from. The key is to select one that has the fidelity to be realistic but that can also integrate seamlessly with the simulator. This often nudges teams towards sourcing models from simulator manufacturers themselves, such as Cruden, AB Dynamics and VI-grade, who have all developed their own physics-based multi-body models. Alternatively, teams can use models from hard real time system manufacturers like dSPACE, simply buy models off the shelf from the likes of AVL, or develop their own in Dymola and Simulink.

Another approach is to utilise models teams already use in their offline simulations.



A diagram showing the main components of integrating HIL into a DIL simulator, as well as all the necessary interactions

These models must be compiled to run in real time, which the likes of Canopy and a few other companies now offer. Using the same underlying model for both offline simulations and the simulator can be beneficial as you avoid having to co-ordinate between two different vehicle models.

'If your driver in the loop simulator uses a different car model from your offline simulations, then you've got another correlation problem to deal with,' highlights Catherall. 'You have to correlate the track car with the offline simulation model and then correlate that with the vehicle model on your hard real time DIL system, but the driver can only sit in one of them. Having the same model behind the simulator and the offline simulations avoids these issues.'

Hard real time systems

The fidelity of the vehicle model, as well as the I/O of the hardware you are testing, will determine the requirements of the hard real time system you need, which is the next step to consider. Most well-known manufacturers, such as dSPACE and Concurrent, have systems compatible with most types of vehicle model, but this is always worth checking.

'One key aspect is choosing the right real time system for your application,' highlights Juan Pablo Ramirez, head of simulation at Mahindra Formula E team. 'There are high-end systems that can cope with high-fidelity models, but understanding the system and the software will take a long time. Whereas cheaper and simpler options may not have the flexibility you need in terms of inputs and outputs.

'Whatever system you choose, there will be a significant learning process, and you need the people with the right skills to do this. Normally, you need a controls engineer to hook up all the hardware and a simulation engineer to interface the hardware with the simulation environment. If you want a very capable system, you cannot have just one engineer managing everything. You need the skills and practises of both engineers to implement the system correctly for your application.'

Integration time

Once all the main components of the HIL system have been selected, the next challenge is to integrate them. This process is the most time-consuming part of developing a HIL simulator.

'Often teams will already have some sort of driving simulator, along with a software tool for lap time optimisation and a test bench to validate hardware such as the ECU,' notes Dennis Marcus, commercial manager at Cruden. 'The temptation is then to combine what you already have and just start integrating it all together as quickly as possible. This may save time initially, as you don't have to investigate different tools or suppliers, but the engineering challenge in the long run could be much bigger.

'It's important to give yourself time to sanity check the tools you already have are what you want moving forwards. You have to ask yourself, is your hard real time system compatible with the simulator? Is the familiarity of systems you've already used worth the potential integration challenges?'

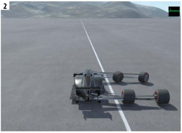
> **'Whatever system you choose, there will be a significant learning process, and you need the people with the right skills to do this'**
>
> *Juan Pablo Ramirez, head of simulation at Mahindra Formula E team*

It is essential to ensure the graphics and the physics talk to each correctly, otherwise you can end up with models like this. Can you guess the errors?

1

1) Wheel positions are rotated in a 45-degree plane about the car body centre

2



2) Wheel position y coordinate has the reverse sign

3

3) Car body orientation matrix transposed so the yaw is in the opposite direction for the wheels and body

Images: rFpro

Once you have all your equipment, the first task is to compile the vehicle model into C code to run in real time on the hard real time platform. It can be quite a challenge to get the code to compile correctly but, once any bugs have been fixed, the model can be re-compiled relatively easily. Consequently, teams will often make significant changes to the model and re-compile it regularly during the development phase.

But once serious testing begins, vehicle parameters are changed in a configuration file to avoid the whole model having to be re-compiled again.

The vehicle model also needs to interface with the virtual model on the simulator, and the simulator itself. While the hardware being tested needs to accurately link to the hard real time system, so the inputs and outputs also need to be configured.

'The hardest challenge is getting the correct inputs and outputs of the hard real time system, as well as the component you are testing,' highlights Waters. 'Once you have your list of inputs and outputs, you then need to work out which signals you can get from your simulator and which ones you need to simulate. It might be something as simple as a temperature sensor, so you just need to send a constant value of temperature. Or it might be more complicated where there are signals that you really can't simulate. In that case, you have to set up dummy loads, which convince the ECU it's in a real vehicle, but in a way that does not affect the outcome you are testing.'

Start simple

As with most complex tasks, the best piece of advice is to start simple. Develop an HIL rig to test a piece of hardware, such as an ECU, in isolation. This will involve a vehicle model running on a hard real time system, the ECU to be tested and a model of whatever the ECU is trying to control (instead of the simulator).

'Try to fully convince the ECU it's in a real vehicle,' says Waters. 'Run a series of tests by replaying data, or feeding in data, from simple vehicle dynamics models. If you can achieve this, then you're in a much better position to connect it to a simulator, which then has an unpredictable driver in the loop.'

It's clear HIL testing offers teams the opportunity to rigorously test hardware from the real car, minimising the impact of reduced track time. Integrating HIL with a simulator adds a new layer of opportunity, but also complexity. Some top-end teams are already pushing this concept to the extreme, incorporating ever more components and sub assemblies from the real car.

Integrating HIL with a simulator adds a new layer of opportunity, but also complexity

As ever with engineering, though, there is no one solution that suits everybody. Before you dive in, you need to understand *how* your team will benefit from HIL and compare that with the resources and effort necessary to develop a successful system.

'The applications of a HIL system might differ from team to team, or industry to industry, but in the end it depends on what the objectives are,' concludes Ramirez. 'Motorsport is very specific, and sometimes our approach is simpler than say, automotive, but sometimes it is more complex because we are chasing performance.

'Overall, the fidelity of the models, the capability of the hard real time system and the complexity of the interfacing depends on the goals you are trying to achieve. The key to making progress is having it all work together as one accurate system.'

Shape Shifters

The shape of Formula 1 is changing for 2022 and beyond in a bid to improve the action on track by changing how car's interact in close proximity

By STEWART MITCHELL

Formula 1 is making a revolutionary change for the 2022 season with one of the most extensive chassis regulation edits ever seen in the sport.

The new cars are flipping the rules on their head by introducing previously banned design and aerodynamic techniques such as ground effect and cutting back on once heavy development elements such as the sidepods.

The 2022 Formula 1 car will rely less on a surface-type aerodynamic regime, whereby much of the generated downforce is by elements seen above the car.

Moving forward, the car's downforce will predominantly come from tunnels under the car's floor that interact with the track surface.

This technique is known as the ground effect and is a far less sensitive aerodynamic regime than a surface-type one, producing less turbulence and a smaller wake.

The philosophy behind these regulations is to allow closer racing, with the potential for more overtakes by reducing the 'dirty air' rejected by a leading car.

Current Formula 1 cars lose 35 per cent of their downforce when running just 20m behind a car in front, measured from the lead car's nose to the following car's nose. As the trailing car closes in, the loss raises to as much as 47 per cent at around 10m distance behind. The 2022 car, which puts a heavy onus on the ground effect, reduces those figures to four per cent at 20m, rising to 18 per cent at 10m.

The journey toward the 2022 aerodynamic regulations started in 2017 when Liberty Media took over Formula 1. The new owner's primary focus was to up the entertainment spectacle of Formula 1, and this rhetoric eventually filtered down to the technical regulations, which govern much of the on-track behaviour of the cars in competition.

Following the Liberty Media takeover, Formula 1's in-house technical team started to look at the then current state of the sport aerodynamically, notably in car-following scenarios, which it had not addressed before.

It was not a priority, nor was it in the scope for teams to investigate car-to-car interaction in this way as they were only ever searching for performance on their own cars.

Formula 1 has a small technical team, with just five personnel in the aerodynamics department, along with a few other engineers on other projects such as power units, vehicle simulation and the like.

Of those five in the aerodynamics group, there are three aerodynamicists and two designers, all with Formula 1 experience. All came from teams in the series. This is a tiny fraction of even the most minor Formula 1 team's aerodynamics department, so they certainly had their work cut out.

Technical resource

However, although the department is small, it has enormous computational resource, collaborating with Formula 1's technical partners, such as AWS, and far exceeding what teams can use.

Formula 1's technical department also has a wind tunnel at its disposal, although it should be noted that most of the work it undertook in this programme was computational. This is because the investigations were predominantly looking at two-car interactions, and there's no wind tunnel big enough to run two F1 cars at a sensible distance from eachother.

In the F1 technical team's investigations, it became clear early on that there were considerable numbers at play in terms of performance delta from nominal to that

Following the Liberty Media takeover [in 2017], Formula 1's in-house technical team started to look at the then current state of the sport aerodynamically, notably in car-following scenarios

The 2022 car has been designed by F1's in-house aerodynamics team to generate better racing, both by reducing the wake produced and also the sensitivity to running in dirty air

XBP Images

associated with car-to-car interaction, and cars were losing as much as half of their downforce in a close following situation.

That has also been a consistent theme in driver feedback since the 2021 generation of the Formula 1 technical regulations.

Drivers have often commented on the challenging feel of the car's handling and system management, particularly cooling, when running close behind another car.

Once Formula 1 understood the magnitude of the problem, it set about deconstructing the cars to understand the elements driving the performance loss. The investigations showed two main areas of influence. Firstly, wake – the aerodynamic losses from the leading car and how they present to the next car. Secondly, the sensitivity of the following car to that wake. No matter what, following cars are always going to be driving through disturbed airflow.

So, the two strands of development became improving (reducing) the wake from the lead car and making the car less sensitive to driving through a disturbed fluid.

Over the years since then, Formula 1's technical team has been evolving various geometries to address those problems.

'We've been very open minded about where to look, and developed and simulated many different options,' says Jason Somerville, head of aerodynamics at Formula 1. 'We even went back through history, looking at how car-to-car interaction was in different eras of the sport.

'We found that there's no magic era where cars were aerodynamically very downforce laden and also followed each other very well.

'We never really saw that, certainly not in our research, though we were able to capture some features that are proven to be particularly bad in those conditions.'

The differences between the 2021 and 2022 cars are readily apparent, as is the scope for development, due in part to the abolishment of existing Formula 1 features in elements such as the bargeboards.

When presented with undisturbed laminar flow, bargeboards are incredibly strong performance devices, but severely inferior when shown a heavily turbulent wake.

So, these were components that Formula 1's technical team highlighted as an area where they could reduce the sensitivities.

Ground effect

Central to the 2022 car's aero package is the shaped underbody with two large tunnels, which relies on the ground effect phenomenon to produce the highest proportion of the car's downforce.

Ground effect works though Bernoulli's principle, which states that an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure, or a decrease in the fluid's potential energy.

So, by using a curved profile to the underside of the car's floor, a low-pressure zone will occur with the highest downforce-generating section at the throat (the section with the lowest volume / closest to the ground). The cross-sectional area available for air passing between the car's floor and the ground then shrinks from the entry to the throat and expands behind it.

This causes the air to accelerate and, as a result, the pressure under the floor drops, while the pressure on top of the car is unaffected. Combined together, this results in a net downward force.

'This is the first time Formula 1 has changed the primary physics of the floor since it brought in the stepped flat bottom regulations in the 1990s,' notes Somerville.

'With a shaped underbody for 2022, the floor will become much more powerful and will be a way of compensating for the lack of barge boards, which are particularly sensitive to driving through a wake. The result will be a car much more resilient to dirty air.

'Provided you're not feeding the underfloor with front-wheel wake, it will then remain a powerful downforce-generating device across a broader range of operating conditions.'

Performance philosophy

Naturally, a major focus for the teams now is to try and exploit the new conditions. In terms of the performance to be gained with the 2022 regulation philosophy, from our research combining the new floor and the new diffuser is a good few percentage points more powerful than the 2021 floors, with scope to be more powerful still.

'The regulations are our end game in terms of our research model,' continues Somerville. 'It hasn't had all the development and extracting performance from it at a competitive team's level yet.

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The 2021 cars are particularly sensitive to dirty air and drivers comment on how difficult they are to manage in following scenarios

'From what we understand, the cars will be running much lower rake in 2022 to get the sealing effect of the floor to generate the ground effect and work the tunnels in the floor in the most efficient way.'

The new, shaped underfloor also affects how the aerodynamic balance shifts when the car is subjected to wake.

The largest aerodynamic load contribution in the 2022 car comes from the centre of pressure of the floor, which is likely to be close to the middle of the car.

In contrast, the highest contributing aerodynamic devices of the 2021 cars comes from the wings located at each end of the car. The change here is reasonably positive for the drivers, as stability will be more consistent in the scenarios the cars see on track.

'We have done a great deal of work to try and ensure that the regulations haven't got anything intrinsically unbalanced about them,' says Somerville.

The cars will be running much lower rake in 2022 to get the sealing effect of the floor to generate the ground effect and work the tunnels in the floor in the most efficient way

'It's inherent that you will see a lot of performance gains from the teams as they develop their cars, and that will have an effect on how the cars operate in dirty air.

'For now, though, they are a lot less sensitive than the 2021 generation of cars. In theory, when a car follows another, the aerodynamic balance will remain quite stable.

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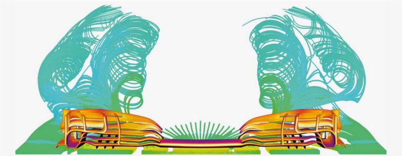
The 2022 car's downforce will predominantly come from a curved underfloor with tunnels that take advantage of Bernoulli's principle to interact with the track surface



Simscale

Controlling the Y250 vortices shed from the front wing was very influential in the wing and underside's downforce-generating capability on the 2021 cars. These will be a thing of the past in 2022

It's not like we're losing a lot on the front or at the rear. It's a relatively balanced loss to both axles, according to the research we've done.'

Lower drag wings

Like the bargeboards, the front and rear wings on the 2021 cars are also very wake sensitive so will become more simplified systems for 2022, less susceptible to dirty air.

The 2022 regulations place less value on the front and rear wings in reaching target overall downforce figures, but the effect of the regulation changes here should produce lower drag cars compared to the 2021 models.

This too will provide more aerodynamic resilience in car-to-car interaction, as a lower drag car is not generating as much disturbed wake for the following car to drive through.

The 2022 regulations abolish the element-less 250mm section across the centre of the front wing in favour of wing elements that connect directly to the nose. As such, the 2022 cars lack the Y250 vortex and its controlling devices, which have been present on Formula 1 cars since 2009. This will have a significant effect on the downforce-generating capability of the front wing and underbody flow feed.

'The element-less 250mm section across the centre of the front wing went quite early on in our research because it was something that didn't stand up to scrutiny,' explains Somerville of that decision. 'It was one of the first things that we found was very sensitive. For the 2022 prescribed nose area, the way it interacts with the front wing gives room for interpretation and there will likely be different philosophies in this area across the grid.'

In the 2021 generation of the Formula 1 rules, an enormous development avenue for teams was to outwash the front wheel wake with front wing end plates, front brake duct furniture and bargeboards.

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The 2022 rear wing enables flow to roll off the top of the wing tips and narrows the expansion of dirty air from the back of the car

XBP Images

Rear wing tip vortices, seen here being shed from the left tip of the Alfa Romeo, have a huge influence on the size and shape of the dirty air shed from the 2021 cars. These won't be a factor in 2022, and the hope is that the racing will be correspondingly closer

XBP Images

The 2022 regulations abolish the element-less 250mm section across the centre of the front wing in favour of wing elements that connect directly to the nose

These elements build up to create a car that still works aerodynamically in a wake situation and doesn't create the disturbing outwash of the 2021 generation cars

These components contribute enormously to placing the front wheel wake wide away from the chassis, not disturbing the aerodynamic features further down the car. With that front wheel wake being pushed outboard, away from the sidepods and underfloor, it is very difficult for a following car to maintain a stable aerodynamic platform when passing alongside it.

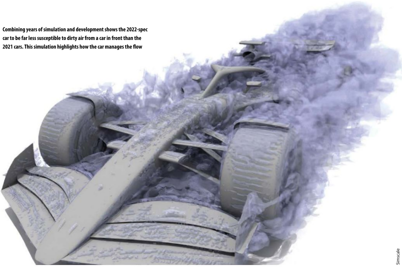
The lack of bargeboards means the ability to generate outwash from behind the front wheels has gone, so teams must now find more subtle ways to manage it.

The 2022 car removes some of these outwash-generating tools, and implements a considerably simplified front wing design with a radiused transition to the end plates, specifically designed to avoid too much vorticity around the front wheel.

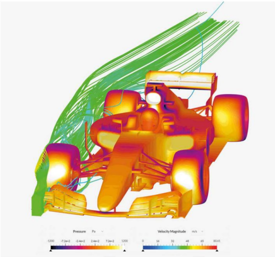
Certain mandated components on the front drums also avoid generating too much outwash behind the front wheels, while the introduction of wake-deflecting fins over the front wheels and wheel fairings further manage front tyre wake and outwash. The aim of these devices is simple: to improve airflow around the high disturbance area of the wheels, reduce lateral wake and make it easier to pull alongside a car ahead.

These elements all build up to create a car that still works aerodynamically in a wake situation and doesn't create the disturbing outwash the 2021 generation cars do.

Combining years of simulation and development shows the 2022-spec car to be far less susceptible to dirty air from a car in front than the 2021 cars. This simulation highlights how the car manages the flow

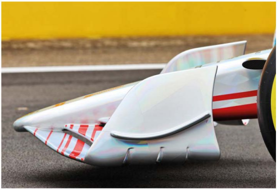


Simscale



Simscale

Under the 2021 rules, an enormous development avenue for teams was to outwash front wheel wake with front wing end plates, brake duct furniture and bargeboards. However, many of the outwash-generating elements have been removed for the 2022 car



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The swept back new front wing end plates take inspiration from the aircraft world in reducing the vortices generated at their tips

A further tightly constrained area by regulation for the forthcoming 2022 car is the rear wing. There is scope for teams to develop some elements to coincide with their philosophies, but it is far less free than the outgoing 2021 wing design.

The restrictions here predominantly focus on the tips, which coincide with the shape and size of the car's rearward wake. The new design enables the flow to roll off the top of the wing tips and narrows the expansion of dirty air coming off the back of the car.

However, according to Formula 1's technical design team, the regulations leave some unique upper profile design scope.

Additionally, the lower wing elements are quite open in terms of the regulations, which will provide a lot of development focus for teams to try and find the most efficient solution, particularly in integrating the wing with the flow coming out from the floor.

DRS to stay

DRS (the controversial drag reduction system) remains for the 2022 rear wings. The benefits Formula 1's aerodynamics department has found by reducing the effective downforce loss in following situations works against the following car's aerodynamics in drag reduction. As such, the 2022 regulations enhance the need for some form of DRS, as Somerville explains: 'Certainly, from our simulation work, we believe DRS is required.

'Because the cars will be able to follow each other closer through the corners, it follows that the cars should be closer to each other on corner exit. But because there's less of a hole being punched through the air by the lead car on the straights, cars will need DRS to get closer there.'

Larger cooling louvres are now permitted on the sidepods and engine cover, giving the teams some opportunity to play around with cooling configurations and, therefore, convergence of bodywork at the back of the car and the pressure delta at the diffuser.

'We wanted to ensure we weren't developing a set of regulations that were going to be enormously expensive, particularly with a budget cap in place,' says Somerville. 'We felt that although cooling louvres had come and gone over the last few years, the new regulations would likely favour reintroducing them as they are efficient ways of cooling. Plus there is no downside to them from the wake perspective.

No sprouts

'Consequently, there's a region within the bodywork where teams can develop louvres and exits. It's reasonably tightly governed so there should be no aerodynamic devices sprouting from various apertures.'

As far as relative performance of the 2022 car is concerned, Somerville is confident about the potential. 'I think the cars will generally be more stable and work very well through the high-speed corners,' he says. 'Where we left this car [in terms of regulations], the performance figures were somewhere south of the current generation of cars, in the knowledge that teams will subsequently find performance.

'Even before the start of the season there is a lot of chatter about teams making progress. If you put the 2022 Formula 1 base car on the 2021 grid, it would be a few seconds off the current car's pace, but I will be very surprised if teams haven't extracted most of that back from their ongoing development ahead the 2022 season.'


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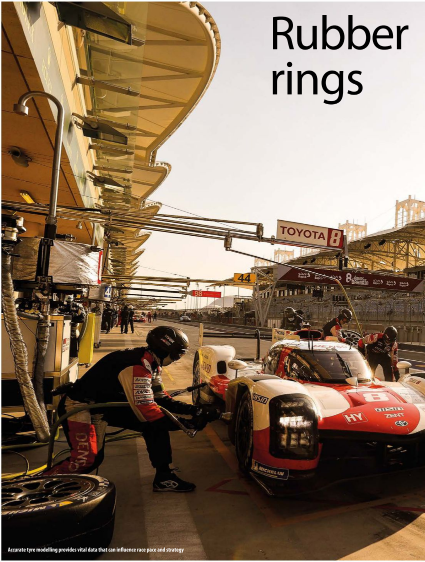

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Accurate tyre modelling provides vital data that can influence race pace and strategy

In the second of three articles on tyre modelling,* Racecar *investigates a new approach that includes thermal and wear effects in the testing and modelling process

By ANDREA QUINTARELLI

In the first part of this series, published in *Racecar Engineering* V31N11, we presented an overview of some common methodologies for tyre testing and an introduction to tyre modelling.

Analysing the main features of both indoor and outdoor testing, in terms of accuracy, repeatability and cost, it became clear how each method has its own advantages and disadvantages. And how, depending on the application, one solution could be more appropriate than another.

Another key conclusion was that 'traditional' methods cannot handle tyre temperature, wear, pressure and external factors like tarmac characteristics as input parameters for tyre modelling, despite their importance for race tyres' performance.

Taking temperature as an example, it is usually measured during testing, and some companies may have procedures in place to either take temperature variation into account, or limit how it affects the data used to create their tyre models, but very few models can really incorporate the effects of tyre temperature in the simulation chain, let alone other parameters such as wear or road roughness.

So, modelling tyres to include the effects of phenomena related to temperature and heat transmission in general, as well as pressure and wear, is extremely complex, but not impossible.

Important steps have been made in this respect in the last few years, with the aim of developing a multi-physical approach to tyre modelling, and adapting tyre testing procedures accordingly. Some interesting new technologies and methods have developed out of this, allowing better characterisation of tyre behaviour from a thermal perspective, without the need for destructive testing, which also helps save cost.

Tyre testing

To find out more, *Racecar Engineering* talked to Flavio Farroni, CEO of an Italian start-up named MegaRide, who has been extremely active in the field of tyre characterisation in the last few years.

The company's first step was developing an alternative method for tyre testing, with one principal goal in mind, as Farroni explains. 'The main driver was to keep cost as low as possible, as the initial investment required for a tyre testing campaign is often a killer for many motorsport organisations.'

The method developed would fall into the 'outdoor' class of testing but, unlike using wheel force transducers, it promises to collect tyre data at a cost an order of magnitude lower, while still offering the same advantages ie the tyre interacting with a real road surface.

The first product is called T.R.I.C.K., an acronym for Tyre / Road Interaction Characterisation and Knowledge.

Farroni explains the key cost-cutting element of the process: 'Using a real car to collect the necessary information, without the need for four expensive force transducers, or other bulky onboard equipment. A vehicle model then processes the signals provided by a single slip optical sensor and by vehicle CAN bus, creating a sort of virtual telemetry that output all the most relevant tyre channels.

> **The main driver was to keep cost as low as possible, as the initial investment required for a tyre testing campaign is often a killer for many motorsport organisations**
>
> *Flavio Farroni, CEO at MegaRide*

'Since such a model needs to depict every detail of the subsystems of the car, an accurate description of the vehicle is required, as this is the vector to output tyres' relevant information reliably.'

Using a real vehicle, on a real track, could lead to lower repeatability compared to lab testing, so it is necessary to plan a testing manoeuvres routine. Still, outdoor testing, where no wheel force transducers are required, has some important advantages:

- Investment is lower, because vehicles normally exist and often already have a data acquisition system fitted. MegaRide, in this example, would provide any missing equipment necessary to complete the test campaign, as well as supervision on the test itself.
- This analysis considers real world thermal and friction interactions between road and tyres, eliminating the non-realistic surface issue, one of the main limitations of tyre bench testing.
- Tyres are an integrated part of the vehicle, which also corresponds to the measured system. There are no additional inertias introduced that could affect results and both the tyres and vehicle influence each other's performance.
- Lastly, it allows a direct identification of tyre model parameters, both physical and empirical, and tuning of their output to fit the collected data.

'The tested car needs to perform some specific manoeuvres that allow us to explore a wider spectrum of conditions,' says Farroni. 'Deriving data from normal track sessions is also possible, but not ideal, because the amount and quality of available information would be limited and so the accuracy of the tyre model would be lower.'

Mobile laboratory

To illustrate how such an approach works, **figure 1** shows an example of a T.R.I.C.K. testing routine. Here, the vehicle is used as a mobile test laboratory, and the information acquired using the CAN bus becomes an integrated part of the process. Together with the additional signals provided by the slip sensor, this provides the car's lateral and longitudinal velocity.

Information measured by traditional data acquisition systems can then be plugged into the built-in vehicle model and combined with the readings of the slip sensor to derive lateral and longitudinal forces at the four contact patches.

T.R.I.C.K. employs a seven degrees of freedom vehicle model: three degrees of which refer to in-plane vehicle body motions (longitudinal, lateral and yaw), four to wheel rotations around their own axis and one degree of freedom to the wheels' steering angle.

Suspension and steering kinematics and compliances are fixed, but their properties are defined by their own K&C (kinematics and compliance) curves. These curves can either be measured on a physical bench or be the output of multi-body simulations, performed with a fully parametrised and validated model.

The vehicle model built into T.R.I.C.K. derives a car's roll angle and front and rear toe and camber variations as a function of vehicle longitudinal and lateral accelerations.

'Using accelerations as an independent variable to derive all important suspension kinematics and compliance parameters enables our model to work easily in real time, and this leads to very high computational efficiency,' says Farroni. 'Using full kinematics and compliance curves in the form of look-up tables [tables where each parameter is specified with respect to another, for example wheel travel or roll angle, in this particular case] would increase the computational effort sensibly.'

Suspension curves can also be input with respect to suspension motion instead of acceleration. For example, using fitted polynomials to keep the computation effort under control.

Because of its importance with respect to the vertical loads acting on the tyres, the aerodynamics of the car must also be a part of the vehicle model. Likewise

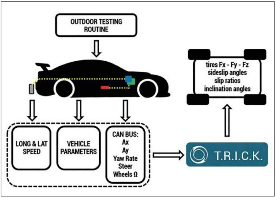

Fig 1: The T.R.I.C.K. operating principle

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Formula 1 tyre models must consider the aerodynamic loads upon them to generate an accurate representation of their performance

rolling resistance and Ackermann steering coefficients. All of these parameters are also included in the T.R.I.C.K. vehicle model.

Tyre forces

All of this helps in estimating wheels forces and slip, both in lateral and longitudinal directions. Lateral slip at each contact patch is obtained by manipulating the slip sensor signal. 'This device can be mounted in any convenient position in the car and the acquired lateral and longitudinal velocity can be than translated to the c of g,

The tested car needs to perform some specific manoeuvres that allow us to explore a wider spectrum of conditions

Flavio Farroni, CEO at MegaRide

assuming the car as a rigid body, to derive the body slip angle,' explains Farroni.

From there, since the vehicle's geometry and key dimensions are known, as is the orientation of the wheels (steering angle dependent) at the front axle, lateral and longitudinal wheels' velocity and slip indices can be calculated.

Since a car is actually an over-constrained system, from a physical point of view (a plane, like the one representing the road, can be defined by knowing three of its points, but a car has four contact points with the road), a simplifying assumption is required to estimate the lateral force exchanged by each tyre with the road.

MegaRide solved this problem using some specific assumptions related to the distribution of vertical loads and to the iterative use of a progressively learning tyre model.

'This proved to be an acceptable approximation, within certain working loads, and was validated by data collected in many testing sessions and for a wide range of applications. For higher loads, more complex iterative processes, such as the ones we recently added, thanks to state observers, are necessary,' says Farroni.

Once the wheels' position and orientation are known, as well as the wheels' velocities and tyres forces, all the information required to build maps of lateral and longitudinal force directions are available.

Temperature and wear

Testing procedures can also be conceived to record data that also incorporates wear and thermal effects.

'Our testing campaigns start with a set of new tyres,' clarifies Farroni. 'In order to collect information about how they perform in these conditions, both the type of manoeuvres performed, and the number of times each manoeuvre is repeated, provide experimental data relative to a very wide operating range.'

The way thermal effects are evaluated and incorporated into this testing loop is particularly interesting. Since the estimation of key parameters is based on outputs of a vehicle model, the thermal side of the modelling also needs to be implemented within the 'virtual telemetry' the tool delivers. This is done with dedicated modules focussed specifically on thermal effects.

Using the calculated tyres forces and slip as an input, these modules can then calculate temperature and temperature distribution as an output, allowing for the thermal effects on tyre forces to be isolated in an iterative process that feeds itself. In the MegaRide case, this is achieved by employing other products in its portfolio.

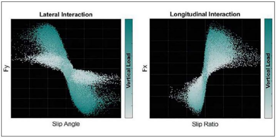


Fig 2: An example of data outputted using T.R.I.C.K. showing the road interaction characteristics of tyres

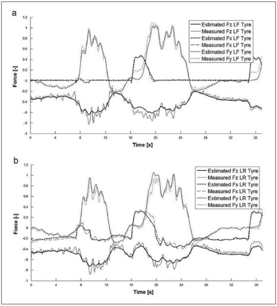


Fig 3: Comparison between T.R.I.C.K. estimation and forces measured with dynamometric wheels for front tyres (a) and rear tyres (b)

'Using a vehicle model and a 'virtual telemetry' is intrinsically based on some necessary, simplified assumptions,' admits Farroni. An example of data produced using T.R.I.C.K. is shown in **figure 2**.

In general, comparing results produced by the T.R.I.C.K. methodology with data collected from more traditional testing methods seems to show good correlation between the two, as illustrated in **figure 3**.

When dealing with tyre modelling, it is critical to have a certain degree of flexibility, and also to be able to manipulate data from different sources and collected by different methods. 'MegaRide's focus has been flexibility in modelling thermal effects, incorporating data gathered using different approaches to ours,' explains Farroni. 'What is important is having a temperature input, either measured as it

would happen on a testing machine, or estimated, as it would be using T.R.I.C.K.'

The ultimate goal here is creating a 'digital twin' of the real tyre, a model taking into account all the most important phenomena, with a particular focus on the energy-driven ones that are so important in motorsport applications, due to racing tyres' sensitivity to temperature and wear.

The next step is fitting a tyre model to the experimental data. The most widely used formulation is Pacejka's 'magic formula', as discussed in part one of this series.

Multi-variable tool

'This is the base for our models,' confirms Farroni, 'and we have developed a tool for multi-variable optimisation, applied to Pacejka's magic formula, called adheLAB.'

Conventionally, such a tool would enable you to isolate the coefficients to be plugged into Pacejka's formulation to produce results that match the experimental data, mainly in terms of forces and moments, that are the traditional outputs of Pacejka's formula.

'To bring thermodynamics into the loop, each coefficient needs to be substituted by a function that varies depending on dynamic parameters like temperature, inflating pressure and wear,' continues Farroni.

This translates into a new way of modelling tyre behaviour that takes into account not only the aforementioned factors, but also the tyres' own properties, such as compound viscoelasticity, and external factors such as road roughness. The first has a critical role in determining how a tyre reacts to energy being injected into it, either mechanically or thermally, which ultimately influences grip.

The second is crucial in defining how the compound interacts with the road.

'This is what another tool in our portfolio called adheRIDE does,' says Farroni. 'It is intended as an evolution of Pacejka's formulation. It is *our* tyre model.

'To characterise tyres thermodynamically, also considering the effects of wear and inflating pressure, a real-time, physical, thermal model for performance analysis and simulations is needed, one that takes into account heat sources and cooling causes. We approach this with a third tool named thermoRIDE.

'One of its most interesting features is that it collects data about the tyre in a non-destructive way. This allows teams to complete testing activities without breaking any agreement with their tyre manufacturers, and without compromising further use of the tyres after the tests.'

Internal phenomena

To model tyres' internal phenomena, what happens in their internal layers must be simulated, because this is where temperature measurements cannot be performed dynamically.

'To achieve this, tyres' structurally different strata are modelled separately, with a slightly different approach depending on each one's material properties,' notes Farroni. In other words, tyres are discretised and their thermodynamics analysed with methodologies based on Fourier diffusion equations, but also taking into account convection phenomena such as heat exchange between external air or gases and tyre tread, or between

One of its most interesting features is that it collects data about the tyre in a non-destructive way

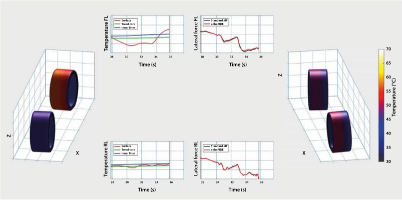
internal air and tyre liner, and conduction phenomena like the interaction between tyre tread and road surface.

This allows modelling of complex effects like tyres being heated by exhaust gases, as well as more conventional ones such as the influence of brake temperature.

On top of this, understanding heat generation caused by friction and strain energy loss, which is related to the forces and moments exchanged with the road and to tyres' slip, inclination angle and local velocities, is a crucial part of the process. As is wear, for it affects how a tyre interacts with track asperities and is also linked to chemical degradation in the rubber. The latter is linked to the thermal interactions taking place inside the compound that cause it to harden and reduce its peak friction capabilities.

This is the reason why road roughness is such a necessary input for any analysis related to wear, as it is linked to both compound indentation and excitation.

'To analyse this, an energy-based tyre wear and degradation model that is able to describe real-time tyre tread thickness reduction, wear effects on tyre thermodynamics and degradation effects on grip is required,' says Farroni. 'Our dedicated tool to do this is called weaRIDE.'



MegaRide

Comparison between the output of standard Magic Formula and AdheRide, accounting for temperature in tyre's inner layers and tread wear

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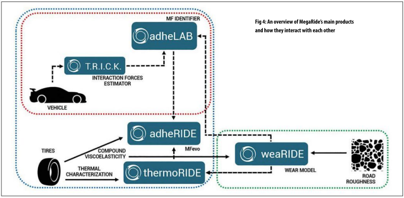

Fig 4: An overview of MegaRide's main products and how they interact with each other

Metrics such as contact patch forces and sliding velocities, tyre temperatures and pressure and compound viscoelastic properties are all necessary inputs for this.

A schematic of MegaRide's suite of products, and how each tool is linked to the others, is shown in **figure 4**.

Bounce around

Every race team would like to be in a position to investigate the properties of their tyres trackside, and this is now possible thanks to a new device, developed by the Group of Vehicle Dynamics Simulations at the University of Naples Federico II, in collaboration with MegaRide. Its appearance resembles that of the guns seen in old sci-fi movies, but its purpose is very different. 'The VESevo project [an acronym for Viscoelasticity Evaluation System – EVOlved] allows you to derive the viscoelastic properties of the tread mix, analysing how a pre-loaded rod 'bounces' on the tread material,' explains Farroni. 'To post-process the collected data, an algorithm has been developed to estimate physical parameters linked to the micro-indentations between compound and rod, such as the coefficient of stiffness and damping, and that is related to the tyres' viscoelastic properties.

'Once again [as shown in **figure 5**], the tyres' parameters that are critical in terms of thermal behaviour can be characterised with a non-destructive test.'

In this article, thanks to MegaRide's cooperation, an alternative approach to tyre testing has been presented, together with a look into how thermodynamic phenomena can be incorporated into tyre modelling.

The main difference, compared to other methods, is the high quality-to-cost ratio, as it does not require expensive equipment, or destruction testing of the tyres. Moreover, being able to actively include thermal and wear effects in both the testing and modelling procedures will be particularly appealing for motorsport applications, where these effects are crucial.

The third and final part of this series will provide a more detailed analysis of some specific aspects of tyre characterisation.

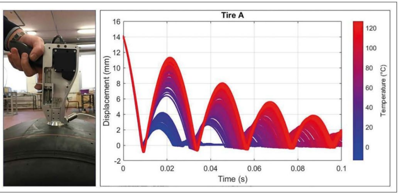

Fig 5: VESevo measurement gun, designed to measure the viscoelastic properties of a tread mix, and an example of outputted results


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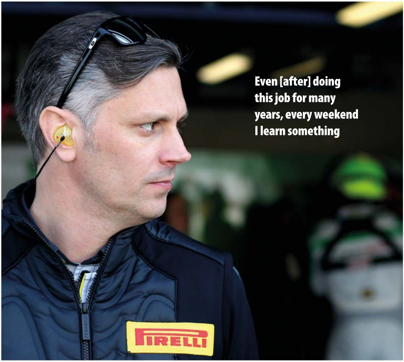

Alex Galli

As racing activities manager with the company, Matteo Braga now oversees the technical effort for the tyre manufacturer's mammoth GT programme, as well as its activities in F1, F2 and F3

Slick work

Matteo Braga has been at Pirelli for nearly 20 years, so is well placed to explain what it takes to be a top-flight motorsport tyre engineer

By MIKE BRESLIN

Race drivers feel the track through the tyres. The contact patches are like fingertips through which grip is gauged, the primary means by which the driver communicates with the road surface. There is another level of vital interaction when it comes to the rubber, though, and that's between those who provide the tyres and monitor their performance, and the teams and drivers that use them. Which is why the ability to communicate well is a key skill when it comes to working as a motorsport tyre engineer.

That's the view of Matteo Braga, anyway, and he should know, as he is chief tyre engineer for Pirelli's GT operations. His job title is actually racing activities manager, and his role involves not just GT, but also any other race series the Italian tyre giant is involved in beyond its flagship single-seater championships of F1, F2 and F3. Remarkably, that amounts to close to 100 series in more than 50 countries.

Braga has been at Pirelli for nearly two decades now and, while he is still very much a tyre engineer, his role is much wider reaching these days.

'I would say that my role, and the role of my department, is to be the filter and the connection between the end

Beyond the top single-seater formulae, Pirelli also supplies race rubber to around 100 series in over 50 countries across the world

Stephen Fisher

Alex Galli

The Pirelli 'village' at the Spa 24 Hours involves around 100 personnel including fitters, technicians, tyre engineers and support staff

user, which can be a team, a partner, a promoter or championship, and Pirelli.

'So, what we try to do is to coordinate the activity of the different departments of Pirelli Motorsport towards the needs of our customers, and collect from them the feedback, their needs, and translate these into some targets… We try to find common solutions from our internal departments and to plan better activities, like R&D and also sometimes administration and financial. But we are the people on the front line.'

Big boots

With so many championships to cover, it's a big operation, while every event also requires quite a few boots on the ground. At Spa for the prestigious 24 Hours, for example, Pirelli takes over 100 personnel, with around 65 per cent of that number in the fitting area, 20 per cent in the pit lane and the rest working in logistics, marketing etc.

The number of personnel does vary, though. 'Usually, it depends on the number of cars, and the level of the race and the teams that are in the race,' Braga says. 'But we have some local motorsport departments. We have China, Japan, Australia, North America and South America – Brazil and Argentina. We have local teams for those, and usually send people from HQ to support them.

'For example, for Bathurst [Australia, for the 12 Hour], we have a local fitting crew and technicians, and maybe from Europe we send between eight and 10 people. That's because it's a big event, though, and in that event we have very professional teams.'

Pirelli's people at the tracks work in areas that can be loosely broken down into three levels, as Braga explains: 'We have the fitters, that is the person that just stays in the fitting area and fits the tyres and checks everything is fine. We usually have a coordinator and a senior fitter that are coordinating the fitting area and all the flow from the [receiving] of the tyres until the delivery of the new tyres to the teams.

'Then we have technicians. They are usually the people we put in straight contact with the teams, and they are checking the teams are using the product correctly in terms of pressures, temperatures, and that there are no strange conditions or situations that are showing up during the sessions. They mainly work with the teams and their mechanics.'

Upper levels

The upper level is the tyre engineers themselves. 'The engineers usually manage an average of between four and eight cars,' Braga says. 'And they are the ones that also can get into discussions with [race] engineers and maybe team managers. If there is something at a higher level to be discussed, like about analysis or BoP – that is one of the main talking points today with the promoter and teams.

'But most of the time we are asked to analyse how the race is going. Just to prove there is not an advantage, or disadvantage, toward some of the brands or teams [and that] everything is just depending on the conditions or characteristics of the car.'

As chief tyre engineer, Braga likes to take a hands-on approach, and at the events he attends he is a very busy man indeed.

'It's a crazy day,' he says. 'Typically, I arrive the day before the start of the running of the activities – and I just focus on the most critical events, as we have a team of engineers more than capable of managing the events.

'My typical day is to follow the sessions most of the time during our weekends. Sometimes during the SRO weekends we have between four and five series, so that means every day we have about eight to 10 different sessions.


Alex Galli

Obviously, race tyre engineers need to carefully monitor the rubbers but, crucially, also the conditions in which they are being used

'I have a few meetings with team managers, and a few meetings with the car manufacturer representatives, as well as briefings with my team and engineers to understand if the results from the sessions are in line with our expectations. Also, if we have any critical situations that we have to manage, or to prevent. The spare time in a day is very limited, I only just about have time for lunch and dinner!'

The schedule is equally punishing for the other Pirelli tyre engineers, too.

'I would say the race weekend starts the week before the event [for the engineers], or even before, because usually when we have to get ready for one event we also have to define which type of tyres we have to load, [and] how many.'

To give an idea of the scale of the operation, it's worth noting that for the Spa 24 Hours, for example, Pirelli takes around 34 trucks and over 12,000 tyres.

Past history

'To get ready for a particular event we try also to collect information from the past years,' Braga adds. 'We go through the reports from the past years, to understand if there were some critical situations or particular aspects that need to be [noted], or we need to advise the team of in advance – just because maybe they don't remember – or whether there is something we need to take care of and keep a particular eye on during the practices.'

Once at the track, it's largely a matter of preparation to begin with. 'And as well we also check all the tyres that have arrived there, that they are in conformity… We then have to create the allocations, in respect of the regulations, and that is quite a big job. Then the fitters will start fitting.

'We have all the paperwork on the sporting side, all the things we have to generate to be registered with the scrutineers, and [we have to] make sure that the teams come to collect everything in good time, and that they have the right paperwork to go to scrutineering in time.

'Then we start the session…'

Once the on-track action begins, the role of the engineer is generally to monitor the performance of the rubber throughout the race but, very importantly, also the situations in which it's being used.

'At the end of the event, or let's say at the end of the season, the best feedback we can collect from the field is always about the conditions in which the tyres are being used. And having a wider picture always give you the possibility to focus on the real problems, or the good points,' Braga notes.

'Sometimes, if you only go to one race and only focus on one car, maybe the risk is that you only have feedback from that specific condition, that specific race. When we have to develop our products, we need to think about the worldwide requirement. So we need to create a very wide picture with all the information, and by having information from every session, most of the cars and every series, every country, we can then show our colleagues the direction to develop [new tyres].'

Which brings us back to the importance of clear communication when you're

I would say the race weekend starts the week before the event, or even before

It's not important to have a big technical background. You need to be able to speak to the people, to understand their needs

working as a motorsport tyre engineer, especially in the sometimes Machiavellian environment of BoP motorsport.

People people

'What I say to my engineers is that, yes, we need to be engineers, but most of the time it's not important to have a big technical background. You need to be able to speak to the people, to understand their needs,' Braga says. 'Because sometimes they explain something in one way, but they want to say something else, and you need to understand what the *real* topic of conversation is.'

This is not something that can be learned solely from experience, and indeed it is a trait that Pirelli looks for in its engineers before they're signed up.

'It's in the nature of the behaviour of the people,' Braga confirms. 'All our engineers, before we see their technical skills, we want to understand if they will be able to be good in a difficult conversation with a customer.'

Beyond the ability to communicate, Braga also likes to see other attributes in prospective motorsport tyre engineers. 'Obviously, there's engineering, they have to know the method and have the knowledge to understand,' he says, adding that a good qualification in engineering is important.

'Obviously, if [the qualification] is in engineering it's easier, because you also have more skills in terms of data analysis, and you know how car dynamics works, and the tyre as well.'

But, as with most jobs in motorsport, it's about more than just having the appropriate qualifications. 'I would also say that what you need is a lot of passion. Because, like any other motorsport jobs, you have to work Saturdays and Sundays, sometimes for many weekends in a row.'

Career development

Braga also has sound advice on developing a career as a motorsport tyre engineer. 'Most of all, you need a lot of practice. It's something that you cannot learn only on the laptop and books, you need to watch, you need to touch, you need to measure by yourself.'

A willingness to learn and a healthy respect for the power of data, from the very start, is also vitally important these days.

'Don't expect to know everything on the first day, or after just one season, because I tell you that even [after] doing this job for many years, every weekend I learn something. It's just looking at all the details, collecting all the data.

'And never think that some of the data that you can collect are useless, because every time you get some data, if they are collected in the right way and measured with the right methodology, they are contributing to create a background and your own personal database that sooner or later will help you in a situation.'

Unsurprisingly, given all this, Pirelli works very hard to recruit and retain the best possible staff, and has been running an intern scheme to help develop tyre engineers for some years now.

'We have a programme, that mainly we run in our motorsport department in the UK, where we select interns with very little motorsport experience, and then we try to coach them and to teach them to be a tyre engineer,' Braga explains enthusiastically. 'Most of the time we need them as a back up for Formula 1, but also to support our series in other markets. We have an average of two or three people come through the programme every year.'

Two final pieces of advice for wannabe motorsport tyre engineers Braga offers might be worth bearing in mind in whatever area of motorsport you happen to work in, or would like to find employment in.

'Something that I always say to my team is that sometimes you don't need to be so much technical, sometimes you have to be more psychological. But always what I say to them is, it's better to say "I don't know", instead of saying something stupid.

'Because what I have learned from the motorsport world is that if you say something stupid, it's very bad. And if you say it at the beginning [of your career], then you will always be a stupid one!'

Drew Gibson

Pirelli tyre engineers typically manage between four and eight cars in the pits during a race, depending on the event. They don't have a lot of time to sit down, just watching the race unfold


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The energy crisis

We need to talk about electric powertrains – the 2021 edition

By DANNY NOWLAN

In July 2019, I wrote an article exploring the then current state of play of electric powertrains. I then re-visited the subject in 2020, exploring their use in categories such as GT3 and Time Attack. If some of this text looks familiar, it should be, but it's worth going back over the ground and reiterating some of the points made because they remain relevant.

However, in the Australian context at least, two significant things have recently happened. Firstly, the Australian government has ditched the French-designed diesel submarines in favour of a nuclear-powered option. Secondly, there's been an about face from the same government on its policy toward achieving net zero emissions, which has wide ranging ramifications.

What I have found very disturbing about some recent decisions, however, is they appear to be being made in a vacuum of technical and engineering ignorance.

As I've said before, one of the main reasons it has become virtually impossible to have a sane discussion about electric powertrains and their associated issues is because of how polarising the subject has become. Some are pro electric, others against, plus now we have the activists who will latch on to one single solution and stick with it with almost religious zeal, regardless of the consequences. Woe betide anyone who should play devil's advocate.

Formula E is leading the EV racing charge, but there are alternatives to batteries that still need to be further explored

Zero emissions

The reason electric vehicles have created so much publicity is because they are classed as zero emission at the tailpipe. That suits the 'green' brigade, and those appealing to them. What has caught the attention of the 'motoring' brigade is the incredible performance figures, notably in drag races, which comes down to the torque delivery of an electric motor vs an internal combustion engine. One of the holy grails of internal combustion motor tuning is getting the torque vs rpm curve as flat as you can. Electric engines by nature have a flat torque curve that responds instantly and, in a lot of cases, can rev up to 20,000rpm. Impressive.

This, of course, segues into one of the advantages of electric powertrains, and that is responsiveness. With electric motors, the only thing you are playing with is the timing on the brushless motors (the angle between the rotor and the magnets) and the PWM (pulse width modulation) frequency. Most electric speed controls will have a perfectly linear response, so it's effectively an afterthought.

The other advantage of electric powertrains is motor packaging. The higher end applications can punch out 250kW, weigh in at 57kg and can fit into a 300 x 200 x 200mm space. Inconceivable for an internal combustion motor. This then offers a plethora of opportunities you can't do with an ICE. A really good case in point is electric motors fitted to all four axles, which also handles the nightmare of the differential quite elegantly.

However, where electric powertrains struggle is when you need persistence. This is one of the most significant challenges to going carbon neutral, particularly when it comes to transport. To better understand this, let's review an analysis I did of an all-electric GT contender at the Bathurst 12 Hour.

For a 380kW motor, this is how the numbers shook down for the battery pack. Given that we'll be running 20 laps over a 45-minute stint, we'll need at least 253Ah of capacity. So, the number of cells we'll need is the following:

$$No\_of\_cells = \frac{V_T}{V_{CELL}} \cdot \frac{Ah_{TOT}}{Ah_{CELL}} = \frac{650}{3.5} \cdot \frac{260}{7.7} = 6324$$

$$Pack\_mass = No\_of\_cells \cdot m_{CELL} = 6324 \cdot 0.2 = 1264.8kg$$

You don't need to be a genius to figure out a pack mass of 1264.8kg is not practical.

Referring back to the Lotus Elise Time Attack study I also did, even for a sprint event you need *a lot* of cells in the battery pack. Refreshing your memory with the highlights, we had a working cell voltage of 3.5V and we need a capacity of 38Ah. The pack configuration is given below.

$$PackConfig = \frac{700V}{3.5V} S \times \frac{38Ah}{3.8Ah} P = 200S \times 10P$$

Bottom line: we need 200 cells in series and 10 cells in parallel. At the time, this came in at a battery pack price of $51,000. So, even for a sprint event, you still need 2000 3.3Ah lithium polymer cells.

For a road car application – where, let's face it, the majority of the political posturing is aimed – one major stumbling block that has to be addressed is that in order for battery-powered EVs to have an impact on the drive for carbon neutrality, they need to be plugged into a carbon neutral grid. The question that must be asked is: are the environmentally popular solutions, such as wind and solar, able to get the job done?

Let's look at the Australian example. Right now, putting solar on to your house is a very popular activity and 6.6kW systems are currently being marketed. So, the power is there, but the problem is you need to store it. And placing even greater emphasis on the energy storage conundrum is the fact solar systems turn off at night. That can be somewhat addressed with molten salt batteries, but LiPo batteries will still be required. Once you start to scale globally, this becomes a problem.

The raw truth

Why? Because supplying the raw materials for battery-powered electric propulsion is a significant concern that can't be swept under the carpet. Let's say, for the sake of argument, over the next 20 years two billion electric battery-powered cars are built. Also, to make the numbers simple, let's use a battery pack mass of 1000kg (one thing to correct from my earlier articles is that an 85kWh battery will weigh in at approximately 600kg). That said, if you are talking about electrifying trucks and battery packs for home use, that 1000kg figure is not a bad metric for discussion.

So, now we have that out of the way, this means we need 2 x 10^{12}kg of raw materials. Presuming the demand for electric vehicles is linear, if we then divide this by 20, we need 1 x 10^{11}kg of raw materials per year. Equating this into tons, we will need 100 million tons of raw materials per year. Which is about a quarter of Australia's annual coal output.

Given what a political football this has turned into, this is something that cannot be ignored. Put simply, the raw materials alone required for electric vehicles on mass underscores why significant steps still need to be taken in battery energy density.

Throw in the added demand of scaling this globally, and the analysis presented here is highly optimistic, to put it politely. Yes, the focus on EV for the Toyota Yaris-type vehicle mitigates this problem to an extent, but it doesn't eliminate it.

The other elephant in the EV room is recycling, another subject conveniently missing from many discussions on the matter. Surprisingly, recycling batteries is not as problematic as some would like to present. One of the things that has been known for years in the R/C community is that once a lithium polymer has finished its operational life and is discharged, it will readily break down, so the recycling issue is not a show stopper.

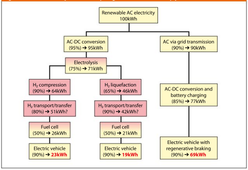
Alternative solutions

But what of alternatives to electric? There is one potential solution to the energy density problem, and that is hydrogen-powered fuel cells. Okay, so hydrogen is not without its difficulties. In his autobiography, *Skunk Works*, Ben Rich, the former director of the Lockheed skunk works, commented at some length on the dangers of producing hydrogen in quantity. This was one of the key reasons the Mach 3 SR-71 was fuelled by a fossil-based avgas, rather than hydrogen.

Pouring further doubt on the question, a colleague of mine ran the numbers on producing hydrogen en mass (make no mistake, the volumes required would be in the same order as petroleum) and the energy quantities required disqualify it as an option. Now, I am happy to be proved wrong on any, or all, of this, but *someone* needs to play devil's advocate.

Figure 1 shows why Elon Musk says Tesla's focus will be on battery-powered EVs.

Fig 1: Devil's advocate position on hydrogen electric vs battery-powered EV



This could very well be Elon being Elon but, again, it's provided as a devil's advocate and, if I am wrong, I am more then happy for someone to write a reply.

Despite all this, for me, hydrogen-powered EV still represent a viable option for electric powertrains that cannot be ignored. There are two key reasons for this. Firstly, weight / energy density. The current LMP2 technology demonstrator from GreenGT, with a hydrogen fuel cell power supply and tanks, weighs in at around 400-500kg. The big difference is it can actually go a useable race distance, whereas the electric GT3 example we discussed needed a battery pack of 1264kg.

And remember, while it has been investigated in the past, this technology remains in its infancy.

Secondly, refuelling. Achieved in minutes, as opposed to hours. These are major advantages that should not be ignored.

The n word

Before we go any further, this discussion is all for nothing if we don't talk about the grid this is plugged into, and for that we have to mention the n word – nuclear.

To most people, when you mention nuclear, images of Chernobyl and Fukushima come to mind, and the green left instantly hit the rev limiter. Some of this response is earned because current nuclear powerplants use water as their primary coolant, which introduces a whole raft of risks. Similarly, the current fuel of choice, uranium 235, is remarkably inefficient and, with nuclear waste having a half life of 10,000 years, disposal of the waste products is a huge challenge.

There is another alternative, which is the molten salt reactor. This addresses both the safety and waste problems elegantly and so, if this is not on the table during a discussion, it is a major omission. A full explanation is outside the scope of this article, but I would encourage the interested reader to search for the molten salt thorium nuclear reactor. The potential is simply staggering.

The other thing we should discuss is this insane obsession with throwing the internal combustion engine under the bus. I don't just say this because I am playing to an audience. In some applications, you are simply not going to do better than a highly efficient internal combustion engine.

And let's not forget, fuels produced by carbon neutral sources, like a nuclear reactor, mute many of the arguments against the ICE.

Conclusions

There's no doubt electric powertrains offer some very exciting possibilities in terms of car running costs, throttle response and, when it comes to motorsport, are the natural choice for sprint events. They also present a clear and viable alternative for the current class of Toyota Yaris-type town car.

However, the battery-powered route still has to contend with significant challenges in terms of energy density, demands on the electricity power grid and environmental impacts from the production of batteries in significant volume.

Hydrogen therefore still offers some enticing opportunities, though its safety and production implications need to be more thoroughly tested and considered.

As for the part motorsport can play in all this, in challenge comes opportunity, and there's nothing the motor racing industry relishes more than a challenge. Even if just from an energy security perspective, we would be mad not to rise to it, as the one thing we *all* agree on is the planet deserves the benefit of the doubt.

IN BRIEF

Lubricant manufacturer, Motul, extended its partnership with IMSA to 2026, having already enjoyed five years with the American endurance series.
Event sponsorships and track signage will continue, as will existing relationships with manufacturers and suppliers.

Racing Optics, which offers products ranging from windscreen tear offs to those for visors in open-wheel racing, has also partnered with IMSA for 2022.

Williams Advanced Engineering and Castrol have announced a five-year partnership to develop electric vehicle fluids. Castrol, therefore, has become the official supplier of EV Thermal Fluids for WAE's growing electrification programmes and electric motorsport activities.
The Castrol ON EV fluids used by WAE are designed for high performance motorsport batteries such as Formula E, Extreme E, ETCR and LMDh.

IndyCar launched a job portal early in November to meet the need for teams and those searching for jobs in the series.
'In an effort to assist our teams, we created a one-stop job portal where job seekers and teams can come together,' said IndyCar president, Jay Frye. 'Judging by the reaction we've had since the launch of the database, it is off to a great start.'
The web portal is here: https://epaddock.indycar.com/careers

The Royal Automobile Club (RAC) has awarded the Simms Medal to Dr Rob Lewis, co-founder and managing director of TotalSim Ltd, one of three entities that comprise Aero Research Partners, the driving force behind the Catesby Tunnel.
The tunnel is a unique testing and vehicle development facility housed within an old 2.7km-long, 8.2m-wide railway tunnel in Northamptonshire, UK, that first opened in 1897.

The Motorsport Industry Association will host its annual Energy Efficient Motorsport conference on Wednesday January 12 ahead of the Autosport International Racing Car Show in Birmingham.

Sierra rides again

Andy Rouse was a formidable competitor in the BTCC in the 1980s and worked with Ford to turn the Sierra Cosworth RS500 into a winner

Touring Car preparation specialist, CNC Motorsport AWS, will build three Andy Rouse Engineering-specification Ford Sierra RS500 Group A race cars in collaboration with the four-time British champion.

Each car will be constructed from an original Ford Sierra bodyshell to an exacting design set by the 60-time British Touring Car Championship (BTCC) race winner.

Just as it was in period, the first chassis, set to be completed by early 2022, will be built from a brand new '909' Motorsport 'shell, which has been unused and carefully stored since the 1980s. Cars will be supplied with HTP papers, fuel cell and rollcage certificates and will be ready to race.

Rouse set up Andy Rouse Engineering (ARE) in 1981 with his team winning the title in 1983, 1984 and 1985, each time with a different car. Rouse then worked closely with Ford to develop the Sierra Cosworth into a successful Touring Car before playing a key role in forming the Super Touring rules that transformed the category in the 1990s.

Rouse retired from professional motorsport in 1995 and this is the first project he has been involved with since the SCV8 concept in 2003.

CNC Motorsport AWS, founded by Alan Strachan, is a renowned restorer and builder of historic Touring Cars from the 1970s to 2000s. In the past two years it has built period-specification Group A Rover SD1, Ford Sierra RS500 and Merkur XR4TI cars, alongside a vast array of machined parts, such as brake calipers and wheels, that it designs and produces for other restorers and race teams at its Gloucestershire workshop.

Strachan worked for Rouse in period, building and running cars in the BTCC between 1989 and 1992 – the height of the RS500's dominance in the series – and from 1993 to 1996. He and the CNC Motorsport AWS team have access to drawings and data to produce the Rouse-specific parts, such as front suspension uprights, rear arms, fuel tank enclosure, heated windscreen, side-exit exhaust and the Rouse-designed steel rollcage to create true ARE-spec cars.

Each car will use a freshly built 575bhp Cosworth YB unit with input from original ARE engine builder, Vic Drake, who in his time has put together over 100 RS500 engines for competition use. The continuation cars will feature a Getrag five-speed gearbox, Proflex Advanced Technology fuel system and later 9-inch viscous differential.

Other features include the correct gauges, metal brake master cylinder reservoir and each one will have its own unique ARE build plate. Cars will be supplied in plain white with options for painted liveries.

'Demand for competitive Group A machines is rising, enabling access to some of the best motorsport events around the globe for correct cars,' says Alan Strachan, founder of CNC Motorsport AWS. 'RS500s are great fun to drive, relatively easy to maintain and considerably more affordable to run than Super Touring cars.

'They're also a great draw for the fans that fondly remember these fire-breathing monsters in their heyday.

'The cars will be all signed off by Andy, as they were in period, with the provenance that can only come from the man who engineered and drove the cars to such success.'


The first ARE continuation RS500 will be built on a new old stock 909 motorsport body in white

McLaren links to Multimatic

Multimatic will be the vehicle dynamics partner to McLaren when the British car maker enters the Extreme E series in 2022.

Multimatic's team will include *Racecar Engineering* columnist, Leena Gade, and her sister, Teena, who will provide race performance and systems engineering support on site and in an ongoing collaborative development programme. Leena will be the team's race engineer, Teena will undertake the performance and systems engineering role.

'We have had a long history of collaboration with McLaren and this is a new chapter in the relationship,' says Larry Holt, executive vice president of Multimatic Special Vehicle Operations. 'Zak (Brown) has consistently proven his instinct for where our industry needs to head, and this latest move into Extreme E is another that I fully agree is imperative to focus attention on sustainability, reduced carbon emissions and ultimately the viability of the sport.

'A further synergy of the initiative is that it co-incides with Multimatic's growing business in the off-road damper sector, and so the learnings that come from developing the vehicle dynamics for the massively challenging events associated with Extreme E will undoubtedly strengthen our knowledge and capability in that space.'

McLaren has confirmed it will use Multimatic's Vehicle Dynamics Centre in Norfolk, UK to prepare its all-electric ODYSSEY 21 Sports Utility Vehicle ahead of the 2022 season, which starts in Saudi Arabia in February.

Extreme E goes from strength to strength with the new collaboration, which sees *Racecar* columnist, Leena Gade, take on the race engineer role

IN BRIEF

The Automobile Club de l'Ouest and Asian Le Mans Endurance Management have announced they will work with the Stéphane Ratel Organisation on the 2023 Asian Le Mans Series. The arrangement will see two invitations for GT3 cars to the Le Mans 24 Hours, including to the winner of the Fanatec GT World Challenge Europe and the Fanatec GT World Challenge Asia and Asian Le Mans Series classification.

The Silverstone Park is set to give the green light to phase four of its planned development and bring forward a new scheme on six acres of land adjacent to the site's Innovation Centre. The Silverstone Park now has more than 80 companies on its premises and is part of a growing destination for engineering, innovation and business development on the estate.

Racing Force Group, which owns Bell helmets, OMP, Zeronoise and Racing Spirit, is set to become publicly owned. The company is based across three continents, has more than 400 employees and over 2,000 product lines that sell to motorsport competitors in more than 80 countries.

FIA warns its candidates

The FIA Ethics Committee published a letter on 8 November warning against undue influence by presidential candidates on members who will vote on who will become the next president of the organisation in December.

It was reported recently that members were being asked to photograph their own ballot paper to evidence their vote, a matter that apparently prompted the Committee to act. It comes as Graham Stoker and Muhamed Ben Sulayem face each other in a battle to take over the FIA presidency from Jean Todt.

'Lobbying and endorsement are legitimate practices, but potentially controversial,' read the statement. 'Exercising political pressure, or any other form of pressure, on an FIA member in order to influence their vote at the presidential elections would constitute an infringement of FIA fundamental principles.

It would be a more severe infringement if such pressure included a request that an FIA member give photographic evidence of the ballots he or she has cast.

'It has been reported that this might be happening at the FIA, which would be a matter of serious concern for the whole FIA community.'

The Ethics Committee went on to state that the FIA Clubs should be able to vote freely, that candidates should not be put under undue influence as to how to cast their vote, and that candidates and their supporters must abstain from encouraging third parties to engage in any activities that the 'FIA doesn't have the power to control.'

Mazda's Super Taikyu biofuel

Mazda entered a 1.5-litre Skyactiv-D Demio in the Super Taikyu race at Okayama in November, running the car on next generation biodiesel.

The car ran in the ST-Q class, introduced to showcase experimental vehicles and new technology, and completed the 94-lap race. The manufacturer now expects to compete for the full season in 2022.

Entered as 'Mazda Spirit Bio concept by Demio', the ST-Q Demio was otherwise unmodified and ran on 100 per cent bio-based fuel called Susteo, made by Euglena from used cooking oil and microalgae fats. According to the company press release, the biodiesel fuels do not compete with the human and food supply chains, which has been an issue with existing biofuels.

Mazda says these types of fuel can be used as alternatives to diesel in existing vehicles without any modification, meaning no additional fuel supply infrastructure is required.

Meanwhile, Mazda also confirmed it would continue its development of hydrogen race vehicles.

The Japanese manufacturer is a member of the Hiroshima 'Your Green Fuel' project, which aims to establish a model for revitalising regional areas by retaining the entire value chain of carbon-neutral fuels, from the manufacture and supply of raw materials through to fuel use.

In August 2020, the project confirmed that the performance of this biodiesel fuel was on a par with petroleum-based diesel fuel, and Mazda has now started to use it in its company diesel cars.

Interview – Kia Cammaerts

360-degree thinking

Ansible Motion used its time in 2020 to develop its latest Delta simulator, the S3, with the first example delivered to Honda's R&D department in Sakura, Japan

BY ANDREW COTTON

Ansible Motion, the British company based in Hethel, Norfolk, recently introduced its latest motion simulator, the Delta S3. A version is already installed at Honda in Japan, with further commissions by such companies as BMW Motorsport and Continental Tyres.

The Delta S3, which also caters to NASCAR, IndyCar, the World Rally Championship and others, differs from its predecessors in that it has four metre lateral and longitudinal axes that offer a wealth of advantages, especially in the hybrid and electric arenas. That makes it particularly suitable for use in series such as Formula E and Extreme E.

Another feature of the Delta S3 is a much higher yaw capability, making it ideal for Rally applications too, while also helping drivers maintain a greater sense of realism within the simulator in extreme and unexpected events, such as spins.

The S3 extends the motion space from a metre out to four metres in both the lateral and longitudinal direction

Kia Cammaerts, founder and technical director at Ansible Motion

'You no longer have to be brave to buy a driver-in-the-loop simulator,' says Cammaerts, and sales of the company's products prove that statement

Educational tool

More than 10 years on from its first collaboration with Ansible Motion, Honda R&D Co was the first customer to commit to the Delta S3 driver-in-the-loop simulator, and the company is already using the device to help with the development of its NSX Super GT car, as well as its Super Formula programme.

Honda's simulator will also be used to help with the development of production cars, including the flagship Civic Type-R and, the manufacturer says, is key to the education of the company's young engineers.

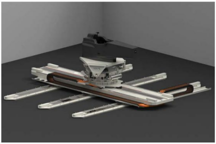
'Other expected applications include understanding tyre wear, circuit acclimatisation and giving drivers and engineers the opportunity to experience scenarios such as new aero set-ups for our Super GT car, or testing limit handling with and without dynamic stability control,' says Kazuharu Kidera, chief engineer at HRD Sakura.

For Ansible Motion, the Covid pandemic gave the company's engineers time to think about what they wanted to do, and time to develop the simulator while also respecting the restrictions imposed by government on working conditions.

It wasn't an easy process as engineers had to provide input remotely rather than in the same room, plus there were delays in the manufacturing and delivery chains that had to be accommodated. However, with Honda, Ansible Motion decided to press ahead with the Delta S3 system as the benefits appeared to be too great not to.

'By observing what was happening, by looking at how our customers were using the product, and by talking to our customers, we came to the view that there was a benefit

Increasing yaw angle capability from the +/-20 degrees of the S2 system up to +/-90 degrees opens up a whole new world of simulation, and applications



As well as extending the motion space, the S3 can accomodate higher payloads than its predecessor

Increased yaw angles open the simulator up to off-road applications, but also are important for driver immersivity

in extending the lateral motion capability of our Stratiform 2 – or S2 – motion system,' says the company's technical director and founder, Kia Cammaerts.

'The S3 extends the motion space from a metre out to four metres in both the lateral, or sway, direction and the longitudinal, or surge, direction. It also accommodates higher payloads and that opens up the possibility for heavier cabins.

'In the formula arena that's not necessarily an advantage because S2 had plenty of capacity for formula-class vehicles, but in some of the GT and saloon racing categories it is more convenient to have a heavier payload available, and one with more equipment going inside as well.'

The higher payload means up to 500kg cabins can be accomodated, while keeping the high dynamic motion capability, and the Delta S3 can accept even higher weights with slightly reduced motion. For most racecar applications, though, half a tonne is ample for the cabin, measuring equipment and driver installed.

Key developments

One of the key developments of the Delta S3 is the increased yaw angles that not only open the simulator up to off-road applications, but also are important for driver immersivity.

'We initially considered increasing the Stratiform 3 to +/-45 degrees, up from the +/-20 degrees we had available from the S2, but once we got started, we got carried away,' admits Cammaerts. 'We therefore increased S3 to +/-180 degrees and that gives us a number of advantages. +/-45 degrees is quite practical for a lot of highly dynamic driving that is typical of high-end motorsport, but there are some occasions when you would like +/-90 degrees, such as in chicanes for example.'

The S3's 4m lateral run allows more accurate simulation of trail braking, for example, making it particularly relevant to electric racing series where this has become a key element of driving style

Going further to 180 degrees means a driver remains fully immersed in the virtual reality experience for longer as the cueing remains consistent.

'It's extraordinary what you can do with the human mind,' says Cammaerts. 'A skilled driver can operate a simulated vehicle more or less as they would a real vehicle, even though they are operating it inside a driving simulator lab, which is a comparatively tiny motion space.

'Having said that, yaw is one of the key senses that you use to detect vehicle stability, and it would be desirable to more or less provide one-to-one motion cues for yaw if the motion machinery could do it. So that's what we went for with the Stratiform 3.

'The increased yaw capacity of the S3 takes us to service level, real-world yaw excursions, but inside the simulator lab. This one-to-one cueing for yaw, in cooperation with the enhanced sway and surge motions, gives a really good natural dynamic feel all the way through turn in, mid-corner and turn out.

'There are some unexpected benefits as well – for instance, when the driver spins the car. With the Delta S3, the sense of realism is maintained all the way through the spin. Conventionally, you don't bother in simulation with spinning because you are not *meant* to spin, but it does happen, especially in a lab environment where you are pressing hard. But if you spin and then just click reset to go back to where you were and carry on from that point, the immersivity has been broken. And the sense that you are a human in control of a real vehicle in the real world, albeit in the simulator, that's been broken as well. The Delta S3 allows you to spin without punishing you with a forced reset.'

You want the simulator to be useful for explorations into maintaining state of charge in the battery system with very complex strategies

The Delta S3 is particularly relevant to electric racing where trail braking in order to increase a battery's state of charge is a key element to driving style. The longer braking distance over the four-metre lateral run of the simulator is incredibly effective, as Cammaerts explains: 'You have to cue if you have braking activity that's 100m long, and you need 100m of motion system to cue that perfectly. That's never going to be practical inside a lab room. But even with four metres, the improvement is significant.

'Things like trail braking are much easier to control and feel with the Stratiform 3 than in previous generations. The longitudinal cueing is not just simulating braking and acceleration in a maximum attack sense. You want the simulator to be useful for explorations into maintaining state of charge in the battery system with very complex strategies that vary around the track and according to the state of charge of the battery, temperatures and other things.

'These strategies are not plug and play, they require significant interaction from the human driver to develop them.'

Virtual miles

Much of the development work of a car takes place offline but, as on-track testing is often limited, the opportunity to accumulate testing miles in a more versatile simulator is invaluable to a team.

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Now that the ice has been broken, and the value of the technology proven, top-level race teams don't want to be left behind in the never-ending race to try and gain that competitive advantage

From a physical perspective, the new Delta S3 system does not require that much more space than Ansible Motion's previous generation simulators. In an environment where factory floor space is often fought over, the Delta S3 requires merely an extra metre of floor space compared to the previous Delta S2.

Measurable surge

Clearly, the purchase of such a system is not an automatic route to victory. The engineers and drivers have to put in the work to learn the system and marry it to real-world applications, but Ansible Motion has noted a measurable surge in sales of its simulators in recent years across a wide range of clients, including tyre companies.

The pandemic is partly the cause as teams had to find ways of working and developing within their factories. But the increased focus on the environmental impact is a key, with simulators reducing travel, as well as wasted real world development products. There is a third aspect to driver-in-the-loop simulators, though, and that is the return is now more quantifiable than ever.

'I think the ice is broken. You no longer have to be brave to buy a driver-in-the-loop simulator,' says Cammaerts. 'These things aren't cheap. If they are big enough to do the job properly, they represent significant investment of capital and research and human resource. There was a reluctance to be the first, but no one has to be the first now as they are in production use across the world, in all categories

The whole world has understood that driver-in-the-loop is here now and, if you haven't got it, you are falling behind

'We've seen a change from people asking can this work? How does this work? To asking why is yours better than the other ones? The Delta S3 demonstrates that just on the sales figures alone. The whole world has understood that driver-in-the-loop is here now and, if you haven't got it, you are falling behind.'

There is a different mindset related to the pandemic as well, where manufacturers were unsure of how the general public would react to lockdowns. Without travel, there was no need for a new car, for example, which meant the high levels of investment were no longer as readily available for such systems. Yet now, Ansible Motion says it cannot build its simulators quickly enough, suggesting its systems are becoming more attractive to well-funded teams, as well as OEMs.

The pandemic will still be causing restrictions for months to come, but race teams cannot afford to stand still and have to keep working in the most effective way possible. Ansible Motion's Delta S3 offers a powerful tool to do so.

Formula E, Racing for the Future

If you ever wondered how hard it was to get an FIA-supported series off the ground, Sam Smith's book on the birth of Formula E provides a candid insight into the challenges and risks promoters have to take. Regardless of the topic, the opening chapters marvellously illustrate the financial and logistical challenges that face potential series organisers.

It's often very simple to look back on what has become a success story and forget how it all started. The Formula E series came about, as many do, from a chance meeting, this one between Jean Todt, Alejandro Agag (who owned a GP2 team), and Antonio Tajani, an Italian politician. The details of the organising body were sketched out on a napkin, and the ball started to roll.

From there, however, it all started to become expensive, very quickly. The FIA had another promoter ready to start the series, but Agag realised he was the better option. 'I called the FIA again and said, "You guys don't have a promoter now, so I'll do it,"' says Agag in the book. 'But Todt was very tough. I had to put in place a €10 million bank guarantee and, if I didn't make the championship happen, they would keep it.'

Why such a high price tag and what the reasons behind it were are not explained, but with no organisation structure, no calendar and no manufacturers, this alone would put the frighteners on most, but perfectly illustrates the risk the series' promoters took.

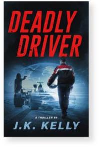
From this beginning, the book then goes on to explain the inner workings of the championship, its successes and failures, and looks at the engineering and technology of the cars. Through all that, it provides a real insight into what it is like to run an FIA World Championship.

The book covers the Spark SRT-01E Gen 1 and Gen 2 racecars, and with Jaguar Racing's technical manager, Phil Charles, looks at the challenges of running an electric single-seat car.

As for the author, *Racecar Engineering* contributor, Sam Smith, has reported on Formula E since the start and is firmly ingrained in the paddock.

● **Published by Evro Publishing**
www.evropublishing.com
Priced at £35.00

Deadly Driver



Author, J K Kelly's fifth thriller, *Deadly Driver* has received enthusiastic reviews from several motor racing champions and book lovers alike. The protagonist, Bryce Winters, is a Formula 1 driver who is being blackmailed by the CIA and forced to act as a spy and hit man.

Racing drivers David Hobbs, Hurley Haywood and Ron Capps are just a few of the big names in racing who have given the title a grin, thumbs up and more.

'Enjoyed it a lot.' 'Hard to put down.' 'Captivating from the start,' are just a few of their comments but clearly this is not written just for racers. BestThrillers.com offered; 'A true original among spy thrillers and a must-read for race fans.'

Explaining the background to the book, Kelly commented, 'I worked in all forms of motorsports for decades. With *Deadly Driver* I took what I knew of auto racing, applied my fast-paced writing style and my love for characters like James Bond, Jason Bourne and Jack Reacher and came up with something truly novel. Pardon the pun.'

Kelly lives near in the United States and wrote for motorsport magazines and served as Darrell Waltrip's public relations director with the Gatorade 88 NASCAR team before spending three decades travelling the world for VP Racing Fuels.

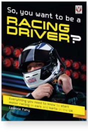
The book is self-published and available in print, digital and audible formats on Amazon globally and wherever thrillers are sold.

● **Published by J K Kelly Consulting**
www.jkkelly.com
Priced at £10 (paperback)

So, you want to be a racing driver?

Focusing on car racing and karting, this book by Leanne Fahy takes the reader through the process of becoming a racing driver, detailing how to gain a race licence to finding the right championship, car and equipment.

So, you want to be a racing driver? also details how to best utilise track time, how to use professional race simulators and how to go about the process of gaining instruction from a professional and joining a grid for your first race.

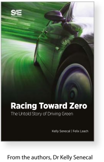


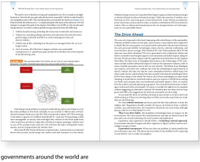
● **Published by Veloce**
www.veloce.co.uk
(available in the USA)
Priced at £14.99

Racing Toward Zero: The Untold Story of Driving Green

Moving toward a more sustainable transportation system is a huge challenge. There aren't easy-to-implement, environmentally-benign, large-scale options readily available, and this book guides the reader through the topics that need better understanding in order to make responsible choices.

The world must move past the idea that pollution is from the tailpipe only and understand that for electric vehicles, manufacturing the batteries and generating the electricity to charge them can produce significant amounts of pollution itself, rivalling a conventional car. This book examines the options for propulsion systems, low carbon fuels and alternative energy sources. Or, as the authors put it, 'Our electric future should be our 'eclectic' future where electric vehicles are just part of the solution.'





From the authors, Dr Kelly Senecal and Dr Felix Leach: 'We've reached a crossroads with transportation. The way we move around today is simply not sustainable, and we must change this as quickly as possible.

'This is why we wrote this book: governments around the world are forcing a switch to battery electric vehicles with reckless abandon, not taking the time to consider if it's truly the best path forward. We applied our passion and our expertise to lay out a better, faster road toward zero.'

● **Published by SAE Internationsl**
www.sae.org
www.racingtowardzero.com
Priced at £29.99

Mr. Le Mans: Tom Kristensen

Between 1997 and 2014, Tom Kristensen won the world's toughest motor race, the Le Mans 24 Hours, a record nine times, and finished on the podium on five more occasions. It is no wonder then that this great Sportscar driver is known as Mr Le Mans to motorsport fans around the world.

Now retired from racing, Kristensen shares in this book his deepest personal reflections and insights from inside and outside the cockpit. He looks back on more than 30 years spent striving for perfection in motor racing and tells of the battles and setbacks that sometimes seemed impossible to overcome, including a terrible accident in 2007.

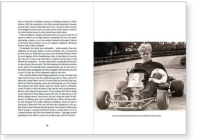
The book covers Kristensen's climb up the racing ladder, including Formula 3, where he won the title in Germany in 1991 and Japan in 1993, then to Formula 3000 and on to Formula 1 in a test role with Tyrrell.

He won Le Mans on his debut in 1997 for Reinhold Joest's team, had a four-lap lead before his BMW suffered mechanical failure in 1999, and went on to win again in 2000, the first of five wins in succession for Audi and Bentley.

His last win at Le Mans came in 2013 in an Audi, but he also made his name at race tracks around the world through his participation in the American Le Mans Series and the World Endurance Championship, both of which he conquered to become champion.

The book makes fascinating reading and won the Royal Automobile Club's Motorsport Book of the Year (below £50) award for 2021.

● **Published by Evro Publishing**
www.evropublishing.com
Priced at £40.00



Motorsport and tuning industries rev up for Autosport International 2022

Autosport International is back after a year's absence, and bookings from exhibitors, trade and fans show there is a pent-up appetite for its return.

The 31st edition of Europe's largest motorsport show will be held at Birmingham, UK's NEC on 13-16 January, alongside the road car-orientated Performance and Tuning Car Show and the trade-only Autosport Engineering Show.

Exhibitors speed to return

More than 200 brands have already committed to exhibiting at the 2022 event, including first-time international entries such as French racecar constructor Funyo, which will be among the many brands and championships choosing Autosport International to unveil their new models for the forthcoming racing season.

With leading motorsport event promoters such as 750 Motor Club, the Roger Albert Clark Rally and TCR UK committed to the show, there will be more than 30 different championships or event organisers helping drivers choose where to compete in 2022.

Many of the biggest brands in tuning, car modification and performance enhancement, including Eibach, Demon Tweeks, Sunoco, Goodridge, VP Racing Fuels and Xtrac will be revealing their latest ranges across the three shows, too.

For those looking to kickstart their motorsport career, there is an impressive array of student opportunities on offer at the event. Universities, colleges and academies will have their own exclusive section of the show, allowing them to discuss educational and development opportunities with prospective students. Degree and postgraduate course advice will be on offer from leading institutions such as the National Motorsport Academy and University of Wolverhampton.

All three shows are open exclusively to the trade on Thursday 13 and Friday 14 January, providing an opportunity to network with thousands of motorsport professionals from around the world, all under one roof. Trade tickets include access to the International Business Lounge, Motorsport Leaders Business Forum and Product Showcase Awards, as well as free access to ASI Connect, the show's official online networking platform.

The Autosport International Show and Performance and Tuning Car Show then throw their doors open wide to fans on Saturday 15 and Sunday 16 January, with star driver appearances, 2022 racecar unveilings and the always spectacular Live Action Arena.

Motorsport, tuning, education or business, you'll find it all on offer at Autosport International

A highlight will be 24 Hours of Le Mans Virtual, a live, televised esports event with $125,000 of prize money to be won.

Ben Whibley, director of events, Motorsport Network, commented: 'The demand from both UK and international exhibitors shows the genuine excitement for the return to face-to-face business events and thrilling live events. All three shows are filling fast, but there's still time to book and be part of Europe's biggest motorsport show.'

Autosport International

Book now to reserve your ticket for the return of Europe's largest motorsport show
https://motorsporttickets.com/en/events/asi

For more information on the trade event and for any exhibitor enquiries, please visit
autosportinternational.com

Inside the world of modern motorsport technology
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DRS dreaming

Has DRS dragged down the art of overtaking?

The 2011 season was fascinating in all walks of motor racing. IndyCar was developing what became the DW12, designed to improve safety and reduce the risk of wheel-to-wheel contact at speed. The ACO and the FIA combined to create the World Endurance Championship and was making plans for a new hybrid era with partners Audi, Peugeot, Porsche and Nissan. McLaren had just moved into NASCAR with its engine management system as the Sprint Cup moved to fuel injection for the first time, while the World Rally Championship mandated contenders should more closely align with production cars and run with direct fuel injection.

Dallara, meanwhile, was working on the development of its new Formula 3 car, the F312, that was to be introduced the following season, while Formula 1 was messing around with blown diffusers, pumping hot exhaust gas into the aero-sensitive area under the rear floor through corners to maintain downforce levels.

Staying in F1, Pirelli took over as sole tyre supplier, bringing multiple compounds designed by regulation to spice up the racing in a controversial move that was perceived by many to be introducing fake racing.

But there was another, even more controversial, change in F1 and that was the introduction of the drag reduction system, DRS, that at the time our columnist, Paul Weighell, described as nothing more than the ability to shoot fish in a barrel.

In short, opening the flap in the rear wing reduces downforce, and allows a following car on track a greater chance of passing, even in turbulent air.

The thirst for action

DRS undoubtedly increased the opportunity for overtaking, and was rolled out across other series similarly struggling to slake spectator thirst for action. Today, however, this rather clumsy device has attracted more criticism than praise.

It is now under discussion that, in the medium term at least, DRS will be eliminated from Formula 1. For me, that indicates by the new 2025 rule set and that day cannot come soon enough. The recent Brazilian Grand Prix was ample demonstration of how DRS is damaging for the sport. Drivers had little defence for the end of the second zone other than excessive weaving, or other equally dubious tactics, at high speed on the straight.

Alternatively, as was also demonstrated, brake too late to make the corner at the end of the straight as there was ample run off and an argument could be won or lost later.

Through the second sector, cars still struggled in dirty air, leaving them needing both DRS zones to make the pass. That meant there was only one real overtaking zone in the whole lap for cars of similar performance.

Actually, there were two, as Sergio Perez showed. The Mexican allowed Lewis Hamilton's Mercedes to pass at the end of the pit straight, and then calmly made his way back past in the second DRS zone. This may have seemed like a great battle, but it was simply seeing the pass coming and getting out of the way, knowing the cards would compulsorily fall back in your favour shortly afterwards.

Opportunity knocks

The prospect of DRS making for the exit is because the forthcoming cars are designed to allow rivals to follow more closely. There will still be the issue of aero sensitivity in the wake to slow the rival in corners, but then be compensated by a tow down the straight, though F1 clearly feels there is a chance the new cars will have the same number of opportunities per lap to pass as now.

> **Going back to steel brakes would be the single biggest contributor to improving the show**

The niggling doubt is, how? Teams have enough resource to out-think the rule makers, so technical solutions will surface, but drivers have grown up in Formula 2 and Formula 3 with the DRS weapon in their arsenal, so will have to unlearn it in favour of old-fashioned race craft.

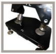
There are other ideas that would aid overtaking. F1 is talking about smaller cars, allowing more space on track and making defence harder. I still think going to steel brakes would be the biggest contributor to improving the show, as longer braking distances would mean outbraking a rival becomes a matter of metres, rather than centimetres.

I don't think that's on the table, even though the extreme heat of the discs and pads is used to improve tyre heating, which would also then be compromised, leaving drivers with less grip out of the pits, or at the start of a race.

As it's nice to end the year on a positive note, one thing I did very much enjoy from this year's F1 season was the extraordinary battle between two rivals that usually comes at the end of a rule set. This is the last year of the current cars and the evenly matched Red Bull and Mercedes have thrown everything at winning, with two fine drivers in the running for the title. They have brought the fire to pretty much every grand prix this season, making this a year that will be remembered for all the right reasons.

ANDREW COTTON Editor

SET UP WHEELS



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