# Simple. Fast. Competitive.

**Rottler's Cylinder Head Machining Equipment** is so advanced that even the most complex operations can be programmed and executed quickly, accurately and reliably. For surfacing, seat and guide installation and cutting and valve refacing procedures, only Rottler has the cutting edge you need to maximize performance and profitability.


Rottler's surfacing machines are the fastest machine for surfacing heads, blocks and manifolds. Designed with the latest CNC technology and proven designs found in Rottler CNC machining centers! Handles the smallest parts to large diesel cylinder heads.


Rottler MANUALMATIC control has revolutionized valve seat cutting! During seat cutting, the operator does not have to operate any buttons, switches or pedals, simply turn the spindle feed handwheel up and down and the MANUALMATIC control takes care of all the functions


Rottler's centerless grinding valve refacing machine is designed to grind a set of valves to equal length from stem/butt end to valve seat. The Rottler Centerless System allows a wide range of valve stem diameters to be ground without changing any collets or chucks.

ROTTLER THE CUTTING EDGE

8029 South 200th Street, Kent, WA 98032 USA+1 253 872 7050

1-800-452-0534 rottlermfg.com

youtube.com/rottlermfg facebook.com/rottlermfg

Leading-Edge Motorsport Technology Since 1990

# Racecar engineering™

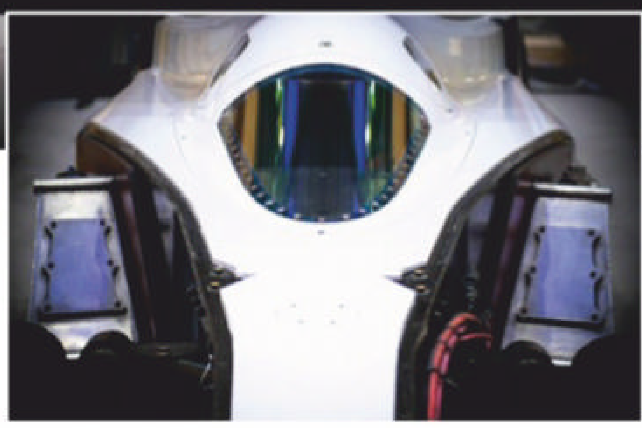
September 2019 • Vol 29 No 9 • www.racecar-engineering.com • UK £5.95 • US $14.50

# Porsche 911 RSR

## The all-new racer that will shake up GTE


## Toro Rosso STR14

How a fresh approach to F1 design has paid off



## Bloodhound returns

Aero guru Ron Ayers on supersonic car stability

## WRC 2022 rules

Is rallying ready for hybrids, spaceframes and SUVs?

# Xtraordinary All-Fluid Filters

**4 DIFFERENT SERIES. . . MODULAR. . .TONS OF OPTIONS**



**71 SERIES -** *Our largest capacity filters. Large 2.47" diameter; Two lengths. Reusable SS elements: 10, 20, 45, 60, 75, 100 or 120 micron; High-pressure core. Choice of AN style or Quick Disconnect end caps. Options include: differential pressure by-pass valve; auxiliary ports for temp probe, pressure regulator, etc.; Outlet caps with differential pressure gauge ports to measure pressure drop.*

**72 SERIES -** *Same large-capacity, 2.47" diameter body as our 71 Series but with a 2-piece body that couples together with a Clamshell Quick Disconnect for quick service. 72 Series uses the same stainless steel elements, mounting hardware and end fittings as 71 Series.*

## 71 SERIES MULTI-STACK - FAILSAFE STAGED FILTRATION

*Multi-Stack adapter sections allow the stacking of two or more 71 Series bodies, long or short, so you can combine a variety of filtration rates or backup elements. Use a coarse micron screen element to filter out large debris upstream, followed by a tighter micron second-stage element to get smaller contaminants. Options include: adapters with take-off ports to facilitate the use of a differential pressure gauge which monitors contamination levels in all stages of the filter assembly.*


**Stack and Stage For Maximum Protection On Race Day**

## SPACE SAVER SERIES - OUR MOST COMPACT FILTERS

**3 Body Styles - 7 Choices of Screens**

*About 1 1/8" diameter, they fit everywhere and they do the job right for so many applications! 2 sets of O-Rings for a variety of racing fluids. Choose from 10, 20, 40, 60, 75, 100, or 120 micron screens suit all needs.*


## INTRODUCING THE NEW 70 SERIES

*Compact 1.97" diameter body features a springless design to maximize filtering area in tight spaces. 70 Series filters are ideal for applications where space and weight are of primary concern. Bodies are available with AN-style end cap sizes -4 through -12, in heavy or lightweight wall versions. 70 Series filter elements come in two varieties: pleated cellulose (10 or 20 micron) or reusable pleated stainless steel wire (10, 20, 45, 60, 75, 100, or 120 micron). Undercut inlet end caps (sizes -4 through -10) offer maximum weight savings and modern look.*

**SPACE SAVER DRY SUMP -** *Same space-saving size, these dry sump filters include a coarse-screen #16 mesh filter that protects your pump in high-volume race applications.*

**70 SERIES Pleated Stainless Steel or Cellulose Elements**


Follow us on Instagram #XRPracing

Like us on Facebook/XRPinc

Go to WWW.XRP.COM for catalog downloads & new products or contact us for 100-page color catalog.

**XRP®**

**THE XTREME IN RACECAR PLUMBING**

UNITED STATES XRP, Inc. sales@xrp.com tel 562 861 4765 fax 562 861 5503
EUROPE & UK Protec Fuel Systems Ltd. info@protecfuelpumps.com tel +44 (0) 121 572 6533

## COVER STORY



## COLUMNS



## FEATURES



## TECHNICAL



## BUSINESS & PEOPLE




DS Techeetah driver Jean Eric Vergne clinched the Formula E championship in New York in July; and he didn't shift gear once. To find out why turn to page 64


HASTINGS
Piston Rings
USA
100 YEARS OF INNOVATION
MADE IN THE USA
MADE FOR THE WORLD
Learn more about
Hastings Piston Rings at
www.hastingspistonrings.com.
ATHENA
ATHENA RACE HEAD GASKETS
KING RACING
HIGH PERFORMANCE BEARINGS
The Science of Speed
2nd place is for the other guy
XP BEARINGS - Tri-metal, Copper-lead
HP BEARINGS - Bi-metal, Silicon Alloy
ACL RACE SERIES
Performance Engine Bearings
Race Series Bearings Provide Exceptional Performance and Outstanding Durability
We Support Revolutions!
ENGINE PARTS (UK) LTD
1987 30 YEARS 2017
Anniversary
Purfleet: 01708 890494
sales@enginepartsuk.net
www.enginepartsuk.net

# Right as rain

There is more than one way to predict the weather before or during a race

Knowing what the weather will do is a big part of race preparation and strategy. Just dry is easy; temperature and track rubbering-up and knowing your compounds and degradation, all fairly predictable.

Full wet, ditto, but with the added problem of aquaplaning, when the water film between rubber and surface can actually lift the rubber from contact reducing your grip level enormously. The antidote to this are sculpted tyres with grooves to channel the water away and maintain rubber contact. These full wet tyres are the most effective solution for heavy rain. The grooves can evacuate 85 litres of water per second per tyre at 300km/h. On an average track that is around 25,000 litres of water per lap, or to put it another way, half the volume of an 2,500,000-litre Olympic swimming pool displaced during a grand prix per car, and we won't even get into the intricacies of intermediates, designed to transition from wet to dry conditions.

Knowing – or more accurately, guessing using data – what the conditions are going to be is part and parcel of strategy, long range forecasting giving you an idea of the possible weather conditions for the race weekend and of which set-up to start on.

Fine grain prediction is not that precise yet, knowing exactly when the rain will start and how much there will be is still in the lap of the gods.

## Just add water

Back in the day there were workarounds. For example, for the BTCC we had observers stationed around the surroundings of the track, all around it, so the call to what tyre to choose on the grid was decided by knowing what the wind-speed was and then the phone-call from the observer upwind to tell you whether it had started to rain. It gave us a win at Silverstone when we started, counter-intuitively, on wets on a dry track, but we had the edge as we knew it was going to bucket down halfway through the first lap.

With single seaters it was a matter of using game strategy, with the cars on jacks on the grid, and observing the opposition in the championship stakes. The best strategy was to run the same choice as your main competitors, on the reasoning that going for the same tyre would minimise the loss if the tyre choice turned out to be wrong, as your main contenders would have to pit, just like you, leaving both even. This used to lead to a game of chicken right up to the five-minute board, to avoid being caught out, waiting for the first one to crack, wings going up and down together with the car having two wets on one side and two drys on the other, so as to only have to change two tyres when the final decision was made.

## Pours for thought

It worked very well most of the time, but at one Spa race it cost us the championship when the driver cracked, despite being briefed on the tactic, when overtaken by a car that wasn't in the running for the championship. We were ahead of the other contenders, but coming in to the pits at Spa, with the longest pitlane of the year, it dropped us behind. Those points sealed the championship positions; we were second, one point behind.

**It's not just driver skill that's tested in a wet race, an engineer's judgement needs to be spot on while luck will also play its part**

Rain also brings out the skill of the driver, as keeping the car balanced with little adhesion highlights the driver's sensibility and has given us the recognised *regenmeisters*. I will just mention Senna's first lap at Donington in 1993 here.

On the pit side the rain has provided some hilarious moments. At Pescarolo we had managed to bring in the French weather service, having a monitor in the pits for rain checking around the circuit, it being notorious for having local rain in parts of the track due to its length. When Peugeot came to Le Mans it took over the radar monitors from us, and the service, factories having precedence over privateers, and to add insult to injury also the first two pits, ours from the year dot and useful in strategy as you could come in full chat till the yellow line then brake straight into the pits, with no pit-limiter nonsense to lose time.

We had the last laugh, though. During the race Peugeot engineers and weather bods were crowding around the equipment trying to see when the rain would come, not noticing the mechanics jumping up and down in front of the pits shouting to call the car in as it was already bucketing down on the pit straight. Never depend too much on equipment lads, use common sense, virtuality is always beaten by real observation.

Another memorable Le Mans vignette was when I was running the Courage 3-litre Nissan-engined C52, backing up the works 3.5-litre R390s. The sight of raindrops on one of the trackside cameras on the pit monitor enabled a quick call to 'pit in' while it was still dry on the pit straight to fit wets, with a very confused driver quizzically asking 'Are you sure?'. But this enabled us to leapfrog the entire field, and most importantly the works R390s, as they had to do a full lap on drys on a wet track, whilst we were on wets. I'm still chuffed about that call.

## Rain of terror

The worst rain incident I recall was at Interlagos, for the Copa Brasil back in the '70s on a steaming hot overcast day when there was an unusual grey, mist-like wall on the opposite straight just at the start of the race. Excited drivers later described their view of the incident: a sudden tropical storm that had every single car running into a zero visibility monsoon that none had recognised until slap-bang into it, and then spinning off both sides of the track, luckily without hitting one another.

It had started raining so hard that tyres in the pits were floating away and we could not see more than a couple of metres ahead of us. We could hear, though, one hesitant engine noise; a Lola 220 Cosworth, the only car that came around, driven by Emerson Fittipaldi, slipping and sliding the waves on slicks. Superlative car control.

Fittipaldi did something similar at Silverstone in the 1975 British Grand Prix, when the entire field went off at Club corner, except Emmo, who had stopped for wet tyres the lap before, and was the only car on the lead lap after the red flag. There is a silver lining in every (rain) cloud.

**We started on wets on a dry track, but we had the edge as we knew it was going to bucket down halfway through the first lap**

# Reverse engineering

Why the return of ground effect, and maybe even fuel stops, is good news for F1

Hurrah! At last, after a very long time, the penny has dropped and today as I sat down to write this column came the happy news that F1 is finally adopting *controlled* ground-effect aerodynamics in its major rules revamp for 2021. Why this should have taken so long is beyond me, considering that flat-bottoms were brought in as a panic measure decades ago. However, time to look forward and for chassis designers and engineers this should be an exciting, if hectic, period ahead.

The opportunity to start with a clean CAD screen (drawing board for Adrian Newey) containing basically the dimensions mandated by the FIA and the fundamental need to accommodate driver, fuel and power unit must be unique in recent times. Concept rather than just endless iteration is surely a fresh and welcome challenge. Unless of course you're the person ultimately responsible for getting it all done on time and within budget.

## Follow closely

Over a period of time the ideas that emerge will coalesce towards the most obviously successful solutions, but for a year or two it should be really interesting technically, may shake up the pecking order a bit albeit short-term, and – most importantly – result in achieving the objective of allowing cars to race in close proximity without so much aero disturbance for the one behind. Now there's rarely such a thing as a silver bullet and the combination of short braking distances and the nature of many of the tracks will still present overtaking issues. Nonetheless, a big step in the right direction.

This welcome change will not be without its problems, of course. Primarily, the matter of finalising the 2020 car designs this year and the development of these through next season while in parallel carrying out the massive amount of R&D, simulation and design of a whole new car. On top of which is the need for commencement of manufacturing to be ready for testing in early 2021.

Not to be overlooked either is the simultaneous move to 18in wheels with low-profile tyres, which one must assume will have a considerable effect overall on suspension geometry and spring/damping concepts, as well as brakes and aero.

The reduced pitch-sensitivity nature of the shaped underbodies should work well together with the reduction in tyre sidewall flex but there are always unknowns (F2 teams, adopting similar wheel diameters a year before, may find themselves being befriended by F1 engineers who would normally shun their part of the paddock).

Then, of course, there is the impact on packaging of the complete powertrain, whether this remains in line with current regulations or becomes something different, plus all the associated cooling hardware. Inevitably all this will work considerably in favour of the better-resourced teams. The possibility of a moratorium on the introduction of new parts after, say, mid-season next year should be considered to try to mitigate this advantage. It's difficult to see how there would be any development relevance to the all-new racecars required for 2021 and this would reduce the burden on the less well-financed outfits. Sometimes it pays to focus on what you've got to maximise every aspect of it rather than getting confused with too many new development blind alleys. A current example could be Haas F1; its erratic performances indicate that maybe it gets lost on set-up and tyre understanding, rather than having a fundamental design problem.

XPB

**Refuelling hasn't been a part of F1 since 2009, but 10 years on and Jean Todt has suggested the possibility of its return to help spice up the show**

## Driving challenge

Drivers will also have to adapt to the different characteristics that these changes will introduce. However, I don't see this as being too much of an issue, though, as top-class drivers by nature should be capable of soon getting to grips with any racing car, as long as it has a decent balance.

There's another reason for optimism about the future of F1, too. FIA President Jean Todt has given me the impression of a dead hand as far as F1 is concerned since he was first elected, being most concerned it seems with safety, on road and track, and having an obsession with motor racing's relevance to automotive industry technology. To the extent, in fact, that I wonder if his political ambitions extend beyond motorsport.

## Filler thriller

With the above in mind, I'm happy to learn that Todt is now actively promoting fuel stops in F1, something which I've often banged on about.

I really fail to see the logic in humping probably 70kg of dead weight around at the race start, in cars which are already gross and when tyre preservation plays such a vital part. Let's get away from drivers having to lap five or six seconds off qualifying pace. While fire is virtually unknown now in crashes it's not impossible for it to happen, so the less fuel onboard the better. Much more relevant is a reduced-size fuel cell which will allow further weight reduction by virtue of a more compact tub. This should assist in providing the space required for the 2021 underbody tunnels. Arguments against, based on potential danger to pit crews and added cost of kit, don't stand up to – look to WEC practice and experience if in doubt.

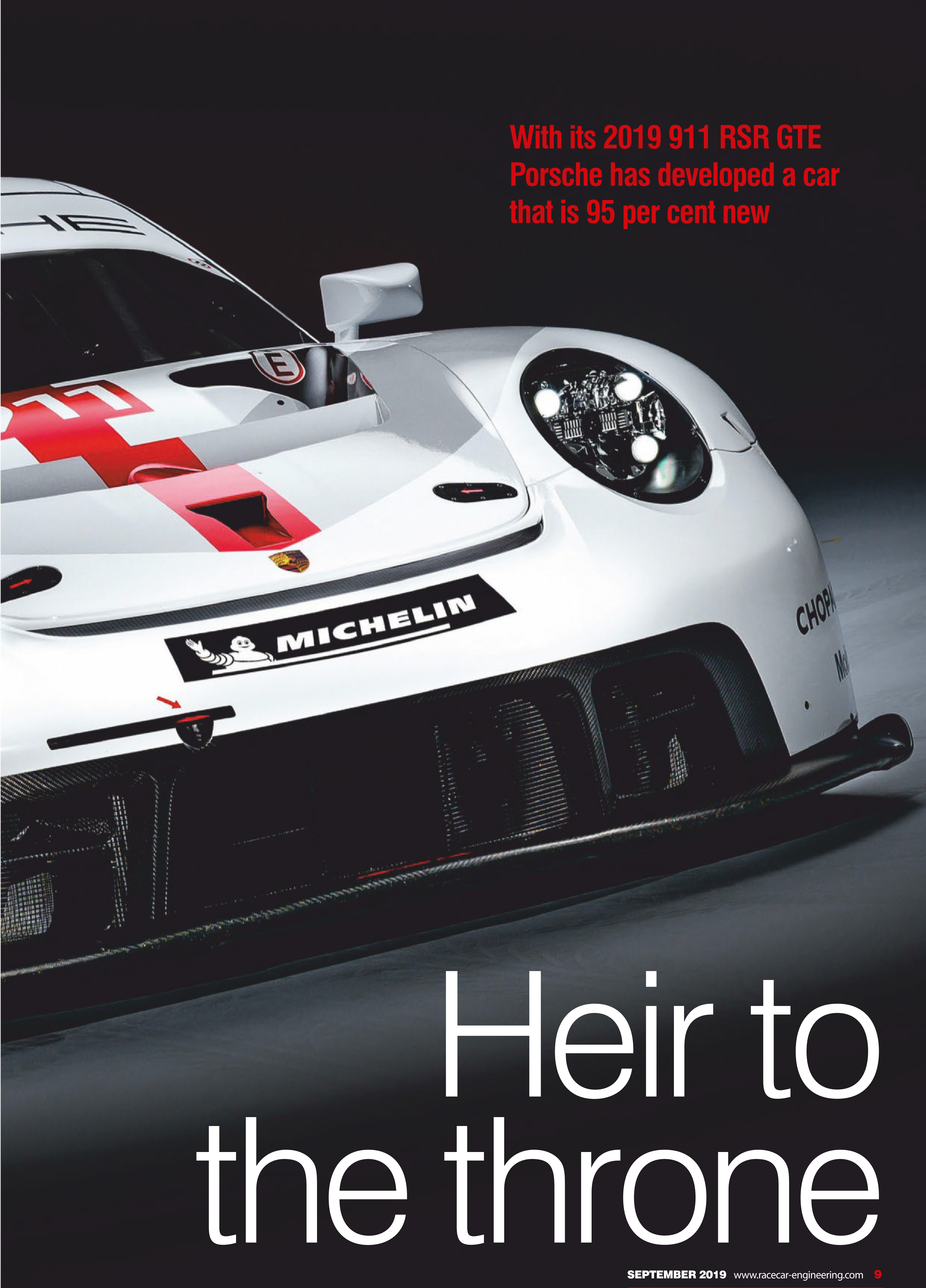
I haven't touched upon engine/PU regulations so far, they look unlikely to change much. All I can say is that current hybrid PUs are highly complex and expensive – so it's no surprise that new manufacturers have failed to join Honda in F1. Given the initial humiliation and the subsequent effort expended by the automotive giant in achieving a competitive level, similarly with Renault, it's even less likely to happen. The only exceptions I can foresee would be Porsche and Audi, because of their LMP1 experience, their relevant resources and their understanding of racing. With so much chassis revolution to handle, maybe a change to less politically-correct and simpler powertrains could be stage two in the revamp of F1. In 2023, after 10 years' return on investment since their instigation?

**The ideas that emerge will coalesce towards the most obviously successful solutions, but for a year or two it should be really interesting technically**


Porsche has designed its new GTE challenger with ease of use in mind

**The new Porsche 911 RSR GTE car will have to go some to equal or beat the record of its predecessor in the WEC, IMSA and at Le Mans, but early indications are that the fabled marque has another winner on its hands with this 991 GT3 RS-based racer**

**By ANDREW COTTON**




**With its 2019 911 RSR GTE Porsche has developed a car that is 95 per cent new**

# Heir to the throne

Porsche used the Goodwood Festival of Speed in July to launch its new Le Mans contender, a racecar which sure does have a lot to live up to. Its predecessor, launched just two years ago, has won the world championship title in both GTE Pro and Am this year and is on course to secure the titles in the IMSA series in the US. It was also victorious at Le Mans in 2018.

Little wonder then that some suggest it is probably good enough to do another year, and they may be right. But Porsche did not want to stand still and in the 2019 version of the 911 RSR GTE it has developed a car that is '95 per cent' new, according to director of GT Factory Motorsport at Porsche, Pascal Zurlinden.

Fundamentally, though, it is still similar to its predecessor, although the team has targeted driveability and reliability as its development focus. To this end it had already completed a 30-hour test and more than 6000km of track running before it was launched. It made its track debut at the WEC pre-season test in Barcelona in July, and will race for the first time at Silverstone for the opening race of the 2019/20 season at the beginning of September. The US debut will be in Daytona in January.

The launch of the new Porsche comes at an interesting time for the category, a time of change and also uncertainty, which has led to both McLaren and Lamborghini pulling the plug on planned GTE programmes. Much of this uncertainty is to do with the regulations, particularly in the top class in the WEC. There was actually a proposal to make the GTE cars the top class, removing their restrictions based around the BoP, but this has been rejected in favour of the new hypercar concept. This has also had a dramatic impact on the GTE class, as hypercars is essentially now the top GT category, as it based on road-going dream cars.

## Class warfare

This has left the GTE category in something of a quandary. Not only is it expensive, factory racing, but it is now not even the top GT class, and so questions at board level are sure to be asked. BMW and Ford have both stopped their GTE programmes in the world championship (although they are continuing in the IMSA series at least until the end of this year and BMW has not signalled an intent to leave the class). Aston Martin has announced that it will support the new hypercar top class with its Valkyrie, which calls into question the future of its Vantage GTE programme, while Ferrari continues to run its GTE programme through its Corsa Clienti division, which is for customers, and is not a full factory effort.

More positively, Corvette is expected to launch its new contender before the end of the year, and we expect to see it racing next season, while Porsche has bitten the bullet and created the car featured here in time for the 2019/20 FIA WEC season. These are strange times for the category that has proven to be the best in manufacturer motorsport for many years, then, and the threat to GTE comes not only from above, with the hypercar, but also from below, with GT3 regulations now becoming more robust, as this enjoys manufacturer interest at some of the biggest races in the world, including the Spa 24 hours where almost half the grid was full factory participation.

## Transatlantic racer

So as things stand Porsche is the only marque committed to the GTE category on both sides of the Atlantic. It will run two cars in the WEC and another two in IMSA, and has had to design its 911s with versatility in mind, catering to the


**The new 911 GTE car completed a 30-hour test at Paul Ricard in June, racking up 6000kms without any technical problems. It will make its race debut at Silverstone in September**

**Porsche has had to design its new 911 with versatility in mind, catering to the many different surfaces on which these cars will need to race**


There has been an improvement in overall downforce, while aero set up should be easier for customer teams

## The car has been developed with more of a GT3 philosophy, with maximum customer involvement in the decision making

many different weather conditions and surfaces on which these cars race.

Overall, the concept of the car is similar to the older version; the same mid-engine layout and normally aspirated flat six, and its weight distribution is also similar. But underneath there has been plenty of change. 'We have made significant progress in the development of our car for the next three-year homologation period, especially in the complex areas of driveability, efficiency, durability and serviceability,' says Pascal Zurlinden, Director of Factory GT Motorsport at Porsche. 'The only components that we have kept unchanged from the predecessor are the headlights, brake system, clutch, driver's seat and parts of the suspension.'

## Customer focus

The key difference, though, is one of approach. This year's car has been developed with more of a GT3 philosophy, with maximum customer involvement in the decision making. While the old car was good enough to win the GTE Am title in the world championship, Porsche still consulted with the, drivers, engineers and the mechanics of its customer teams before finalising the spec of the new car.

This is quite a statement of intent from Porsche as the Am category in the WEC is allowed to run cars that have competed the previous season, and so Porsche clearly has a long-term vision for the category that is not apparently shared by other manufacturers. It is only the WEC that has a category for customers of GTE cars; in the States it is GT3-based cars that form the customer racing class. The customer-focussed philosophy is evident everywhere on the new Porsche GTE; it's all about ease of use, from the cockpit for the drivers, to the wider operating window, making it easier to set up.

'For the electronics we learned a lot from our customers,' Zurlinden says. 'We asked all the customer drivers, and the bronze drivers, and ours [works drivers], so the cockpit layout is brand new. It is all made according to these driver requests. If you take a look at the steering wheel, it is more like an LMP1 steering wheel, because it is easier for customers not to look across the cockpit, so we tried to put as much as we could on the steering wheel.'


Driver-friendly steering wheel is crammed with info

### TECH SPEC: Porsche 911 RSR GTE

**Body**
Weight-optimised bodyshell in aluminium-steel composite design; removable roof hatch; FT3 fuel cell in the front of the car; welded-in roll cage; aerodynamically-optimised and quick-release body components made of CFRP; rear wing with swan neck mounts.

**Engine**
Water-cooled 6-cylinder boxer positioned in front of the rear axle; capacity, 4194cc; stroke 81.5mm; bore 104.5mm; power, 378kW (515bhp) depending of restrictor; 4-valve technology; direct fuel injection; dry sump lubrication; single mass flywheel; power output limitation via restrictor; electronic throttle; side-exit exhaust system.

**Transmission**
Weight-optimised 6-speed sequential constant-mesh gearbox; twin-shaft longitudinal layout with bevel gear; shifting via electronic shift actuator; shift paddles on the steering wheel; magnesium gearbox casing; multi-disc self-locking differential with visco unit; three disc carbon race clutch.

**Suspension**
Front axle: double wishbone; four-way vibration damper with coil spring set-up; anti-roll bars, adjustable by blade position; electro-hydraulic power steering. Rear axle: integrated rear-axle subframe with double wishbone axle; 4-way vibration damper with coil spring set-up; anti-roll bars, adjustable by blade positions; electro-hydraulic power steering; tripod driveshafts.

**Electronics**
Cosworth Central Logger Unit; CFRP multi-functional steering wheel with integrated display; shift paddles and quick release; Collision Avoidance System; controlled alternator in connection with LiFePo4 battery; LED headlights; LED tail-lights plus rain light; illuminated car number and leader light system; electric adjustable wing mirrors with memory function; tyre pressure monitoring system (TPMS); drink system; air conditioning system; membrane switch panel on centre console with fluorescent labelling.

**Brakes**
Two independent brake circuits for front and rear axle, adjustable via balance bar. Front axle: one piece aluminium 6-piston racing calipers with quick release coupling; internally ventilated steel brake discs, 390mm diameter; race brake pads; optimised brake cooling ducts. Rear axle: one piece aluminium 4-piston racing calipers with quick release coupling; internally ventilated steel brake discs, 355mm diameter; race brake pads; optimised brake cooling ducts.

**Wheels and tyres**
Front axle: one piece forged light alloy wheels, 12.5Jx18 offset 25 with centre-lock nut and wheel nuts; Michelin slick 30/68-18. Rear axle: one piece forged light alloy wheels, 13Jx18 offset 37 with centre lock nut and wheel nuts; Michelin slick 31/71-18.

**Dimensions**
Length, 4593mm (without splitter, rear wing, diffuser); width, 2042mm (front axle), 2050mm (rear axle); wheelbase, 2513mm.

**Weight**
Base weight 1245kg.

The driver seat position is fixed, as it was with its predecessor; at the B pillar to increase safety in case of a side-impact. The pedals and dash are still moveable through a spring-loaded system that will accommodate different size drivers. Side impact protection has been increased with the optimised roll cage, and additional impact protection for the drivers' legs.

The car also features the collision avoidance technology that privateers ran at Le Mans for the first time this year. One driver in the Am category described it as a 'game changer', having used it there. This system, developed by Bosch, features a rear camera and indicators to show faster cars coming from behind, and which side they will pass. It is also capable of delivering an audio message into the driver's earpieces, to make the message loud and clear.

## The last 991

Although Porsche has recently launched its 992 road car, this new racecar is still based on the older 991 model as there is not yet a GT3 RS version of the new car, and the racing team does not know when that will be launched. This car will last through a three-year homologation cycle, so we can expect this to be the last of the 991 GTE cars. That said, the chassis construction is completely new and with the covers off the car is noticeably different to its predecessor. 'We took the regulations and looked to see the freedom to improve the packaging,' says Zurlinden. 'When you put the bodywork off, you can see that it is a different chassis.'

**The engine size has increased and at 4.194-litre it is now the largest power unit fitted to a 911**

The first designs of the new car were created in CAD in 2017 and in August 2018 the car started its test programme on the company's own test track at its Weissach test facility. By March 2019 the car was ready for its first endurance test at Paul Ricard, which featured the works teams from the States and Europe, and the cars covered more than 6000km during this 30-hour run without technical difficulties.

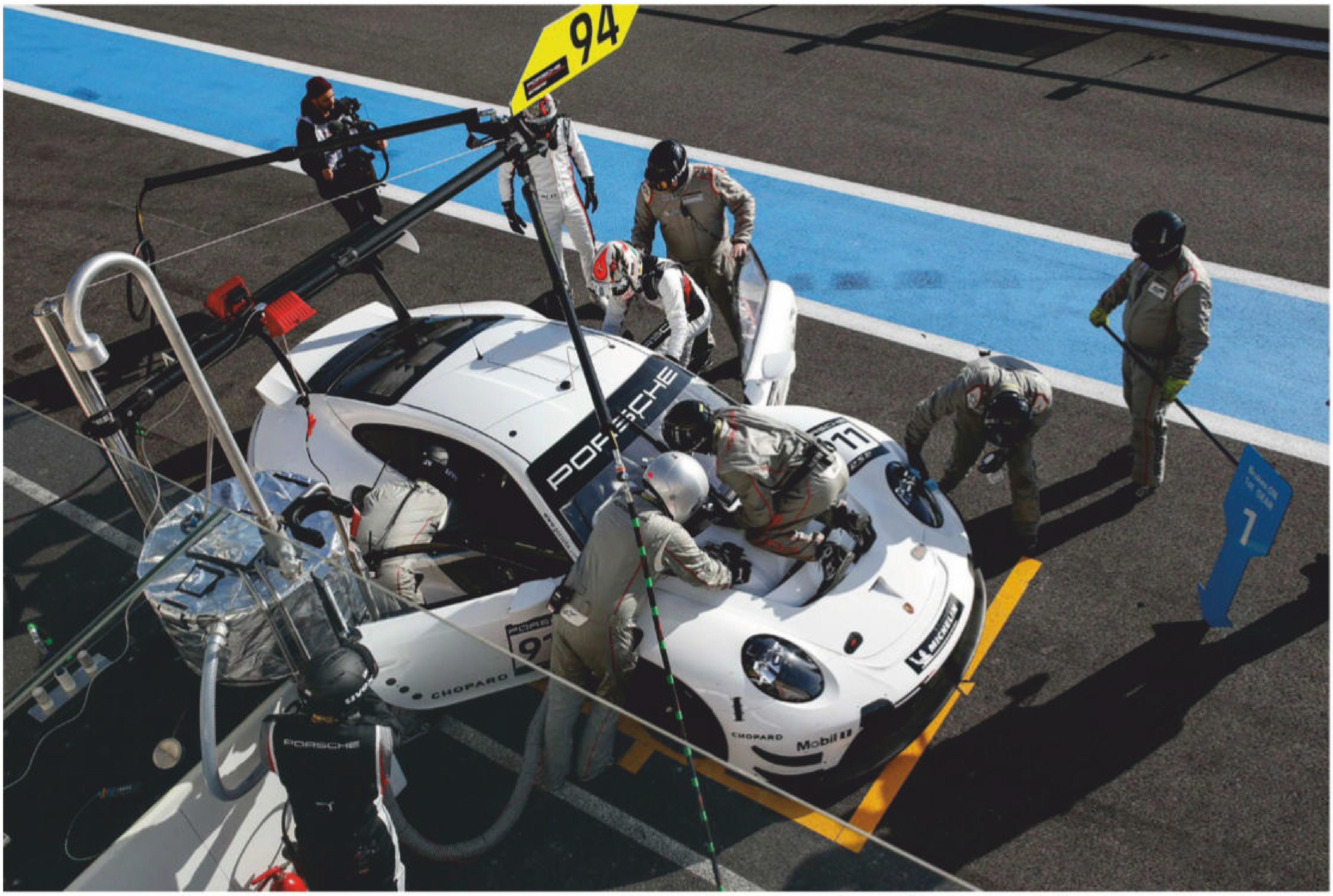
There is still no mid-engine road car, but the new racer retains the layout, with the engine ahead of the gearbox and in front of the rear axle leading to better weight distribution and tyre wear. However, this year's car has side-exhaust pipes, exiting ahead of the rear wheels, which also opens up the possibility of using the exhaust gasses intelligently at the colder races to heat up the tyres. The side exit also reduces the length of the tubes, helps the torque of

The initial designs of Porsche's new GTE were created in CAD in 2017. This car is likely to be the last of the 991 GTE racers

Early testing took place at Porsche's own facility in Weissach. The new car will need to work on a wide variety of race tracks


Side exhausts are a stand-out feature. Porsche says these help boost engine torque while also bringing packaging benefits

## 'We had the feedback from customer teams and from the works teams and 90 per cent of the points that they requested are now in the car'




**The car is expected to be easier on its tyres, which could prove to be a significant factor in longer WEC races now that refuelling and tyre pit stop rules for GTE have been changed**

the engine and offers up more aero freedom, particularly under the rear of the car, which now has space for a more efficient diffuser.

'We took side pipes for two reasons,' explains Zurlinden. 'One is the torque and driveability, and the second is the weight and packaging. The exhaust is as short as possible, and it benefits aero too. The exhaust flow on the side is more adequate aerodynamically than at the rear. It is still the best sounding GTE car [and will remain so as] it is a normally aspirated car.'

## Pit the younger

There has also been aero development at the front of the car, and overall downforce has been improved. All this, coupled with a development programme with tyre supplier Michelin, means that tyre wear should be significantly improved. With the WEC going back to separating out refuelling and tyre changes during the pit stop sequence, this could prove to be a significant advantage in the longer-distance races.

The engine size has increased and at 4.194-litre it is now the largest engine fitted to a 911. This has helped to improve the driveability and the team says that it has also improved the reliability. Fuel consumption is also a little better than the old car, but with the balance of performance system that does not make a big impact on the performance and was not a primary target. That said, in the sprint races in the States fuel consumption can make a difference to the overall race result.

'This is more than an evolution, I would call this a brand new engine,' says Zurlinden. 'The torque curve is more flat, which [makes] the driveability better, this was the target. We see with the customers this was an important point, to make it easier to drive, and this was also the point with the aero, to make it easier to set-up.'

Porsche has also improved the gearbox, which is now lighter and more rigid than its predecessor, while offering drivers faster gearshift times, the company tells us.

The primary focus for the car was to improve the driveability, with a view to competing on the various different race circuits around the world. The US tracks are typically low abrasion, while the WEC typically operates on Grade 1 circuits with higher abrasion and more grip. Porsche struggled on some circuits more than others, and so the team worked on improving the operating window. 'Now it is more predictable,' says Zurlinden. 'Before, you had a sweet spot to find, but this [new car] is really easy to set up. The suspension has changed. It is an evolution of the previous concept and some parts are even the same. We got the feedback from the customer teams, and from the works teams, and 90 per cent of the points that they requested are now in the car. We worked together with customer drivers, teams, mechanics and engineers as well as the works teams. Since we have the GTE car running in customer hands we have learned a lot, also about reliability and how to use things, how people see it, and this is an important step for all of us.'

## Racing ahead

While this might be the last of the 991s, it may also be the last of a generation of GTE cars, depending on what happens to the top class in the WEC and what the manufacturers commit to. There are rumours that Porsche may compete in the hypercar category itself, against Aston Martin and Toyota, but with no final regulations in place no one can plan that far ahead. For now, Porsche is happy to have produced its new Le Mans challenger, and to have places to race it. Now it just hopes it will be as successful as its predecessor.


BBS
MOTORSPORT
BBS Motorsport GmbH
Im Mühlegrün 10
D-77716 Haslach i. K.
Tel.: +49 (0) 78 32 / 96 09 5-0
info@bbs-motorsport-gmbh.com
www.bbs.com
A7/19 www.merzcreativ.com
FORGED


Primary
Designs

# Plan B

**Toro Rosso has once again produced a solid F1 car in the STR14, but it's the Red Bull B team's completely new aero approach and build philosophy that are the really exciting developments at Faenza. Jody Egginton, STR's technical director, talked us though these changes and the racecar that's the result of them**

**By SAM COLLINS**


Formula 1's only official B team was created out of what was once Minardi when Red Bull acquired the Faenza, Italy based outfit. The team that was the result of this, Scuderia Toro Rosso, now exists chiefly to give young drivers an opportunity to prove that they are worthy of a seat in the main Red Bull Racing team, and the title challenging expectations that come with this.

Despite this unique driver-focussed approach the Toro Rosso team has always done things its own way technically, and that was the case even when it was using chassis designed by Red Bull Racing. Yet with its 2019 F1 car the team has in fact taken something of a different direction, in terms of both the aerodynamic development and the car build.

Work on what was to become the STR14 began in the early part of the 2018 Formula 1 season. The team developing the car was split between two main locations, Toro Rosso's main facility in Faenza and also its wind tunnel and technical centre in Bicester, England.

Despite a significant change in the aerodynamic regulations for 2019 the Toro Rosso engineers started the STR14 project by looking at the shortcomings they had already identified with the Honda-powered 2018 car, the STR13, and then they set about resolving them. But to do this the team first looked at why those shortcomings existed in the first place.

'We had a list of things we considered weaknesses with the previous car, from that we worked out what our priorities would need to be to improve the competitiveness of the car,' Toro Rosso technical director Jody Egginton says. 'Last year we brought a couple of updates to the track which didn't deliver everything we expected. Some of the things we learned from this we put into the changes we made for this car in terms of how we develop it aerodynamically. We've had a really big evaluation and thought about a lot of things, we've got quite a young engineering team but the guys have worked hard over the winter. We changed a lot of stuff in the background. One of the big things is that the way we develop the car in the wind tunnel has changed.'

## Wind power

Toro Rosso has its own 50 per cent scale open jet wind tunnel, and this has been undergoing some upgrade work recently. The facility was originally built by Reynard and was later acquired by Jaguar Racing, which later also acquired the former Arrows and British Ministry of Defence tunnel near Bedford. When Red Bull purchased both the Jaguar team and Minardi, the latter was given the Bicester facility to develop its cars. The tunnel is thought to be similar in design to ARC in Indianapolis and the Penske facility in Mooresville, NC, but it has undergone many upgrades since it was built.

## ‘We have to avoid the peaks and troughs in performance that we had with the STR13, especially with the midfield battle so tight this season’

The rear wing on the STR14. Toro Rosso has changed its aerodynamic development methodology this year


The STR14 chassis is all Toro Rosso but there are a number of other parts that have been bought in from sister team Red Bull

‘The wind tunnel hardware development was ongoing anyway ahead of 2019, but we changed some methodologies,’ says Egginton. ‘Without giving too many details away there are a number of metrics you look at when developing the Formula 1 car, for example you might look at the amount of load you have, and that has a set of metrics which quantify whether a new part is working. It lets you see what parts of the aero map are influenced in terms of load and drag. Well we totally revised all of that, asking ourselves how do we want to change the way we look at things in the wind tunnel so that those metrics better reflect what we are seeing on the race track.

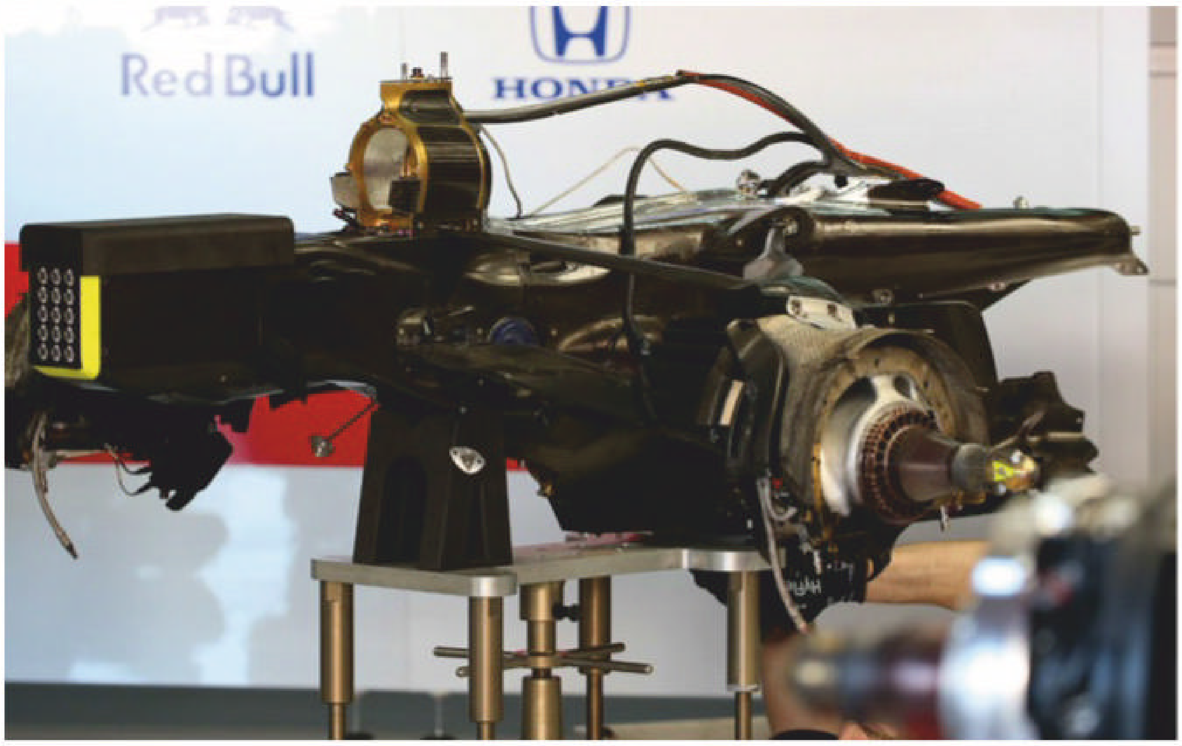
‘We developed a number of new metrics which allow specific areas of the car’s aerodynamic performance to be tracked and evaluated,’ Egginton adds. ‘Doing this has meant that we have lost our direct comparison with last year. That reference was gone because the way you are capturing the numbers is different, and so not directly comparable.

‘Despite this we felt that this approach gave us a better opportunity to develop the car,’ Egginton says. ‘It is specifically effective on certain circuits, so rather than just aiming at just putting more load on the car we would be able to focus on a specific scenario, like low speed and high yaw, for example, and we made a lot of changes in the background to do that.’

## Metric measures

Like every major racing team in the current era Toro Rosso is not solely reliant on its wind tunnel for its aerodynamic testing, and it also utilises a very advanced CFD cluster, as well as full scale track testing, and these areas have both also been influenced by this new development methodology.

‘From the changes we made to how we work in the tunnel, we came up with a new set of metrics on the way we look at CFD, and in turn we can use those metrics to develop certain parts of the aero map,’ Egginton says. ‘Aligned to that, in testing we have done a lot more running of pressure tap rakes on the car and that is feeding back a lot more into the aero development process. This all allows us to identify an issue and then get something on the car to resolve it as opposed to building up a package of parts and introducing them all at once. Doing it this way means that we know where we are the whole time. It’s great if you can bring a big update package, but if it does not work it can be quite challenging to work out what the issue is. This sort of rolling update philosophy avoids that and allows our aerodynamic updates to be better targeted against specific identified needs. The belief is that these changes will have reduced the probability of any updates not delivering what we expect. But, of course, that is the target of




**Red Bull RB14 gearbox was designed for use with a Renault engine, but it also fits the Honda in the STR14**

### TECH SPEC: Toro Rosso STR14

**Chassis**
Moulded composite monocoque.

**Engine**
Honda RA619H (see page 26).

**Transmission**
Red Bull Technologies (2018 specification) composite casing with Xtrac internals; eight forward gears, one reverse; multi-plate carbon fibre clutch.

**Suspension**
Unequal length carbon fibre double wishbone, with pushrod actuated torsion bars (front), pullrod actuated (rear); Inboard front parts and all rear components supplied by Red Bull Technology.

**Brakes**
Carbon-carbon with Brembo calipers to Toro Rosso design.

**Tyres**
Pirelli.

**Weight**
743kg minimum (80kg driver minimum).

every team; you invest a lot of time and money and you want it all to work.'

With the methodology of how the racecar would be developed, adjusted and potentially improved set, attention turned to the design itself, and the previously mentioned shortcomings of the STR13. 'We felt that the operating window of last year's car was not big enough, it was difficult to set up and on occasion it was difficult to drive,' Egginton says. 'With the STR14 we wanted to open the operating window and give the engineers more freedom. We wanted to allow them to set the car up without suffering the negative impact of an aeromap which was perhaps too sensitive or peaky in a high yaw condition, or [of having] a rear ride height characteristic that perhaps meant that you had to run the rear end stiffer than you otherwise might have wanted in a small ride height range.

'So the challenge was to expand all of that, which can cost you performance. We especially wanted to improve low speed performance as well. Then on top of that we had the regulation change so actually on paper all the things we were trying to do, all the changes we were making, were a little bit scary because we were not sure how we would recover the losses from the changes in the front wing, for instance.'

## Aero concerns

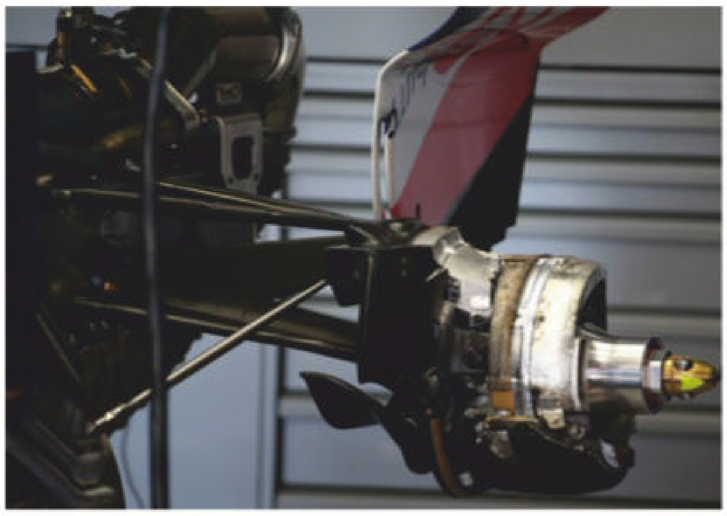
The 2019 aerodynamic regulation changes meant worry for the STR14 designers because a key objective of the car's design was to make it as adaptable as possible. 'We developed the concept of the car to give us as much freedom as possible to develop and add performance without having to make background architectural changes. We have a development path for our car in the wind tunnel, but at any given moment one change can lead to something else and that can lead you down a different avenue,' Egginton says. 'We are not really in a position where we can bring complete update packages to change our direction and that means we have an evolutionary development approach, rather than revolutions.'

## Bull market

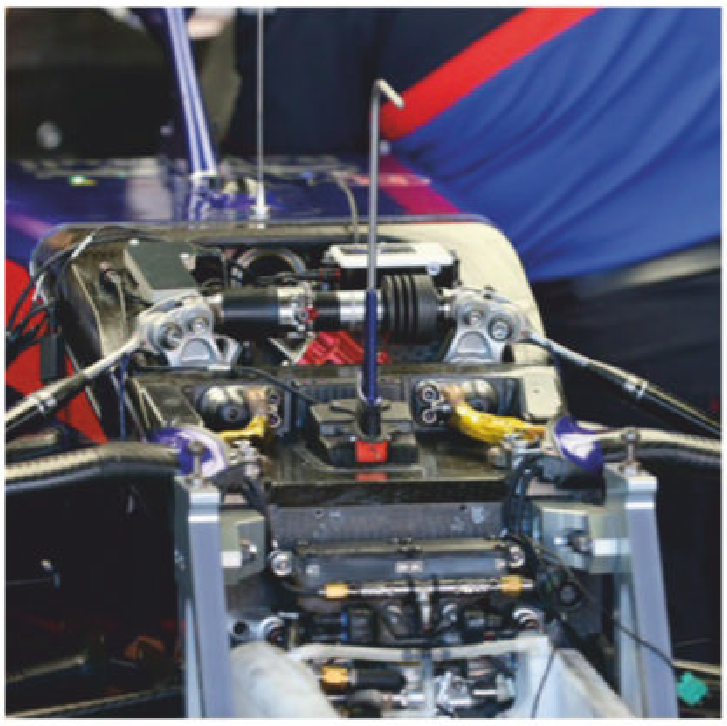
One way that Toro Rosso reduced the level of uncertainty with certain areas of the STR14 design was to revise its model of what is made in house and what is bought in. For many years the team has prided itself on having bespoke transmissions, even when Toro Rosso used Ferrari-engined versions of Adrian Newey's Red Bull Racing chassis it persisted with its own gearboxes. That has all changed in 2019, with many parts of the STR14 being supplied by Red Bull Racing including the gearbox, making the STR14 the first car in many years to come out of the Faenza factory without a bespoke casing.

'The rear end has been provided by Red Bull Technology. We are taking a gearbox casing and rear suspension although many of the internals of the gearbox are similar to parts we have used in the past,' Egginton says. 'It's a bit of a mix of parts, the rear end of the car, the gearbox casing and the main suspension parts are from the Red Bull RB14 [the 2018 car]. The time-scales for using RB15 [the 2019 car] parts were not really compliant with our timetable, our design process and timing is different to them, as is our car build. But the RB14 parts are fine, there is no compromise there, it just made more sense to use them. They are a known quantity.'

Using the Red Bull RB14 gearbox gives the STR14 a composite casing, with internals from Xtrac. However, a key issue with the 2018 'box is that it was designed for use with



**Rear suspension, brakes and uprights all come from the RB14**



**Many RB14 front suspension parts are also used on the STR14**

a Renault power unit, yet the Toro Rosso is Honda-powered. The French and Japanese units have significantly different shapes, with the latter using a split turbocharger layout, with the compressor at the front of the block, while the Renault has a conventional design with compressor and turbine at the rear. This

**'The operating window of last year's car was not big enough, it was difficult to set up and on occasion it was tricky to drive'**

## ‘We thought that maybe we would have to make some modifications, but the gearbox casing just fitted into the STR14 without a problem’

normally has substantial implications for the design of the bellhousing, which has to accommodate some of these parts.

‘That was one of the big factors we had to review, but we quickly realised that there were no packaging compromises,’ Egginton says. ‘We thought maybe we would have to make some modifications, but the gearbox casing just fitted without a problem. Going in the other direction [fitting a gearbox designed for the Honda to a Renault engine] might have been a problem. Had it not fitted we might have done something different, but it did so we decided to just do it. I don’t think we would get that lucky every year. The gearbox we have in the back of our car has done a season already, we just put it in the car and it works. As long as we treat it correctly and operate it in the right environment it is fine.

‘That all meant that we could focus our efforts on other things, and for a team like Toro Rosso that is a big benefit.’ Egginton adds. ‘We can concentrate on improving the car performance rather than fault finding and things like that. But there are other parts of the car, small parts, which also come from the RB15, as it made sense to use those.’

## Rear view

As mentioned, it’s not just the transmission casing that comes from the RB14, most of the rest of the rear end also comes from the 2018 Red Bull too, including the complete rear suspension and uprights. ‘On one level I do miss having that technical freedom at the rear, but when you look at how best to develop your car, then we have got a finite amount of resource, human and financial, and it was actually helpful to do it this way,’ Egginton says. ‘We integrated that rear end into our aero concept and re-deployed the people to other areas. It’s a help in developing the car quicker. So it was not such a nightmare to get that all on the car, you just commit to that model and develop around it. We had a clear view before we committed to the RB14 parts about what ride height range we wanted to be in and the RB14 bits offered us the range of set-ups that we wanted.’

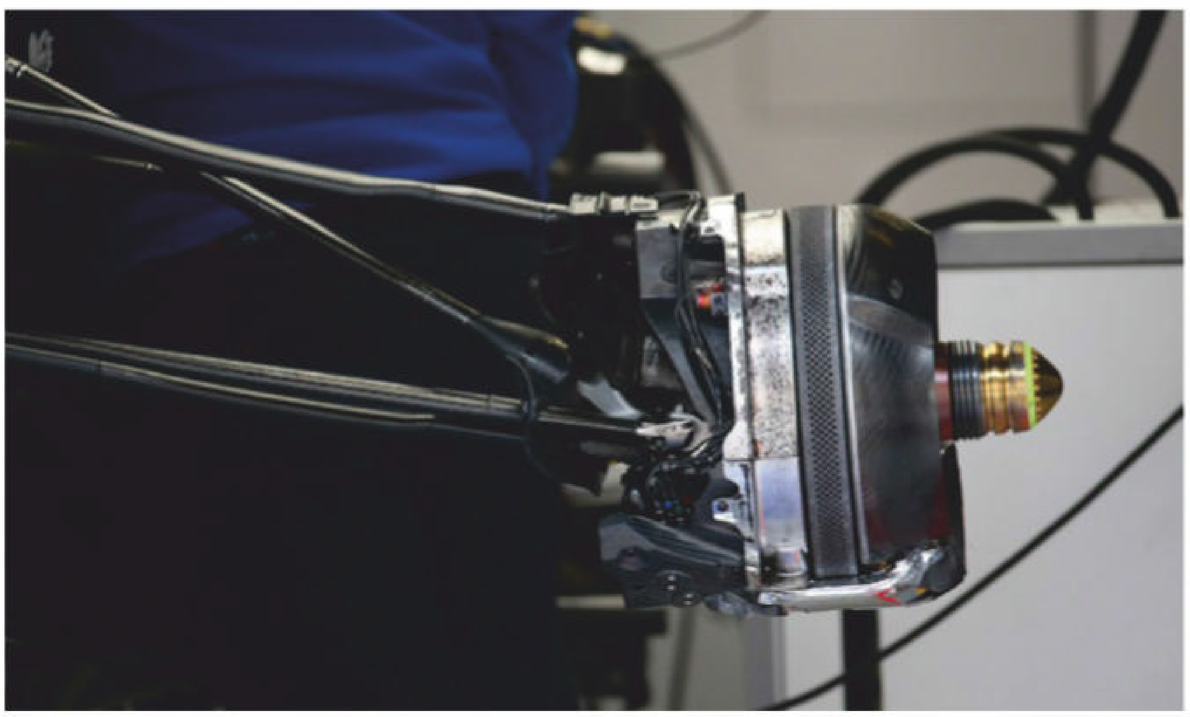
Much of the front suspension also came from the RB14. ‘It is a fairly conventional layout. There is the third element which employs an inerter, there is a heave damper, roll damper and it is a rocker activated system with pushrods,’ Egginton says. ‘It packages well and it is as small as it needs to be, which is one big reason we decided to use it. It fits the chassis and has the operating range we needed. Had it been larger or shaped differently it might have caused issues with our nose and front chassis design and if that were the case we would not have used it. It is a minimal compromise and another job we don’t need to do, giving us more resource to redeploy on other parts of the car.’

The STR14 outboard front suspension is something of a departure from the concept seen on the STR12 and STR13, where the outboard upper wishbone mounting point was positioned on an extension to the upright to try to get an aerodynamic gain. This does not feature on the 2019 car and according to Egginton that is as a result of the changes to the new front wing and brake duct rules. ‘The front wing regulation change drove quite a lot, such as your wishbone position and wishbone twist,’ he says. ‘We were initially intrigued to see how we could recover some of the losses by losing all that furniture on the front wing and end plate. So we spent a lot of time in the wind tunnel looking at the front suspension and the solution we have arrived at worked out to be the best. We looked at some different brake duct concepts. Some of them were quite fundamental changes, but what is on the car is the best we found. For a team like us to redevelop the front suspension is a big job, and you would not do it unless you are sure that it was worthwhile.’

## Gives you wings

A number of front wing concepts are on display in Formula 1 in 2019, and there remains little consensus on what is the best design. ‘Our front wing concept is a little different to that of a lot of the teams,’ Egginton says. ‘It gave some nice gains in the wind tunnel initially so we went with it. We have a more loaded outboard front wing concept than some others, we looked at other solutions but they did not work across the whole aeromap so we focussed on the concept we have now. It is possible that had we


New front wing and end plate regulations have meant that Toro Rosso has had to rethink its wishbone design for this year



The STR14 front brake set-up. Toro Rosso designs its own carbon-carbon system which uses Brembo calipers

got a different front wing in the tunnel earlier the front suspension would have evolved differently. The thing is you have freeze dates, when you have to have defined the inboard pickup points, the outboard points, and after that you just have to work with what you have. Even a few races in and with some front wing and brake duct updates this concept is still providing a return for us so we are quite happy with it. Having said that, we are still looking at other concepts and some of them are better, but maybe not across the whole aeromap.'

## Bully beefed

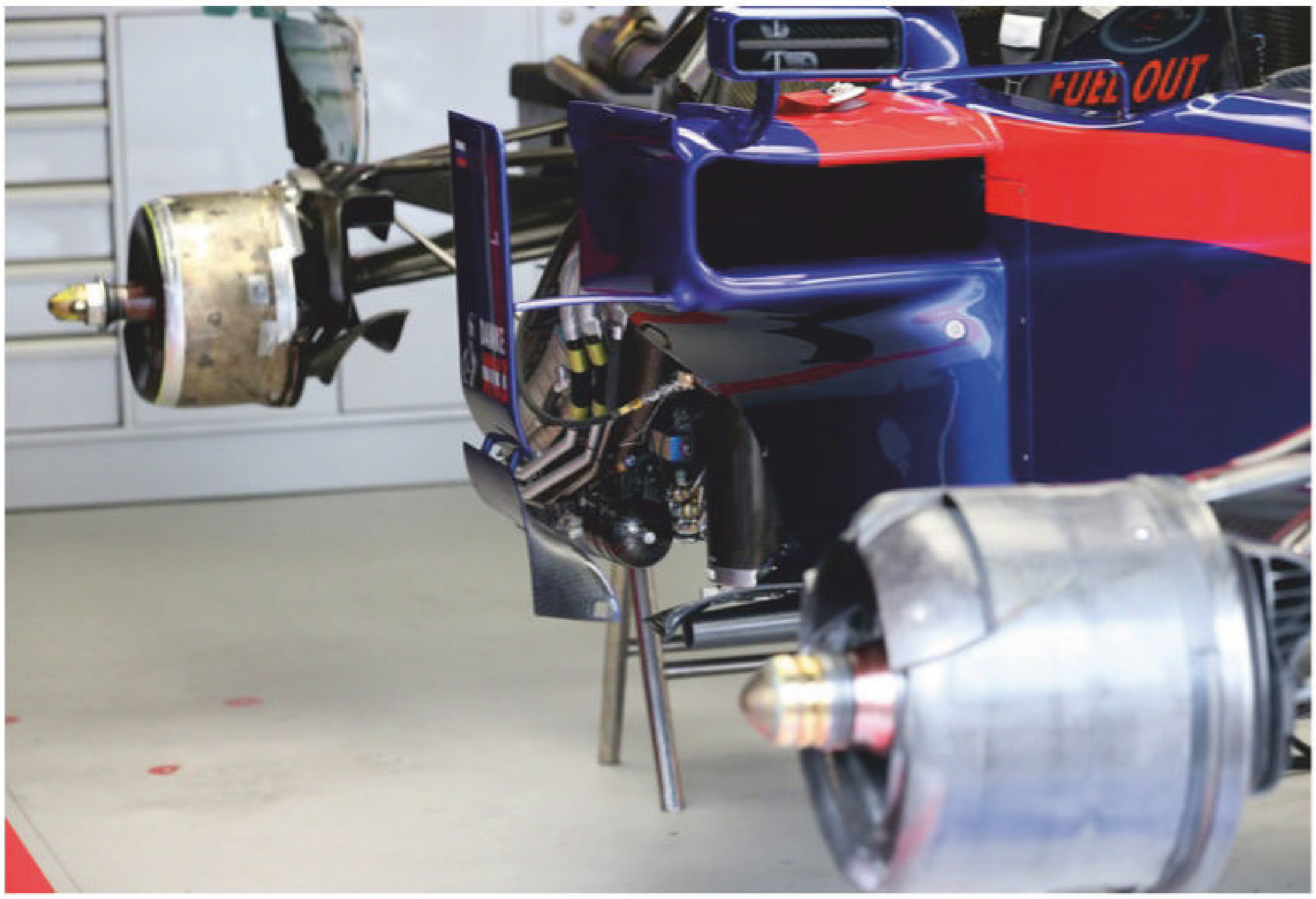
The utilisation of components from Red Bull has seen Toro Rosso move its engineering resource to other parts of the car, such as the outboard front suspension, but the biggest focus of all has gone into the monocoque.

'It all allowed for an increased focus on the design of the chassis structure, packaging of the brake ducts and front suspension, and the integration of the fuel and cooling systems into the chassis,' Egginton says. 'All of this results in packaging and mass reduction benefits and provides the team with more potential for aero development, one of our key aims. The chassis itself, as per regulations, is a complete Toro Rosso design, along with all aspects of the cooling systems, power unit installation and steering column.'

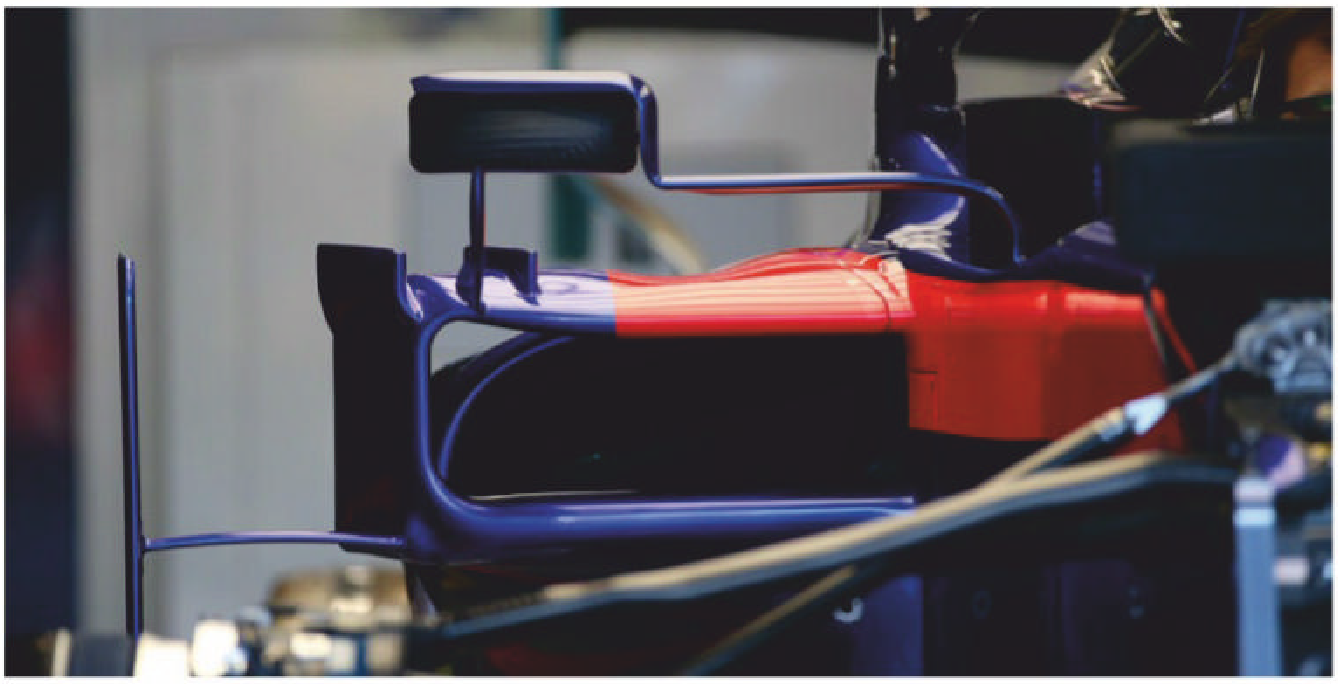
## Hot tub

At the first public run of the STR14 Egginton told the press that the monocoque on the car was the most complex that the team had ever created. 'It is especially complex in terms of integrating it with the power unit,' he added at Monaco. 'It's far more complex than last year's car. Because we had that extra resource, we were able to do more on the chassis and I think that has created a better all-round car. The targets we set ourselves for packaging things like coolers, the plumbing and electrical boxes to get the tightest and most efficient package possible was one aspect of it. You can run in to problems doing that quite easily but the guys avoided that well. Secondly, we wanted to give the aerodynamic team as much freedom as possible while avoiding the need to redesign mid-year. Some of the shapes and structures were changed to give that aero freedom. While the chassis team might have been comfortable in some areas we kept pushing to create potential areas for the aerodynamics to be exploited later in the season.'

According to Egginton, while reducing weight and increasing stiffness remain important, the major goal with the STR14 tub was reduction in its physical size in some areas.




Efficiently cooling the electrical boxes was a key design target for what's been called the most complex STR chassis ever



Toro Rosso still uses small sidpod ducts, with the side impact structure below the main duct. Note the low drag mirror housing

'The gains are really coming from packaging, that was the focus,' he says. 'At the end of the day you want to optimise your cooling package and integrate that into the monocoque, and gains made there give aerodynamic freedom. All the teams are fantastic at optimising mass, and they all have the stiffness targets and that is all overcome. If you can avoid putting a bit of the chassis in an area that you might want to develop then it gives you the freedom to change bodywork, develop aero surfaces, without having to redesign a lot of the car. It's really a packaging exercise as far as I'm concerned. We took a big step with this car and it is worth highlighting that Honda gave us a lot of opportunities with the power unit. We had more time to do that with this car. In the past, that has held us back a bit. While Toro Rosso has become fantastic at getting engines integrated at the last minute it is nice to be able to think about it a bit more, and focus on the detail.'

## Stable relationship

Toro Rosso is indeed well-known for its regular power unit swaps each season, having used units from three of the four manufacturers that are in the sport since the current formula was introduced in 2014. In 2015 it used Renault, in 2016 Ferrari, in 2017 Renault again and then in 2018 it switched to Honda, and all of these were fairly late deals. Now entering the second year of its Honda supply deal the Toro Rosso team has been able to fully optimise its cooling system around the Japanese power unit.

'Historically we have changed engines a lot, and that means dealing with different heat

**'Because we had that extra resource we were able to do more on the chassis and I think that has created a better all-round car'**

## ‘We have seen in the past Formula 1 cars with fantastically small inlets and huge exits, but at the end of the day you need a balanced system’

rejection numbers, installation requirements and different philosophies in general,’ Egginton says. ‘So the second year with a supplier is a huge opportunity for us. In terms of the fundamentals of the architecture of what the engine wants the 2019 Honda is fairly similar to last year, though the heat rejection figures change as they find more power.’

## Cool for CADs

According to Egginton, getting the most out of the cooling layout is not just about the thermal management of various components and systems, but it can also offer notable aerodynamic gains. ‘We are constantly reviewing if there is a more efficient cooler, and looking for cores which might give us more efficient cooling performance,’ he says. ‘Minimising radiator area is critical as you want fewer and smaller holes in your car. On top of that you need to package it in a way that the ducts work well. You could do a brilliant packaging job but if you can’t get enough air mass out the back of the bodywork it’s all for nothing. It’s a huge loop of packaging and aerodynamic optimisation, CFD and rig tests to try to understand how to get the cooling performance you want. On this car it was a big project on every cooler, cooling line, even down to the electrical boxes, as they need cooling too.’

Of course, management of the cooling system on the STR14 came back once again to the aerodynamic development of the car, and it was clearly an area of significant focus for the Toro Rosso engineers. ‘It was, and is, about flow management though the car,’ Egginton says. ‘You need the right amount of air to the right part of the car, and you have to extract it too. We have seen in the past Formula 1 cars with fantastically small inlets but huge exits. At the end of the day you need a balanced system. The aerodynamic department know where and how they want to operate the car, but if you are having to open up the car for cooling it creates a big deficit, so you have to operate on the right part of the cooling curve without the need to open up the bodywork.

‘You have various levels of bodywork, we run the car a lot more open in Monaco than we do at Silverstone, for example, you want to ensure that you can run at the cooling level you want at the different events,’ Egginton adds. ‘If you see a car running massively open bodywork in winter testing then you know something has gone wrong, so we want to avoid that. If you get it right there is a mass saving to be had too. With STR14 it was a massive challenge and we have learnt a lot, but we now need to move to the next step as there are probably other teams a bit further on than we are.’

## Out on track

The STR14 took to the track for the first time in a short shakedown run in Italy ahead of the main pre-season tests in Barcelona. Notably this was also the very first time one of the team’s drivers, Alexander Albon, had ever driven a Formula 1 car. As the season has progressed the car has shown strong pace and the team is largely pleased with the STR14, if perhaps not the number of points it has scored so far.

‘The general behaviour of STR14 versus the STR13 is quite different, the drivers are commenting a lot on the way this car is working and reacting,’ Egginton says. ‘I think it’s operating window has increased, you have more options to set the thing up and that makes it easier for the drivers. It is easier to get the car into the operating window and keep it there. We have to avoid the peaks and troughs in performance we had with the STR13, especially with the midfield battle so tight this year. With this car we can get the performance out of it everywhere, and that is the biggest achievement. We had quite a lot of targets to hit with this car, mass targets, stiffness targets, and getting maximum freedom on the rear. The team ticked every box and I’m really proud of what they did.’

## Eighth wonder

At the time of writing Toro Rosso was joint-eighth in the constructors’ standings, just seven points behind sixth placed Alfa Romeo (sixth is STR’s best result, in 2008), while Egginton is now already working on improvements for its 2020 successor. ‘We have a long list of things about the car we want to make better but I’m not going to reveal what those are,’ he says. ‘With every car there are things where you think that you could do better, but on this car there is one thing we really do need to improve, and it’s a pretty minor thing, unless you are the driver, and that is the drinks system!’

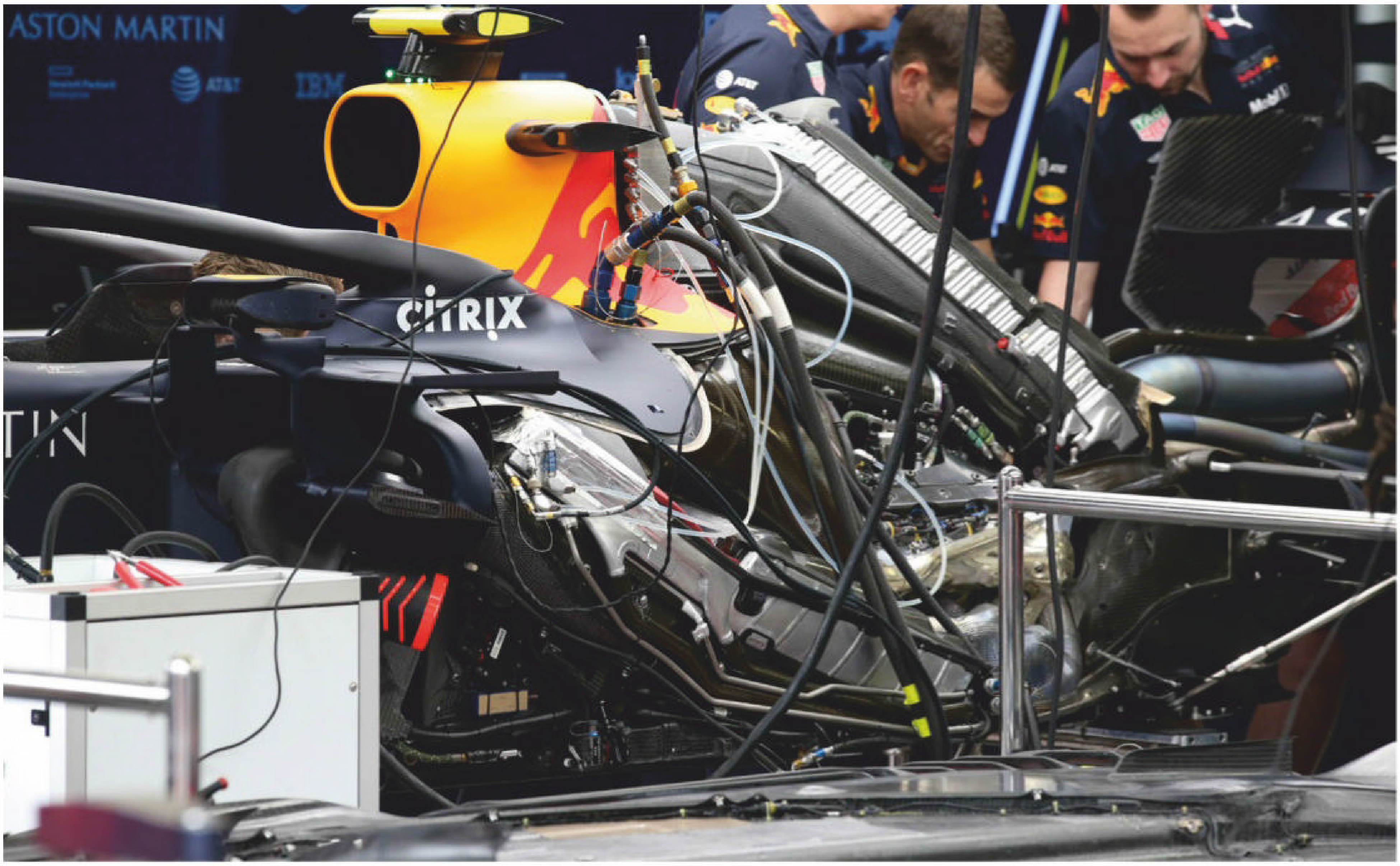

**The STR14 has proven to be a decent midfield runner and at the time of writing it was in joint-eighth in the constructors’ standings, with the team hoping for sixth by season’s end**

# The power and the glory


Honda is supplying both Red Bull and Toro Rosso with its RA619H this season. The RB15's win at the Austrian GP was the first since 2006 for the Japanese firm

**Honda finally ended its 13-year wait for another grand prix victory in Austria at the end of June, but just what did it take to transform the firm's power unit from what was an unreliable also-ran just two years ago into an F1 winner in 2019? *Racecar* traces the development of the RA619H to find out**

**By SAM COLLINS**




The RA619H installed in the Red Bull RB15. Honda says that improvements in the combustion chamber, as well as friction reduction, have contributed to the PU's better performance

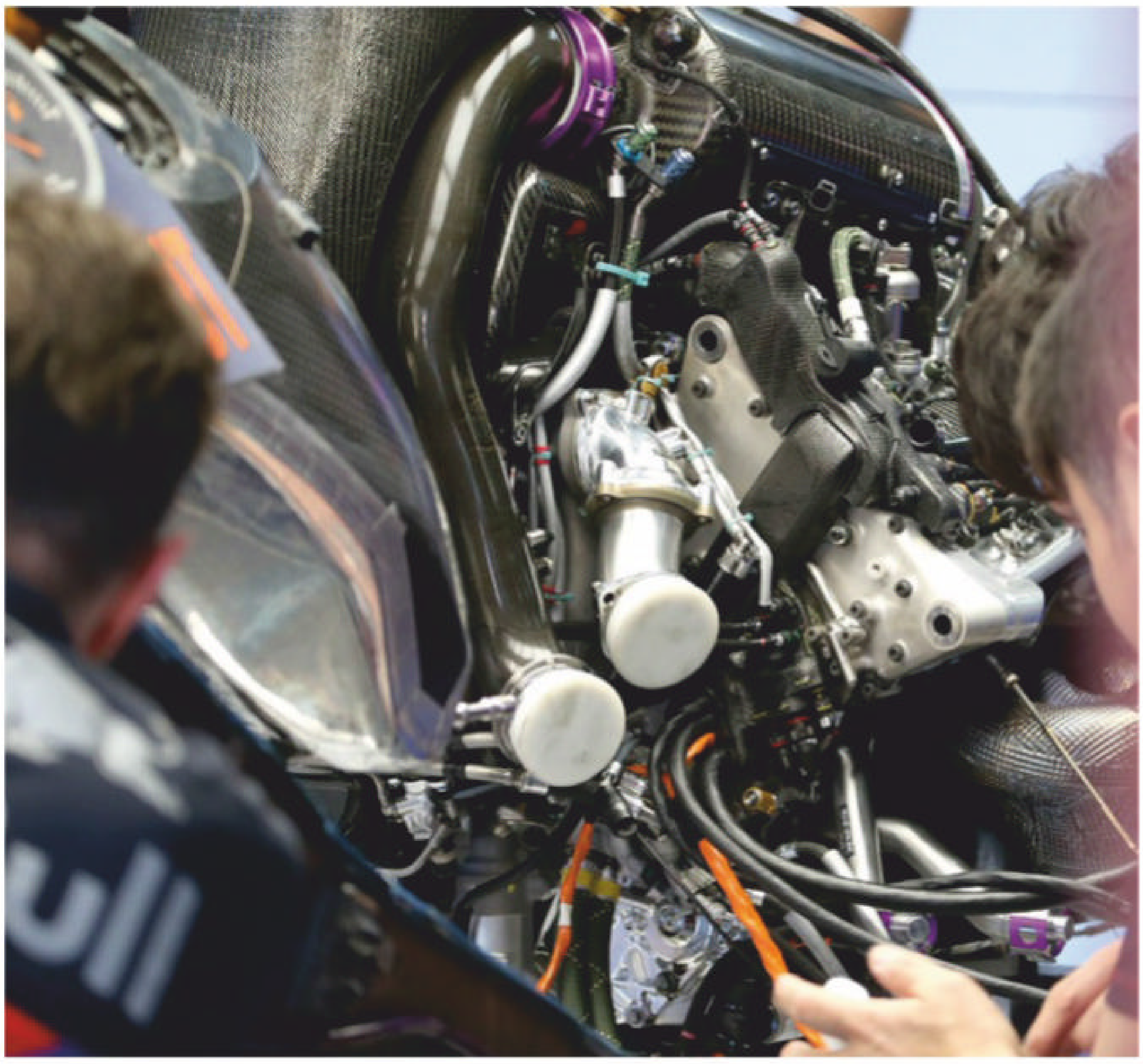
When the flag fell at the end of this year's Austrian Grand Prix a celebration broke out in a modern complex of buildings not far from Utsonomiya, in Tochigi Prefecture, Japan. This is the home of Honda Racing Development Sakura, the organisation responsible for designing and building the Formula 1 power units used by both Red Bull Racing and Toro Rosso. The celebration was for the first win for a Honda powered car in F1 since the 2006 Hungarian Grand Prix.

Just a couple of seasons ago the idea of a Honda-powered Formula 1 car winning a grand prix seemed inconceivable, as the Japanese manufacturer had struggled to get both performance and reliability from its power unit when fitted in the back of three different McLaren designs. A short notice switch for 2018 to supplying Toro Rosso coincided with a concept change for Honda, and this is now beginning to bear fruit in the back of the Red Bull RB15 – for which it has also started to supply power units this year – and, to a lesser extent, the Toro Rosso STR14 (see page 18).

## Lean machine

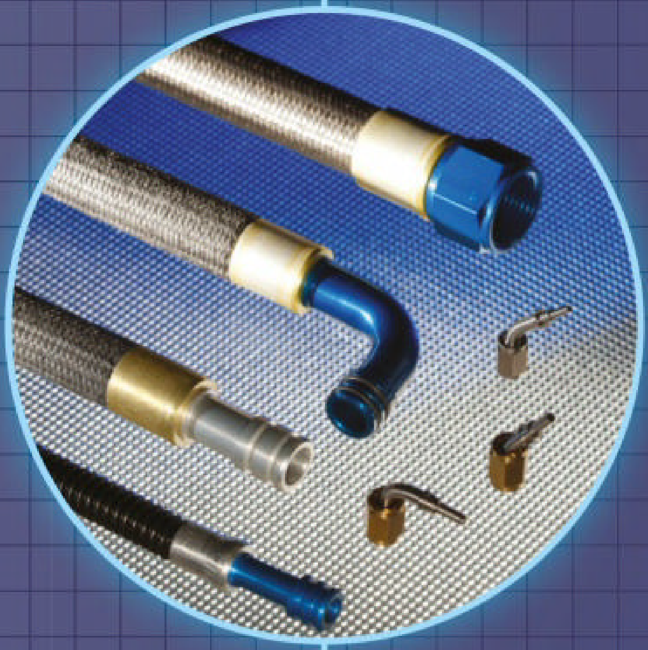
The Honda RA619H is, on paper, a typical Formula 1 power unit. At its core is a turbocharged 1600cc V6 engine with a 90-degree bank angle, variable inlets and direct injection. It is mated to a hybrid system featuring exhaust gas recovery and kinetic energy recovery systems, the former also working as an

**Just a couple of seasons ago the idea of a Honda-powered Formula 1 car actually winning a grand prix seemed inconceivable**



RA619H is an evolution of last year's PU and the block and heads are similar to those used on the RA618H

# INTELLIGENCE CONNECTED



**Flexible Hose and Fittings**

**Rigid Lines and Swagetite**


**Filtration**

It's not by accident that, over the years, we have developed many successful partnerships with customers throughout motorsport – particularly in F1, endurance racing and WRC.

By applying intelligent analysis of their problems in the area of fluid transfer in high performance, high energy situations, we have established ourselves capable of providing innovative and cost-effective solutions.

## SERVICES:

- 3D cad design service
- hose assembly
- hard-line manufacture
- cnc machining
- filtration design
- laser marking

## PRODUCTS:

- **Titeflex smoothbore and convoluted hose products and fittings**
- **Swagetite fittings and hard-line system solutions**
- **Pall Filtration systems**
- **CIRCOR Industria solenoid valves**

FHS
MOTOR RACING

INTELLIGENT CONNECTIONS

Maintain system integrity, save weight, cut costs.
**Make the connection now.**

To find out how the quality of your own fluid transfer requirements can be improved, call our Technical Sales Team on

**+44 (0) 1753 513080**

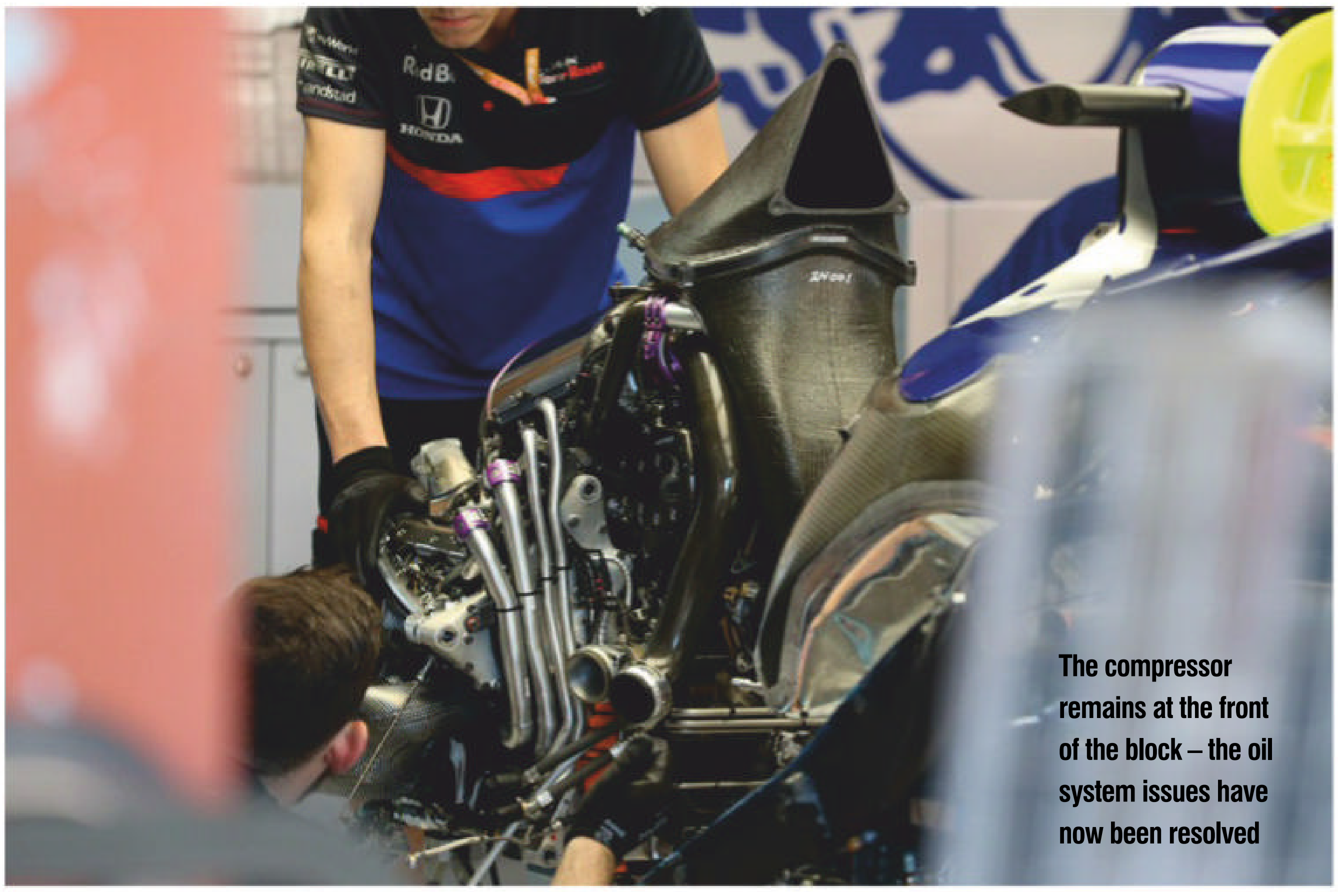
FHS Motor Racing Ltd | 656 Ajax Avenue | Slough, Berkshire | SL1 4BG UK Tel: +44 (0)1753 513080
Fax: +44 (0)1753 513099 Email: info@fhsracing.co.uk Web: www.fhsracing.co.uk

## The work started in 2017 when Honda tried to increase efficiency by raising the compression ratio and running a leaner mixture

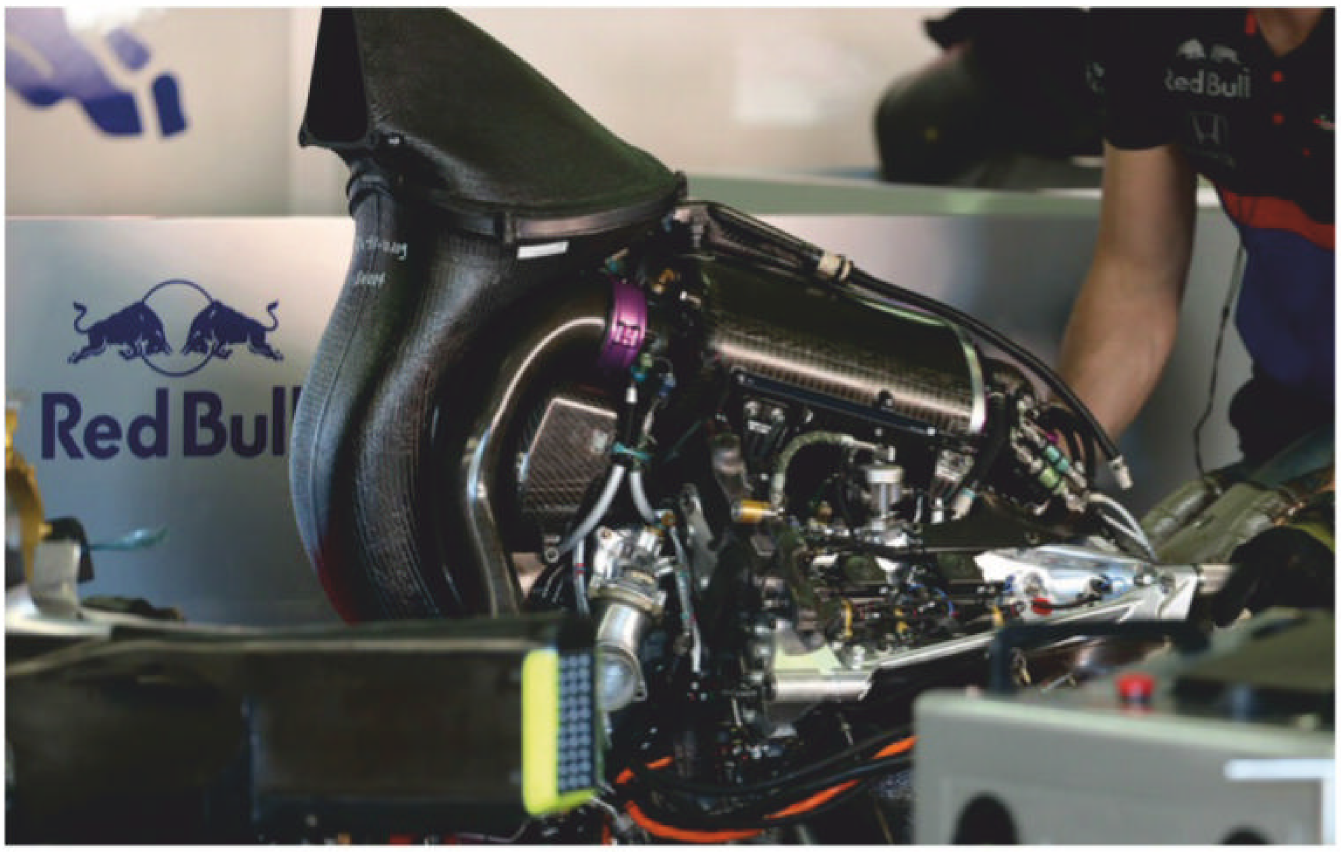
anti lag system. The regulations force all current power units to meet this description, but there is still scope for innovation in the power unit, and in a fuel flow restricted formula this is mostly focussed on the combustion chamber.

This work actually started in 2017 when Honda tried to increase efficiency by raising the compression ratio and running a leaner mixture. To do this it had to change a major element of the design, and this had unintended consequences. All of the previous Honda power units mounted the compressor at the front end of the block but entirely between the cylinder heads. It sat on a common shaft with the MGU-H and the turbine mounted at the rear of the block. To increase the compression ratio Honda felt that it needed to increase the size of the turbine, so on the RA617H it did exactly that, which had the additional benefit of allowing the MGU-H and turbine to be lowered, which resulted in a significant lowering of the centre of gravity. It also freed up some space for the variable inlet system to take a slightly more optimal shape, improving performance.

However, this relocation of the compressor meant that an irregular shaped oil tank had to be used and this resulted in reliability issues for the unit throughout 2017. Honda solved these problems, but it was too late for McLaren, which opted to part ways with the Japanese company and use Renault power instead.



The compressor remains at the front of the block – the oil system issues have now been resolved




The plenum shape has changed from how it was on the 2018 power unit. This is possibly due to a new variable inlet system

## Chamber made

Late in 2017 Honda introduced a pre-chamber ignition system to the RA617H to prepare for the 2018 season. The power unit development continued iteratively from that point throughout the 2018 season and on into 2019 and the new RA619H power unit. 'The name of the power unit is new but we have kept the same concept, but have developed it to improve both performance and reliability, that was the main target and goal, improving durability and performance,' says Toyoharu Tanabe, technical director Honda F1. 'It is hard to put an exact percentage number on how much has changed. While we have not made any big changes we have made many tiny steps right across the unit. So yes you could say that most of the design has carried over from the RA618H, the block and head castings are really the same. In terms of the weight of the unit it is the same too, but the weight has been made differently, so we have added weight in some areas to improve reliability, but in other areas we have saved weight, so adding in some areas losing in others.'

## 'While we have not made any big changes we have made many tiny steps right across the unit'

Visually, however, it is clear to see that the plenum is an area that has been modified for 2019, like the RA617H (and RA618H) it is split into two independent sides, one for each bank of the engine but the shape has changed. This is thought to be due to a new variable inlet system, but Honda will not confirm this. 'That part of the unit has been improved a fair bit, the execution is quite different but the overall concept is pretty much the same,' Tanabe says. 'The shape is a bit different, but its not a drastic change. I should say that in terms of improving the performance we did not just focus on combustion, we also looked at other areas of the unit, however it is fair to say that the most direct area where performance has been improved is of course in the combustion chamber, but the difference is not night and day, it is again many small things. Friction reduction is also an area we have worked on.'

A major change for Honda is that it is supplying two teams in 2019, for the first time since Super Aguri collapsed early in the 2008 season, when Honda was in F1 with its own works team. While Red Bull Racing and Toro Rosso share the same owner and many

## ‘Having the two teams to supply, with both Red Bull and Toro Rosso, definitely appears to have accelerated our development’

mechanical parts, the racecars and the teams are different to one another. But, notably, both designs have similar cooling layouts with a large heat exchanger on the centreline of the car.

‘Information which can flow between the teams has been of considerable use and it’s always interesting to see how someone else uses the power unit, even if they don’t give you the details,’ Red Bull Racing’s chief engineer Paul Monaghan says. ‘It’s also nice that Honda is prepared to look at the engine in terms of its layout and design, and try to improve things for our chassis installation. Generally, the interaction is better this year, so I quite happily give up the sort of familiarity that comes with continuity to have this change … When you change supplier you lose your continuity from the previous five years to run the engine, and you lose the familiarity of the operational aspects, the installation aspects; but equally it’s nice to have a different set of challenges.’

According to Tanabe the biggest difference between the two teams is not actually the installation of the power units, but rather how the drivers use them. ‘We can get double data compared to the one team with two teams, and then there are some differences in the team philosophies, or ways of working,’ he says. ‘Having two teams to supply appears to accelerate our development definitely, the differences to the installation are not enough to really impact our development. That said, you have four drivers with different characteristics, you do see a slight difference between them, the way they apply the throttle, the downshift timing, things like that. So we have to do some software things, in terms of engine braking or the torque map, we adjust those to each driver, generally speaking.’

## Vee for victory

Honda is already looking to the future and the development of the RA620H power unit and beyond. With only minor changes to the power unit regulations expected in 2021, it seems that the manufacturer’s iterative development will continue. ‘We are still in the position of catching up to the top PU manufacturers, in terms of power and also reliability,’ Tanabe says. ‘We are still developing for both as we know our position is a little bit down from these top competitors. We have started this season with a reasonable performance and reasonable results. But reasonable means not yet fantastic, so we really need to push to improve our performance, we’ll keep pushing.’

At the start of 2019 Toro Rosso team principal Franz Tost predicted that the Red Bull RB15 would win races during the season. He was proven right in Austria, and it seems unlikely that Honda and Red Bull will have to wait for another 13 years before the next win. In fact, the next step for Honda is to get to the stage where it can compete with Mercedes and Ferrari for world championships.

### TECH SPEC: Honda RA619H

**Combustion engine**
6-cylinder in 90-degree vee configuration; aluminium alloy block and heads; overhead cam; pneumatically actuated valves; variable inlet; direct injection.

**Turbocharger**
Single, split on common shaft with MGU-H.

**Capacity**
1600cc maximum.

**Speed**
15,000rpm maximum.

**Valves**
24.

**Bore**
80mm.

**Compression ratio**
18:1 maximum.

**Hybrid system**
MGU-H: 7kg; max speed 50,000rpm; max torque 200Nm; max power 120kW. MGU-K: 4kg; max speed 125,000rpm.

**Energy store**
Located in monocoque under fuel cell.

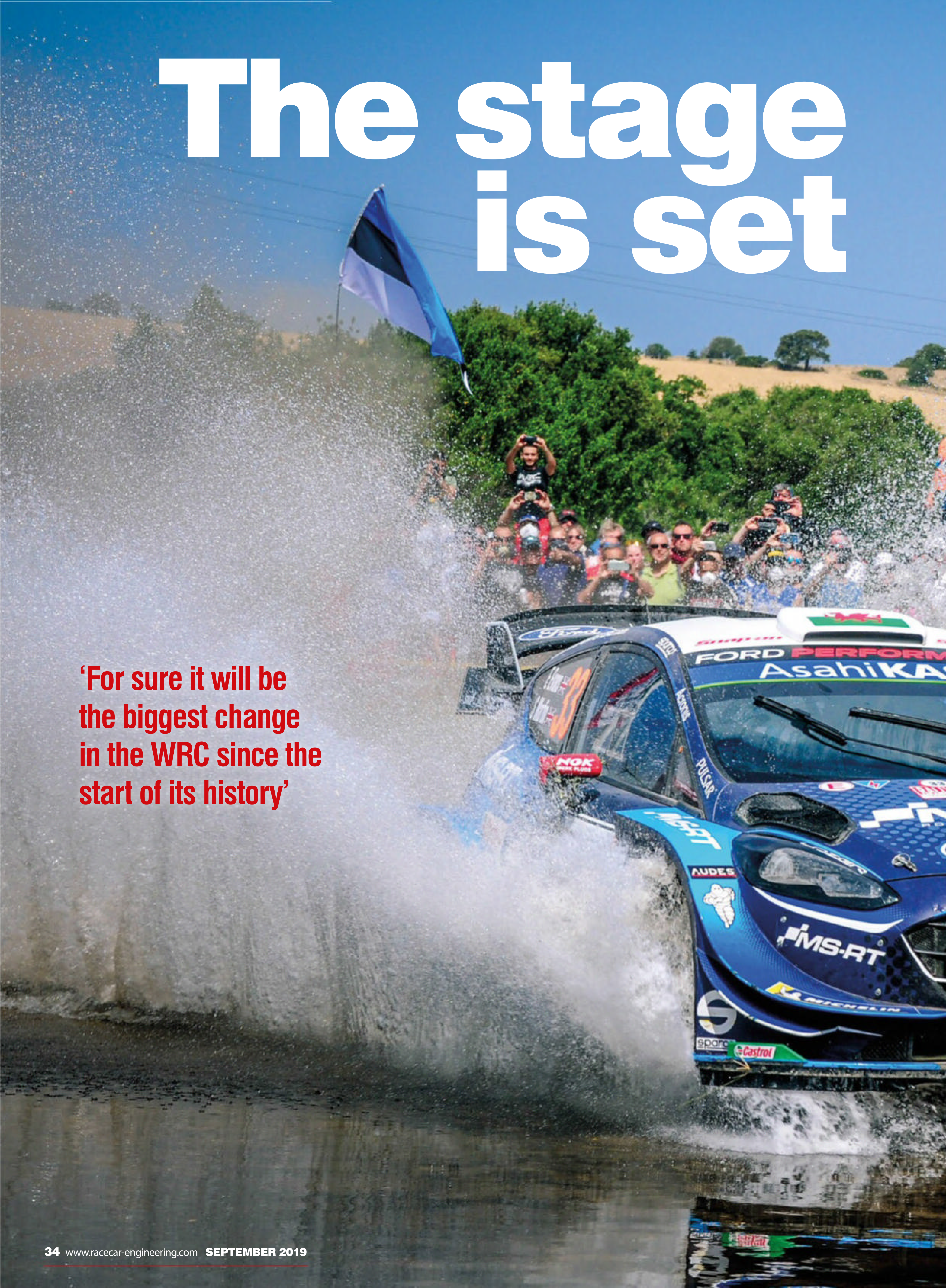
**Weight**
145kg minimum for complete power unit.

The Red Bull and Honda partnership has already proven to be a potent one and the team has been pleased with the way its PU supplier has helped it with chassis installation matters


ENGINEERING THE ADVANTAGE
THROUGH QUALITY DESIGN
Our innovative design and precision performance engineering makes us your perfect partner. Our world-class engineers are committed to delivering world class services where your exacting requirements will be mirrored by our exacting standards.
Contact us to see how we can engineer your competitive advantage.
T. +44 (0) 1480 474402
sales@titan.uk.net
www.titan.uk.net
TITAN
Dynamic Engineering


THERMA
MOTORSPORT
Temperature
is our Business.
The sophisticated Specialist in
Thermo Sensor Technology for Motorsports.
Sensors for tyre and braking systems
Sensors for exhaust gas systems
Sensors for fluids
Display devices and transmitters
Thermocouples Accessories
Individual solutions
You need a special solution or a individual adjustment of our standard products? Simply contact us.
Therma Thermofühler GmbH . Schreinerweg 8 . 51789 Lindlar . Germany . Tel.: +49 2266 8026 . www.therma-motorsport.de

# The stage is set



‘For sure it will be the biggest change in the WRC since the start of its history’

**It's to be all change for World Rallying in 2022 with hybrids, a spaceframe chassis option, plus the possibility of fielding cars from very different market segments. *Racecar* canvassed the opinion of the existing manufacturer teams on the WRC's bold new technical direction**

**By MARTIN SHARP**


A radical WRC revolution from 2022 onwards was voted-in by the FIA World Motor Sport Council in June. And in this particular case the word 'revolution' is very much justified, as what's being proposed will mean big changes for the World Rally Championship.

The new generation of WRC car will have a five-year homologation cycle, while another crucial change is that manufacturer teams will be allowed to use production-based bodyshells or prototype tubular structures to existing WRC body size dimensions.

Also approved is the option to scale the body within prescribed limits, thereby allowing 'larger' car models to compete while complying with WRC dimensions. This new rule will enable car makers to choose the model on which their World Rally Car is based from a wider choice of car segments, not just the B segment as it is now. The FIA will also define visual elements from production vehicles in an effort to make WRC cars resemble their road-going counterparts.

But the real headline-grabbing announcement is that for the first three years, supplementary to the existing 1600cc turbocharged IC power unit, the new WRC cars will also have a hybrid propulsion system with common electrical components and software. Potential for more electrical power design freedom is planned from 2024, with the level of hybrid technical development allowed during this second phase depending on the success, or otherwise, of the first period of the hybrid WRC regulations.

## Work in progress

Currently these approved rules are just guidelines, and full technical details of the 2022 regulations are expected at the end of this year, while manufacturer teams must submit 2022 WRC entries in the second quarter of next year. Yves Matton, FIA rally director, said: 'This is the time-frame we agreed with manufacturers. The normal time-frame to develop a new car is 18 months; here due to the fact that it's quite new technology they want to have more time, and they have six months over the normal time-frame.

One of the driving philosophies of the new regulations is keeping costs down. 'The target is to stay at the same cost as at the moment, trying to make some economy on some other technical parts of the car,' Matton says. 'Everything which is not a technical return on investment for a manufacturer we will try to make as cost-effective as possible.'

On top of all this control tyres will be mandated for all the four-wheel drive World Rally Championship classes from 2021 to 2024, so as to help to reduce the costs associated with an escalation in tyre development.


Citroen has made it clear that its future in the WRC depends on some element of hybrid/electric power in the new regulations and so it will not be disappointed with the FIA proposals

There is not much in the way of detail as yet and discussions between the manufacturers, as a group, and the FIA continue. It is clear, however, that the new tubular spaceframe concept and the 'scaling to mandatory dimensions' option opens the door to existing WRC manufacturers which might wish to field C segment WRC cars, or even SUVs. At the present time it is looking like Toyota wishes to stick with the B segment Yaris, while M-Sport/Ford, Hyundai and Citroen favour larger models.

## Current affairs

Citroen has stated it will not continue in WRC if hybrids and zero emission zones are not included. Right now that seems to be the way it's going, but the question of whether it will be high or low voltage electric power has still to be addressed. Citroen Racing chief engineer Olivier Maroselli says: 'The problem with low voltage is you are talking about [such a] high current that you need huge cables and you are going away from all the current trends in hybridisation.

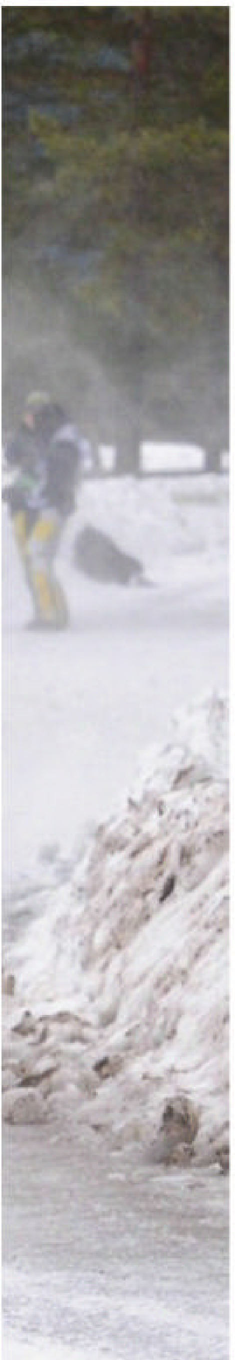
'By international rules, above 60 volts you're basically switching to a high-voltage system in terms of safety issues, because when you are above 60 volts there is a risk of electric shock, which is basically only related to voltage,' Maroselli adds. 'Sixty volts is very low for a high-end hybrid or a fully electric car; which are running more than 300, 400, up to 800 volts – the higher the voltage the less current for the same power and then a lighter system. Citroen want hybrid to be mandatory and full electric for some sections [of the stages], as well. So that is something we have [to have] to get the [board's] permission to carry on with the sport.'

Maroselli's calculations indicate the electric driveline; the battery, the electric motor, the inverter, will weigh about 100kg. Currently the FIA plans to stay at the current 1190kg minimum car weight with the new cars and allow extra body lightening, but discussions are difficult as car weight is a secret subject between teams, because of ballasting benefits.

But there is excitement about this prospect: 'For sure it will be the biggest change in the WRC since the start of its history,' says Maroselli.

Toyota Gazoo Racing WRC chief engineer Tom Fowler also believes the choice between

Working on hybrid/electric rally cars will bring added complications but most in the WRC believe safety will not be an issue




Toyota is likely to stick with its Yaris model and not take up the option to build a new WRC car from another market segment

high and low voltage needs to be made. 'That's a question the teams and FIA need to find a solution to,' he says. 'Safety mitigations can be made to make it safe, but I think in general that answer needs to come from good data and research and not just speculation about what's safe and what isn't. So a real technical and safety analysis will have to be done to decide whether a low or high voltage route is safe in one direction or the other.

**The FIA's plan is for WRC cars to run exclusively on electricity in cities**


The marketing-inspired Peugeot 307 CC WRC in 2005. The new regulations should make projects such as this much easier

'From a packaging and performance point of view, generally speaking the low voltage is generally a bit more of a challenge,' Fowler adds. 'From a true performance point of view in terms of the power output and the power-to-weight ratio the high voltage has its advantages, but that then needs to be traded off against the safety, so it's not a simple topic.'

## Quiet zones

The FIA's plan is for WRC cars to run exclusively on electricity in cities, while also having an electric power boost which could be deployed on special stages. Current estimates set the hybrid kit at producing around 90bhp. 'I think that's in the ballpark, but it's more about the duty cycle we're discussing, so that's how much time can you actually use it for,' Fowler says. 'That's related to the size of the battery from a capacity point of view and also how do we arrange the software or the control systems; how do we re-deliver and how do we regenerate? The answers don't come [exclusively] from the technical [side]; they come from the sporting side as well. There will need to be changes to the sporting regulations to accommodate it because if it's a road section-based system, then it's going to have to be regulated as to when you use it and what happens if you don't use it, which is going to be a bit difficult from a regulation point of view.'

One thing that is often talked about when it comes to hybrid rally cars is the safety. But fear of injury or death by electric shock from the hybrid is mistakenly driven by today's chassis-grounded systems, and high voltage hybrids would not be grounded to the chassis. 'There's an awful lot of ways you can minimise the risk,' says chief rally engineer at M-Sport, Chris Williams while also making this very valid point: 'If you told someone we were going to carry round 70 litres of highly explosive stuff that leaks on the floor and will burn you to death, everybody would think you were mad!'

More generally Williams says of the hybrids: 'There are a lot of proposals on the table, it's just [about] trying to steer the direction. I don't think the manufacturers will get the choice. I think it will just be put down by the FIA: "This is what you're going to have to have and this is how you need to work to it". It depends on how you want to do it, everybody's got a different agenda, so it's very hard for everybody to actually agree on exactly what it should be.'

## Congestion charge

While supercapacitor/battery combinations are likely to be used, Williams makes the interesting point that batteries cannot be charged fast enough when using energy from, say, a brake energy recovery system. 'Think of how much energy you actually have from braking and if you were to use all that energy and try to ram it into the battery in a few seconds. That's why KERS works so well because you go *bang*! and you suddenly accelerate a flywheel and then it's there and you can use it immediately; you can't do that with a battery,' he says.

Flywheels have been discussed, although Williams doesn't think this will happen. However he adds: 'I think it [would] be interesting, I think it suits rallying. [But] the big players with KERS have battery technology which is ridiculously priced and maybe their stuff will accept really fast charge rates, but I don't think that's something that we're ever going to get [in rallying]. I think it's cost-prohibitive.'

Williams also points out that electricity based assistance is effectively a torque infill to the internal combustion engine, and that teams already have experience with this from using anti-lag systems. More broadly he believes the new rules are timely. 'I'm not sure that it's sustainable, not as we are now [In the WRC],' he says. 'I think some of the teams have put in an awful lot of funding and not actually got anything out of it as it stands today. Which could jeopardise their future and this would be my worry if you just leave everything as it is now.'

Compared to its rival teams it's not long since Toyota entered the WRC to market its Yaris and it's believed it will stick with this model for the new regulations. One problem it has faced is packaging within the small engine bay, and it


Hyundai welcomes the new regulations, its team principal saying the wider the chassis options for manufacturers the better

will face further headaches with a hybrid WRC version of the Yaris, but as Fowler points out: 'If you had a completely open choice about which model of car from your brand you could take rallying with a hybrid it still depends heavily on the hybrid regulation, because the hybrid can be positioned in different ways. It is effectively our job to read the regulations, understand what the limiting factors are, and then look for the car which suits it the best.

'But everybody's already thinking what car they're going to use, so that's how we end up driving the regulations originally towards a specific car, because we're looking at it from the wrong way round,' Fowler adds. 'In order to choose the car you are going to use you should have the regulation book in front of you, but we

**'I'm not sure the WRC is sustainable, not as it is now'**

don't have that, so now we're at the point where we're now going to write the regulations from different viewpoints, based on what vehicle they [the manufacturers] want to use.'

## Marketing drive

While admitting he is not an engineer, M-Sport team principal Rich Millener is very experienced in the sport and, as a motorsport fan and team boss, identifies the critical essence of the potential success of the new rules. 'From my viewpoint you have to involve the manufacturers' marketing people,' he says. 'Unless you go to the marketing department of every manufacturer and ask: "What do you want out of this?", if you come up with a fantastic set of regulations that don't meet their marketing structure, they are not going to invest [in the WRC]. So we have wasted our time.

'It needs to be relevant and interesting to new manufacturers as well,' Millener adds. 'It's so important to get the manufacturers on-board at an early stage. The regulations for 2022 do need to attract new people [manufacturers] but they also need to ensure that as soon as the FIA turns around and says: "Right, you have to sign-up now that you are going to commit to 2022", then we [the manufacturers] all do it.'

## Size matters

M-Sport's Williams has considered the engineering implications of the options in the new rules and he predicts difficulties in the mixed model segment scenario: 'A fundamental problem is that everybody's going to have to scale the car,' he says. 'There will be dimensions of the box that your car needs to be in; not just maximum, but minimum as well.

'I would imagine you'd have some that are maximum and some that are minimum,' Williams adds. 'Just think of your basic car: how long is it? How wide is it? What's the wheelbase? What's the roof height? And you'll very quickly get to a car.' (There will be no change to the 3.9m minimum length rule, incidentally).

But Williams believes such difficulties can be overcome. 'This is not something that isn't done elsewhere,' he says. 'I would not be too sceptical. There are ways and means; you have just got to have the freedom to adjust what you need, where you need to do it. At least this way people will come with multiple different cars and I think that was the problem with the manufacturers; you have got the people who want to use a B car; you have got people who want to use an SUV, and how the hell do you compete with all [these] cars together? As long as the opportunity is there for everybody to get to the

same competitiveness, that is key. We need the regulations to be open enough to allow you to be comparable with your competitors.

'As an engineer, can you come straight out with no compromise in your design? I don't know,' Williams says. 'If you had to have a tubular chassis with certain constraints; or your own chassis with no constraints, which one would you go for? It's guiding principles and there's no detail in the regulations [yet].'

## Pump action

Fuel consumption has been discussed, but Williams has concerns here. 'We've got to be very clear of what the World Rally cars are and try not to introduce too many smaller things that are simply additions,' he says. 'If they were to suddenly throw in a fuel restriction which has a reasonable effect we are just starting a combustion war, which means combustion modelling; and the person with the biggest and best models and most money will win.'

Some consultation documents on the new regulations from the FIA have been written by Michel Nandan, the ex-Hyundai Motorsport boss, who is now working as a consultant for the FIA. 'He's been there and done it on multiple cars,' says Williams. 'He's not stupid either, but I don't think it's going to be easy to do the new regulations. If they've got him involved it's better than the FIA, which has *never* developed a World Rally car, trying to tell the manufacturers: "This is what you're having". At least there's somebody credible in the rallying fraternity with recent knowledge working on this, somebody who has a good idea of what's plausible; what's remotely plausible [and not] you're having a laugh here.

**'It is better that people understand we are in 2019 and no longer in the 1980s'**

Anybody who's looked after a World Rally team you have to have some respect for.'

The man who has replaced Nandan as team principal at Hyundai, Andrea Adamo, welcomes the new regulations. 'It is clever because I want everyone to use the car they wish to…And it is better that people understand we are in 2019/2022 and no more in the 1980s, so it is better that people understand that the wider [the choice] the better if we want to let WRC survive,' he says. 'Life is a matter of choices.'

A time-served motorsport engineer, Adamo is also in favour of the new chassis rules. 'These kinds of rules will allow much safer cars than the present ones because you can build a proper chassis, because you can build a proper safety cell. You can put the seat in the proper way; you have a proper space to put the deformable foam structure along the side.'

IC engine position is not, as yet, specified, but the general feeling among teams is it will remain in the front of the car. But an interesting take on the subject is put forward by long-time Citroen Racing engineer Alexis Avril. 'Perhaps it's not the best solution, but as some manufacturers don't want to change too much I think we will keep the engine at the front,' he says. 'But for sure to go to the dream rally car for me it would be at the back. It's a lot more easy to have the electrics at the front, IC engine at the back, and to have no exhaust in the tunnel, only a propshaft, with the electric machinery on, but this is perhaps too radical.'

As things stand things are quite radical enough, but we will have to wait a little while yet before we know exactly what the 2022 WRC revolution will look like.


VAN DER LEE
Turbo Systems
Turbocharger:
• Prototyping
• Design
• Development
• Project management
• Series manufacturing
• OEM special programmes
YOU DESIGN THE ENGINE
VAN DER LEE Turbo Systems offers high-end technical solutions in design, development, testing and manufacturing of turbo systems. With a background in motorsport, we deliver solutions for maximum power output with optimal reliability. We understand your needs and the time pressure you work under. Supported by our knowledge of automotive design and aviation quality systems we can offer motorsport products that are of constant – and highest quality which allows you to push the limits and gain competitive advantage.
WE PROVIDE THE BOOST
WWW.VDLEE.COM
Phone 0031(0)20 894 3444 - E-mail info@vdlee.com


CONTROL VALVE
H/L
INTELLIGENT
COMPRESSION SYSTEM
DOUBLE
PISTON
ADJUSTMENT
CORNER
CONTROL VALVE
HIGH/LOW SPEED
COMPRESSION
DRIVEN BY
THE AMBITION
TO BE
THE BEST
SUSPENSION SYSTEMS
THERMOSTATIC
COMPENSATION
HYDRO-JACKS
THE BEST SUSPENSION FOR:
Rally - RallyCross - RallyRaid - AutoCross-
MotoCross - SidecarCross - Enduro - Trial - Quads
Reiger Suspension BV
Molenenk 5a
NL - 7255 AX Hengelo Gld.
Tel.: +31 (0)575 - 462077
info@reigersuspension.com
www.reigersuspension.com
REIGER
SUSPENSION

# Two of a kind

**Formula 3 Regional has opened up new opportunities for racecar manufacturers in a market that sits between International F3 and F4 – we took a close look at the F3R offerings from Tatuus and Ligier to get an insight into the tech that underpins this intriguing category**

**By LEIGH O'GORMAN**

When it was decided that GP3 would, effectively, be renamed International Formula 3 and take its place on the F1 bill, as it has this year, there was a feeling within the FIA that there would be a need for something to fall into the gap between the new Formula 3 and F4. FIA single seater commission president Stefano Domenicali even talked of an 'F3 Lights', but the new formula was eventually given the name of Formula 3 Regional (F3R).

F3R was actually due to begin in 2017, but it faced various delays, meaning the new category did not debut until this year. Thus far, two chassis manufacturers – Tatuus and Ligier – have been selected for the four championships that run as F3R categories. And having previously designed F4 cars for championships in Europe and the Middle East, designing an F3 Regional car made perfect sense for Tatuus.

'The concept is mainly based on the requirement of the FIA to define the parameters from F4 to F1,' says Corrado Casiraghi, technical director at Tatuus. 'Regional F3 is the next step up from F4 and is a car that should be the first [that has] some higher power and some [more advanced] aerodynamics for driver training.'

Where F3R differs from its higher level cousin is that whereas it is a spec formula within specific championships, it's not just one car across the world. 'The regional programme is like Formula 4 where every country has the choice of a chassis and an engine programme and it's not like Formula 3 International, where it is one [specification]; that is a very different set of rules,' says Max Crawford, general manager of Ligier's North American division.

## Regional accents

In a relatively short time-frame Ligier released the JS F3R, the car chosen for the F3 Americas Championship, where it is powered by Honda's I4 2-litre K20C1 engine. Tatuus, meanwhile, produced the T-318, which has been selected for the F3 Asian Championship (and its winter series), the Formula 3 Regional European Championship, the W Series (all powered by Alfa Romeo engines) and Formula Renault Eurocup,

‘To have something like 120 racecars in one year makes this project successful for us’

Photo: Gavin Baker


The Tatuus T-318 in action in Formula Renault Eurocup. The regulations have been designed so that manufacturers can ensure their cars will be able to pack a wide range of engines

with the New Zealand-based Toyota Racing Series being added to the mix in 2020.

Although the concepts for the Ligier JS F3R and Tatuus T-318 were defined in 2017, both were hit with reduced development time-frames, albeit for very different reasons.

According to Casiraghi, the concept for the Tatuus T-318 was born during September 2017, with development accelerating quite sharply thereafter. However, the Italian manufacturer was thrown something of a curve-ball when the FIA announced that the F3 Asia Winter Series would be using the T-318 in January, bringing its competitive debut ahead by approximately three months. 'It was really a super sprint in order to be ready, because originally the plan was to have this car for 2019, but then the FIA allowed for an early start in Asia,' he says. 'We got the very last set of regulations published in March 2018 and we managed to have 20 cars ready by the end of June.'

## Under pressure

Despite the shortened time-frame for development Casiraghi says that the T-318 has not suffered any major reliability issues. But the early start did create some pressure, as it squeezed the homologation and crash test process, and Casiraghi admits that had anything gone wrong it could have spelled disaster for the project. 'We had to be extremely careful in the design to be sure to respect the requirements of the FIA,' he says. 'If anything goes wrong, we have to repeat everything from the beginning and so it is something that is quite [worrying]. It was quite a long process to have all of the FIA certification and an FIA crash test. We went up to something like 33 static and dynamic tests on the chassis, so it can withstand [crashes]. We spent most of the month of May last year just on the homologation itself.'

## Safety push

For Ligier, its late start came about following the F4 crash at Donington, which severely injured Billy Monger. 'Originally it [F3R] was designed to be F4 with upgrades and after the Billy Monger accident that changed,' says Crawford. 'We designed and built a new chassis to the new rules and regulations, so it has all of the features that an F1 car has for safety, including the Halo. It changed the design time, because we had already done a car and that had to be binned, and we started another one. But on the reliability side it's been more than satisfactory. It's been a fantastic little car from the outset.'

All F3R cars have been drawn with a low nose profile to help prevent the tip of the nose from entering another car's cockpit during nose-to-side contact. The nose tip also has to sit below the rear wheel axle. The idea is that if the following car makes contact with the rear wheel of the car in front, it's not projected upwards. 'The idea is to avoid incidents where cars may take off when touching the nosebox [on to] the rear wheel of another car,' says Casiraghi, adding that as the position of this section is dictated by a range of 5mm in the regulations each F3R design will invariably look similar from the front.

The anti-intrusion panels have also been bolstered, and now completely cover the

### TECH SPEC: Tatuus T-318 (in Asian Formula 3 configuration)

**Chassis**
Carbon composite monocoque; Tatuus Halo; Carbon composite front, rear and side crashbox; roll hoop (all FIA homologated).

**Bodywork and Wings**
Carbon Fibre.

**Transmission**
Sadev SL-R 82 6-speed gearbox; paddleshift; Magneti Marelli ESA.

**Suspension**
Front: double wishbone with pushrods; twin shock layout; camber and toe adjustable. Rear: double wishbone with pushrods; twin shock layout; camber, toe, roll centre, anti-squat adjustable. Dampers, Koni 2-way; springs by Eibach.

**Electronics**
ECU, Magneti Marelli SRG 140; LCD dash integrated in steering wheel; data acquisition by Magneti Marelli;

**Brakes**
Brembo 4-piston monolitic calipers; Brembo discs and Pagid pads.

**Wheels**
OZ aluminium front 10x13in, rear 12x13in.

'Originally Formula 3 Regional was designed to be Formula 4 with upgrades, but after the Billy Monger accident that changed'

# The individual championship promoters are allowed to opt for whatever engine, gearbox and electronics package they desire

side-wall of the survival cell from the bulkhead behind the driver, down to the front of the chassis and also across the bottom of the chassis, wrapping underneath the driver's legs. On this, Ligier and Tatuus diverged somewhat, with the former choosing Zylon panels, while Tatuus opted for reinforced fibreglass, which performs like Zylon, but is less expensive.

'To stay within the price cap and the budget for this car, we had to go for this material rather than the Zylon, which is slightly thinner and lighter, but is also far more expensive than reinforced [fibre]glass,' Casiraghi says.

In addition, each wheel has an extra tether designed to hold the wheel close to the car in case of an accident, with each tether designed to withstand 6kJ of energy.

## Hello to Halo

As mentioned above, as with all new FIA single-seaters, F3R has incorporated a Halo into its design. 'We were the first to homologate a steel Halo, for the same reasons as the side intrusion panels,' Casiraghi explains. 'The existing Halo [designs] were only titanium, which is lighter but very expensive. Just to give you a number, the titanium Halo is something like €15,000 minimum, and we have an overall cost for the chassis of €80,000, so the titanium Halo would have just been unaffordable. We had to design a steel version of the Halo and establish and test the design of this at the FIA laboratory at Cranfield. It is something that we sell all around the world to other manufacturers.'

All of these safety advances have resulted in extra weight, bringing the mass of the Tatuus, without driver, to 670kg, while the Ligier weighs in at just 630kg. 'The Ligier JS F3R is very balanced and the weight distribution is very good,' says Crawford. 'The additional safety parameters actually helped the balance with the extra weight on the front.' Casiraghi is also keen to note that despite the extra weight the T-318 possesses good weight distribution.

## Pass notes

Both of these machines were conceived with a focus on trying to reduce aerodynamic sensitivity for following cars, in an effort to make overtaking easier. With this in mind the front wing had its mid profile defined in a similar manner to current Formula 1 regulations, with the aim of making the turbulent air less critical. At the rear, the diffuser size is limited, with the aim of minimising the upwash that could disturb following cars. Crawford says: 'You do get a little bit of aero wash, but it's minimal.'

Although each chassis is spec, individual championship promoters are allowed to opt for whatever engine, gearbox and electronic package they desire, although both Casiraghi and Crawford say this has not presented them with too much of a problem. 'This has been mainly part of the work we have done with

### TECH SPEC: Ligier JS F3R (in F3 Americas configuration)

**Chassis**
Carbon composite monocoque to FIA F3 technical regulations; full 2018 FIA safety compliance.

**Bodywork**
Composite.

**Engine**
Honda 2-litre, 4-cylinder 16-valve with turbocharger; power, 303bhp for the F3 Americas Championship.

**Gearbox**
6-speed sequential; pneumatic paddleshift.

**Suspension**
Double wishbone, front and rear; pushrod adjustable ride front and rear; JRi 2-way adjustable dampers; front and rear adjustable anti-roll bars.

**Steering**
Rack and pinion; quick release steering wheel; safety collapsible steering column.

**Electronics**
LED backlit colour display; CAN controlled power management; 3-axis plus yaw accelerometer; damper potentiometers; high speed 4GB Logger.

**Brakes**
Alcon 4-piston monobloc calipers; PFC vented steel discs; Tilton adjustable pedal mounting assembly.

**Safety**
Front crash structure; rear crash structure; side impact structures; Halo; side and front anti-intrusion panels; 6-point harness; 6kJ wheel tethers (two per corner); on-board fire control system; headrest compatible with HANS; extractable seat (all 2018 FIA compliant).

**Dimensions**
Length, 4895.5mm; width, 1850mm; wheelbase, 2920mm.

**Weight**
650kg.

Photo: Ligier Automotive

**The Ligier JS F3R. Halos are mandatory while the design of the nose is tightly controlled for safety reasons. This means that all F3R racecars will look very similar from the front**

The W Series is currently using the Tatuus T-318 F3R racecar while New Zealand's Toyota Racing Series is to switch to this chassis for the start of its 2020 season

## 'We built a mule car and experimented with the radiators and the intercoolers and now we have very few issues with the cooling'

the FIA to standardise the interface of the components,' says Casiraghi. 'It makes it easier for the life of the design of the car, because we don't have to design specific bodywork for each of the engines. It's the same for the engine pick-up points; it is a standardised pattern on the chassis and the engine suppliers follow the pattern that is in the FIA regulation. Similar things apply to the wiring loom. The wiring loom has a common standardised interface between the chassis and the engine, which again makes it possible to keep most of the same electronics when we go, for example, from an Alfa engine unit to a Renault engine unit, so this is a very efficient way to work on the design.'

'The engine bay is quite large and the bodywork is quite large, because these are for production engines,' Crawford adds. '[Also], you have a lot of options on the back of the tub for the mounting of the engine.'

## Engine ancillaries

For Tatuus the process of assessing each engine fit begins once info from the manufacturer is obtained, allowing it to calibrate surrounding systems such as cooling. 'The main job is working on the systems that are engine-related; every engine has its own cooling system,' Casiraghi says, adding that in the case of the Alfa Romeo and Renault, the former had an exhaust on the left side, while Renault's exhaust emerged from the right. 'We had to redesign the exhaust system and the cooling system for the different architecture of the two engines.'

Ligier also had to work hard to optimise cooling solutions, mainly to counteract high temperatures in certain areas of the United States during the summer. 'In the States, we struggle with temperatures,' Crawford says. 'It's not unusual for us to run on 100degF [38degC] days, so we spent a particular amount of time with CFD and track testing with the radiators. We also built a mule car, and we experimented with the radiators and the intercoolers, so we now have a huge window for cooling, and little in the way of issues with cooling.'

The throttle is a fly-by-wire system and the brakes hydraulics with sensors, with safety cut-offs built-in to allow for engine shut off should the system believe the driver is applying significant pressure to the pedals simultaneously. 'In this case, in the ECU, they have to shut down the engine,' Casiraghi says. 'If the driver is pushing the throttle and brake while crashing, the engine shuts down. This is something that is required by the FIA and only possible if we have the fly-by-wire system.'

The suspension for the T-318 is a relatively traditional layout with double wishbone and pushrods for both front and rear, with dampers arranged on top of the monocoque. At Ligier, it was built in-house as aluminium machine billet uprights. It is double wishbone, pushrod, rockers and runs with JRI shocks. 'It's just a conventional pushrod rocker system, all aero tube,' Crawford says. 'The dampers are on top of the monocoque for ease of change. Any spring changes and adjustments are just a matter of removing the damper cover and doing that.'

As it stands, Formula 3 Regional uses 13in profile wheels, but the door is open to move to larger wheels. 'We expect this to happen sooner or later and it will happen for sure when Formula 1 moves to them,' says Casiraghi.

Creating a car that is technically astute, powerful, reliable, bolsters safety, but also comes under a tight cost cap has proven a challenge for manufacturers and one that becomes greater still when spare parts are also capped. At €80,000, the cost cap leaves little room for manoeuvre, and Casiraghi acknowledges this. 'It is difficult, there is not really one magic part that can help you; rather it is very detailed work on every little part of the racecar to save costs,' he says.

## Early success

For both Tatuus and Ligier these are still relatively early days in Formula 3 Regional, but so far it's all been largely positive. 'At the moment, we are very satisfied, because mainly what we have seen is that we started less than one year ago and we have four series racing the car and a fifth one ready to go,' says Casiraghi. 'We have now four championships with more than 80 cars racing. We have the car for the Toyota Racing Series, which will start racing next winter. In one year to have something like 120 cars makes this project successful for us.'

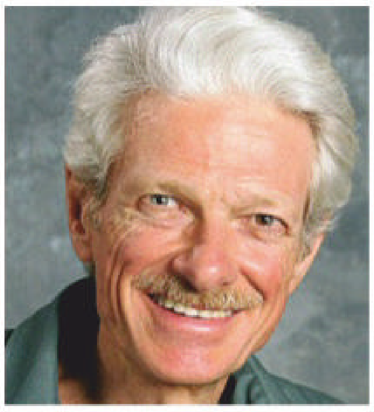
Crawford also believes that the Ligier JS F3R has proved its worth. 'Cost containment is one of Ligier's main objectives and when drivers and teams thank us for keeping costs low, it's a huge win not only for Ligier but the series as well.

'We are also seeing the progression of race drivers from karting and even through into prototypes,' Crawford adds. 'These Ligier open wheel racecars are great platforms for development. Seeing our drivers progress into higher profile pro racing already defines the Ligier JS F3R as a successful car.'


texense
sensors by TEXYS
Miniature embedded sensors for automotive, defense, ground or flight test centers
IRN2
Linear analog & digital infrared sensor (4/20mA, 0-3V, 0-5V or 0-10V output)
IFBN
Fiber-optic infrared sensor for harsh environment
IRN8-WS
Wireless 8 ch. Infrared temperature sensor
THN2XWS
Wireless 2 ch. Thermocouple conditioner
A-CAN DG V4
Analog to CAN converter (strain gauge, 0-5V, -/+ 10V, RTD, NTC, ...)
V2-mA
4-20mA interface for 0-5V or 0-10V input
RAD6
6 axis IMU with CAN output
XN4
Digitally controlled strain gauge miniature amplifier
Conditioners
Force - Movement
Temperature - Pressure
www.texense.com
TEXYS
Z.A. des Chamonds rue Édouard Branly
FRANCE - 58640 VARENNES-VAUZELLES
Tél. : +33 (0) 386 212 718 - Fax : +33 (0) 386 212 449
with the courtesy of Brembo S.p.A.
Lechat et la Souris - 03 86 71 05 85


CARTEK
MOTORSPORT ELECTRONICS
GO TO OUR WEBSITE TO VIEW OUR FULL RANGE OF MOTORSPORT ELECTRONICS
www.CARTEKMOTORSPORT.com
POWER DISTRIBUTION PANELS
A switch panel and Power Distribution Module in one.
Our Power Distribution Panels are a fully integrated solution designed to replace all the fuses,switches and relays of your race car.
• CONFIGURE CHANNELS IN 5A STEPS UP TO 30A.
• CHANNELS CAN BE PROGRAMMED TO CONTROL HEADLIGHTS/WIPERS/RAD FANS/STARTER MOTORS etc.
• EACH OUTPUT IS PROTECTED FROM SHORT CIRCUITS AND OVER-CURRENT.
• ADDITIONAL INPUTS ALLOW CHANNELS TO BE CONTROLLED BY ECU OR SWITCHES ON STEERING WHEEL.
• COMES WITH LABEL SHEETS FOR FULL CUSTOMISATION - RETRO EDITION NOW AVAILABLE.
• NO COMPLEX CONFIGURATION SOFTWARE - AMP SETTINGS AND LOGIC FUNCTIONS ARE SELECTED THROUGH THE FRONT PANEL.
8 and 16 channel versions available
SOLID STATE BATTERY ISOLATORS
Cartek Battery Isolators are designed to overcome all of the problems and restrictions associated with mechanical and electro/mechanical battery disconnects.
• FULLY ELECTRONIC WITH NO MOVING PARTS - COMPLETELY RESISTANT TO SHOCK AND VIBRATION.
• MUCH SMALLER AND LIGHTER THAN TRADITIONAL KILL SWITCH.
• MEETS NATIONAL AND FIA REGULATIONS.
• STATUS LED FOR FAULT DIAGNOSIS.
• SEALED INTERNAL AND EXTERNAL SWITCHES REPLACE TRADITIONAL PULL CABLES THAT ARE PRONE TO SEIZING.
• MOUNTS CLOSE TO THE BATTERY FOR REDUCED CABLING.
• QUICK AND EASY TO INSTALL.
BATTERY ISOLATOR XR
Designed for motorsport ECU's/PDM's
BATTERY ISOLATOR GT
Designed for OEM ECU's/Ignition systems


THE PERFORMANCE RACING INDUSTRY TRADE SHOW
DISCOVER NEW TECHNOLOGY. IDEAS. BUSINESS.
DECEMBER 12–14, 2019
INDIANAPOLIS, INDIANA
USA
The PRI Trade Show is the racing industry's No. 1 venue for new technology, ideas and business opportunities. If you're in the business of racing, you can't afford to miss this event.
• ALL FORMS OF AUTO RACING
• OVER 1100 EXHIBITING COMPANIES
• A TRADE-ONLY EVENT
PORSCHE
MICHELIN
PORSCHE DESIGN
Mobil 1
Esso
THE BUSINESS OF RACING STARTS HERE
PRI
Learn more at pri2019.com



# Biased thinking

## Why achieving the perfect brake balance on a NASCAR Late Model stock car involves weighing up a wide range of variables

**By MARK ORTIZ**


Photos: NASCAR

A NASCAR Late Model in action. When fuel is used up throughout a race the weight distribution will change and the brake bias will need to be adjusted to account for this

**Q I run a NASCAR pavement Late Model. You always hear racers talking about changing the brake bias during a race, so how does that help the car later in a race? Also, what would be a good per cent from front to rear to start out at? How does it affect corner entry? And how do different per cents affect setting up the car?**

## THE CONSULTANT

A The simplest reason for adjusting brake bias while running is to correct for change in weight distribution due to fuel burn-off. But there can be other reasons as well.

A gallon of gasoline weighs about seven pounds. Twenty gallons, then, is about 140 lbs and 15 gallons is just over 100 lbs. Suppose that we have a car that weighs 3100lb at the start of a race, and that the car has 50 per cent rear in that condition: 1550 lbs front and rear. Suppose that the fuel load is carried 20 per cent of the wheelbase length back of the rear axle. Suppose then that we burn off 100 lbs of that fuel. What is the rear percentage now?

That 100 lbs of fuel was adding 120 lbs to the rear wheel loading and taking 20 lbs off of the front. When it's gone, we have a 3000lb car with 1570 lbs on the front wheels and 1430 lbs on the rear wheels. We now have 47.7 per cent rear and 52.3 per cent front. The front wheels statically carry 140 lbs, or about 4.7 per cent of the weight, more than the rears. If the car was set up so it locked the front wheels just before the rears in straight-line limit braking at the start of the race, it will now lock the rears first.

**Ordinarily we want the fronts to lock first, that way it doesn't try to swap ends when we approach lock-up**

Ordinarily we want the fronts to lock first, at least for a pavement car. That way, the car doesn't try to swap ends when we approach lock-up. On dirt, though, we often use the brakes to get the car rotating in yaw on entry.

The brake bias needed to make the fronts just barely lock first is not a constant. It varies depending on the coefficient of friction between the tyres and the race track surface. It also varies depending on whether we are cornering or running along a straight.

This happens because the dynamic loading of the wheels varies as the vehicle undergoes accelerations. When designing or adjusting non-ABS braking systems, we primarily concern ourselves with the rearward *x*-axis accelerations that we are trying to produce when we apply the brakes. However, we should note that *y*-axis (lateral) and *z*-axis (normal to the road surface) also affect wheel loadings.

To calculate what the brake force distribution should be to produce shortest straight-line braking with directional stability, we need to know the loads at the front and rear wheels in straight-line limit braking on a level surface. For this, we will need: the static front/rear weight distribution; the overall c.g. height; wheelbase; and the rearward acceleration we think the car can attain under favourable conditions.

## Brake clause

The percentage of the car's weight that transfers from the rear to the front is the c.g. height as a percentage of the wheelbase, times design rearward acceleration in *g*s. For example, a pavement Late Model stock car might have a c.g. height about 15 per cent of the wheelbase and slicks that allow it to brake at about 1.2*g*. That would mean that 15 per cent of the car's weight transfers forward per *g*, and 18 per cent transfers at 1.2*g*.

If the front end has 50 per cent of the weight statically, it then would have 68 per cent dynamically. If the coefficient of friction were a constant, all four wheels would lock together at 1.2*g* if the front wheels do 68 per cent of

# To understand the effect of front to rear brake bias when a race driver is trail braking it is necessary to get to grips with the traction circle principle

the braking. Since the coefficient of friction diminishes some as load increases, the fronts would probably lock just a little before the rears. So we want a brake bias somewhere in the range of 68/32 to 70/30.

The retardation force at the contact patch depends on: the ratio between tyre radius and brake pad acting radius (roughly the radius to the middle of the swept surface); the pad to rotor coefficient of friction; the caliper piston area (more area gives more force); and the hydraulic pressure fed to the caliper.

The hydraulic pressure fed to the caliper depends on: the master cylinder piston area (less area gives more pressure); and the force on the master cylinder pushrod.

The force on the pushrod depends on: force on the pedal; pedal pad to balance bar motion ratio; and apportionment of balance bar force between the two master cylinders.

A pavement Late Model has similar tyre sizes front to rear, although there are small variations, mainly to achieve stagger. Brake rotors (discs) are generally as large as the wheels will allow, front and rear. Calipers are generally of similar design front and rear, but with bigger pistons in the fronts. The most common combination is 1.750in in front and 1.375in in back. This means that the diameter ratio is 14/8 to 11/8, or 14/11, and the area ratio is the square of that, or 196/121. The front caliper piston area percentage is then 196 / (196 + 121) = 61.8 per cent. The brake bias would be about 61.8/38.2. The rears would lock first, if the line pressures are identical.

## Front loading

We can give the front a bigger share of the line pressure by giving it a smaller share of the master cylinder area. To give the front 70 per cent of the stopping power when the balance bar is centered and pushrod forces are equal, the *rear* master cylinder needs to have (70/61.8) x 50 per cent = 56.6 per cent of the piston area and the front one 43.4 per cent. The front master cylinder area needs to be about 43.4/56.6 = .767 times as great, so the diameter ratio needs to be the square root of that, or about .876. That's just about exactly 7/8, so we would be close if we use a .875in front master cylinder and a 1.000in the rear.

We can then adjust from there using the balance bar. Typically this will only give us about a seven percentage point adjustment range – from about 73/27 to 67/33. It is possible to build ones with broader range, but size and rigidity become issues, so commercially available ones are fine tuning devices, and we need to get close using the rest of the system.


**On dirt tracks a bias to the rear brakes is often useful on turn-in to help rotate the car. There can also be plenty of lateral bias**

So far we've been assuming a symmetrical car, braking in a straight line. However, with an oval track car, things get considerably more complicated. We often will not have the same rear percentage on both sides of the car statically, due to wedge adjustment. We often will not have equal longitudinal load transfer on the left and right in braking, due to asymmetrical springing and suspension geometry. We usually will have more than 50 per cent static left weight. We will usually have tyre stagger at both ends of the car.

Often, the driver is going to trail brake: the car will be turning while braking. Depending on the track, the driver may be braking for the first third of the turn. The car may never be running entirely straight. The turns will probably be banked, and in many cases there will be some banking on the straights.

On asphalt, our concern may be to keep the car from spinning while the driver is trail braking. On dirt, we may be using the brakes to persuade the car to rotate in yaw.

The engine will also be a factor. Engine braking may effectively add rear brake. Also, the driver may be a left foot braker who uses the throttle to partially overcome the rear brakes, in a controlled manner.

The racecar will also usually have a side-to-side brake bias, as well as a front to rear bias. Even if the right and left brakes are identical, tyre stagger and tyre pressure difference will create unequal retardation on the right and left sides of the car. This is the main effect that front tyre stagger has on the racecar. But it doesn't affect the car much except in braking.

Dirt cars can have huge amounts of lateral bias. Rules permitting, they often have no right front brake at all. When the rules require a right front brake, they often have a driver-controlled proportioning valve for the right front.

## Judge tread

To understand the effect of front/rear brake bias when trail braking, it's necessary to get to grips with the traction circle principle: the tyre can make about the same amount of force in any direction. If it's at the limit of adhesion in cornering, it will break loose if you ask it to make braking force at the same time. If it's at the limit in braking, you cannot get any cornering force from it. You can get some of each, but when you ask for more of one, you can't get as much of the other.

Therefore, more front brake adds understeer, or makes the car tighter, when braking and turning at the same time. More rear brake adds oversteer, or loosens or frees the car.

### CONTACT

**Mark Ortiz Automotive** is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis set-up and handling queries. If you have a question for him, please don't hesitate to get in touch:
**E:** markortizauto@windstream.net
**T:** +1 704-933-8876
**A:** Mark Ortiz
155 Wankel Drive, Kannapolis
NC 28083-8200, USA


CD34
THE BEST JUST GOT
BIGGER
RPM 7400
KPH 126
LAP 00:00.0
BEST 00:00.0
4
OILP AIRT COOL BATT
GEMS
CD34
> 8in widescreen LED backlit TFT
> 9 tri-colour shift lights
> 200Mbyte data-logging memory
> Fully configurable layouts
> Up to 100 display pages
GEMS
PERFORMANCE ELECTRONIC SYSTEMS
www.gems.co.uk


THINK AUTOMOTIVE
Think Automotive are specialists in oil cooling systems and all aspects of vehicle plumbing. We are the manufacturers and distributors of Mocal® and Laminova products.
Aeroquip
MOCAL
DAVIES, CRAIG
laminova
PWR
NEWTON EQUIPMENT LTD
Setrab Pro Line
WELDON RACING PUMPS
BMRS
KRONTEC
Seals-it
CANTON
SPEEDFLOW
Jiffy-tite
MADE4YOU
Stant
Radiator Pressure Caps
XRP
We stock and distribute the finest automobile products, such as oil coolers, hosing, hose fittings, filler caps, water pumps, oil pumps, heater, gauges and more.
Tel:02085681172
Web: www.thinkauto.com
Email: info@thinkauto.com


Intelligent Fully Featured Battery Power Control Systems
POWERBOX
HP 8441
NEW
Cost Effective
Practical
Incredibly Versatile
Fully programmable
power control in a
user friendly package.
Future Upgrade Path
to HP8440.
Main Features:
- 180 Ampere continuous.
- 34 Output channels controlled as a function of conventional switches, CAN inputs or Virtual channels. With wiper Park on dedicated channels.
- Weight 496 gr.
MEMBRANE PANEL
CAN Controlled
Membrane Switch Panel.
Tactile Operator Feedback.
Multi Tap Capability.
Warning LED's.
Available With Your
Custom Design.
POWERBOX
HP 8440
HP ELECTRONIK
Main Features:
- 200 Ampere continuous.
- Programmable Inrush Currents
- 34 Individually Programmable Output Channels
- 11 Conventional Switched Inputs
- 32 CAN Input Channels
- 20 Virtual Logic Channels
- CAN Export Facility
- Weight 680 gr.
Future Proof With
Firmware upgrades
OVER 1000 UNITS SOLD WITH PROVEN RELIABILITY
ENGINEERED & PRODUCED WITH OUR EXPERTISE IN HOUSE. LEARN MORE AT HPELEC.DK
HP ELECTRONIK
Lundvej 17-19, Lund
7400 Herning · Denmark
Tel. +45 9626 4333
Fax +45 9626 4233
info@hpelec.dk
www.hpelec.dk


QUALITY
PERFORMANCE
RELIABILITY
SUPERTECH
WWW.SUPERTECHPERFORMANCE.COM
VALVES
PISTONS
RODS
HEAD GASKETS
COMPONENTS
SUPERTECH

# Braking new ground

## OptimumG's lead engineer talks us though the braking zone in the new instalment in his key performance indicators analysis series

**By CLAUDE ROUELLE**

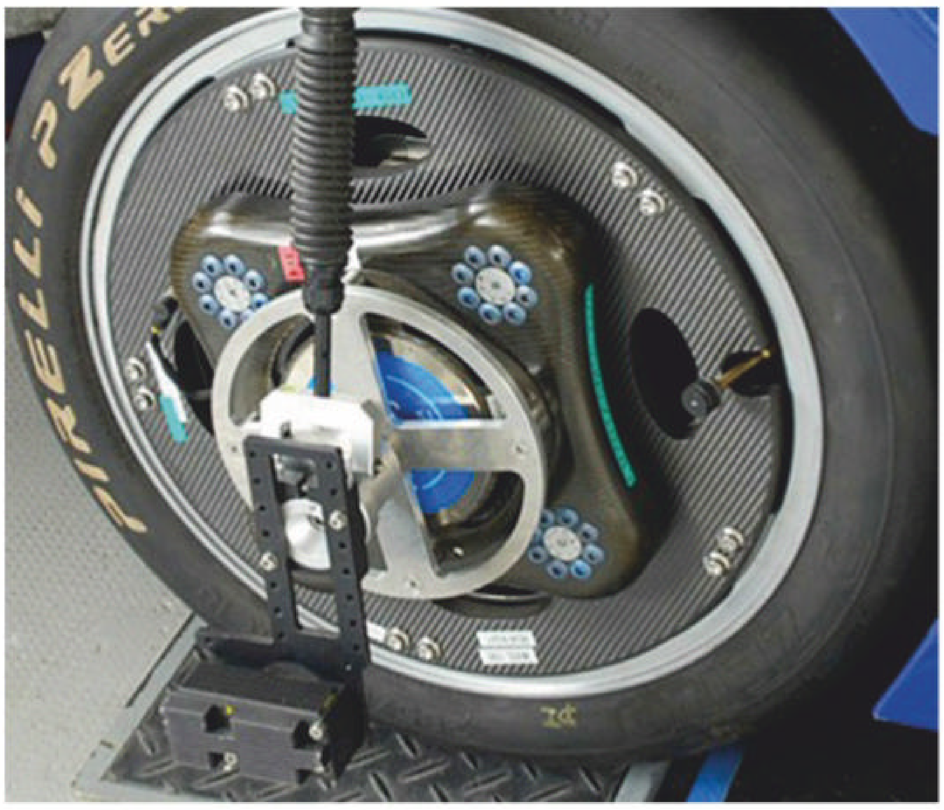
Continuing with our study of braking KPIs (key performance indicators) from the July issue (V29N7), this month we will look at vehicle stability under braking.

Stability represents the yaw moment acting against the natural rotation of the car per degree of body slip angle. It's quantified in Nm/degree of yaw moment per degree of body slip angle. This reaction moment acting against the body yaw should have a negative value.

In a practical setting stability can be looked at as the predisposition of the vehicle to stay in the directional state it is in, which can have direct effect on a driver's confidence in a vehicle. An unstable car will reduce confidence. We also need to mention that high stability is often (though not always) in opposition to fast response. Though good vehicle dynamics simulation shows that there are design and set-up choices that can give, if not both a good stability *and* a good response, at least better compromises.

### Slip angle sensors

One of the most important areas to have a high stability will be under braking. Using a slip angle sensor, we can measure the true vehicle stability under braking. The slip angle sensor will record the angle between the direction the car is heading (car longitudinal axis) and the direction in which it is effectively moving. If we know the yaw inertia of the car, we can calculate the yaw moment using the derivative of the yaw rate sensor: *Yaw Moment = d(Yaw Rate)/dt * Vehicle Yaw Inertia.* Stability can then be measured as the change in the yaw moment divided by the change in the slip angle of the vehicle.




**Slip angle sensor; the wheel force transducer measures all tyre forces and moments**

While it would be ideal to run a slip angle sensor and determine the true vehicle stability under braking during every driving session, it is often impractical to run during a race weekend due to series rules disallowing this kind of sensor and/or the risk of damaging the sensor through contact with other vehicles, or the financial burden of purchasing the sensor to begin with.

But, for most circumstances we can correlate vehicle stability with yaw rate smoothness and steering smoothness anyway. Therefore, an alternative approach can be used to approximate the stability by looking at both the steering smoothness key performance indicator and the yaw rate smoothness KPI.

This approach will then be supplemented by showing how simulation can improve efficiency at the race track, by a presentation of the change in stability that can result from different set-up options.

First we need to determine the style of braking being used. To make things simple, the focus here will be on straight-line braking rather than trail braking (**Figure 1**). To differentiate our straight-line braking and trail braking, we will define a Boolean operation that returns a value of 1 when the vehicle is in a straight-line braking state, and 0 when it is not. First, we will sum the front and rear brake pressures into one channel. Then, we will combine the brake pressure with the lateral acceleration signal. A threshold of 0.2 lateral *g*s will be defined as the transition value between straight-line braking and trail braking based on a 10 per cent value of the average lateral acceleration that was generated on this course (2.0*g*). The 10 per cent value was chosen based on experience with the circuit and the vehicle sensitivity to cornering.

### Residual pressure

We also need a test in the math function that shows if there is more than residual pressure in the braking system. To find the residual pressure for the vehicle the braking pressure can be read from an area on a long straight where there should be no braking input. In this vehicle, the residual pressure is being output as 0.2bar, so that will be the trigger. With the thresholds set, the straight-line braking channel will return the value 1 when the total brake pressure is higher than the residual pressure of the system, in this case 0.2bar, and the absolute value of the lateral acceleration is less than 0.2*g*. The trail braking function will return 1 when the absolute value of the lateral acceleration is equal or greater than 0.2*g*.

**Table 1**, below, summarises the math channels in MoTeC i2 Pro data analysis software. For a better context of the transition point we can now move on to compare the straight-line braking trigger to the total brake pressure and the lateral acceleration of the vehicle.

**Table 1: Equations for braking stability using steering smoothness in MoTeC i2**

| Math channel name | Math channel equation |
|---|---|
| Total brake pressure | 'Front Brake Pressure' [bar] + 'Rear Brake Pressure' [bar] |
| Straight line braking | choose('Total Brake Pressure' [bar]>0.2 and abs('G Force Lat' [g])<0.2, 1, 0) |
| Trail braking | choose('Total Brake Pressure' [bar]>0.2 and abs('G Force Lat' [g])>=0.2, 1, 0) |

**The slip angle sensor will record the angle between the direction the car is heading and the direction in which it is effectively moving**

To generate the braking stability KPIs, we will want to look at the yaw rate smoothness, the steering smoothness, and the partial lock-ups during the straight-line braking segment defined above. The steering smoothness and yaw smoothness math channels have been addressed in previous articles, so they will just be given. If you wish to have a more detailed explanation, check out our article from the November 2018 edition (V28N11). **Table 2** summarises the math channels for slip ratio, partial braking lock-up, yaw rate smoothness, and steering smoothness which allow for the stability KPIs to be calculated.

The steering smoothness is being used to show how much additional steering wheel input the driver is adding when braking. This in turn suggests how the chassis slip angle or the yaw moment is changing, causing more driver corrective inputs. The yaw rate looks at how quickly the vehicle is rotating. Our KPI will look at the ratio between the steering smoothness and the yaw rate smoothness.

A greater difference between the smoothed yaw rate data and the logged yaw rate data suggests that the car is rotating much more aggressively than the driver might prefer, meaning that very little yaw moment is required to change the rotation of the vehicle. If we have a high ratio between steering smoothness and yaw rate smoothness, it indicates that more steering variation is required to induce a yaw rate variation. Therefore, for our KPI, a higher value indicates a more stable vehicle.

## Partial lock-up

A partial braking lock-up is any instance where there is a difference between the vehicle speed and individual wheel speed beyond the peak slip ratio. We can determine the slip ratio of the vehicle by creating a math channel to find the ratio between the wheel speed and the vehicle speed. We can create a trigger when it surpasses the ideal slip ratio. For this vehicle, the ideal slip ratio was determined using an anti-lock braking system (ABS) which was set to regulate the slip ratio of the vehicle. The slip ratio that corresponded to the highest longitudinal acceleration was used as the upper bound for slip before

**Table 2: MoTeC channels for slip ratio, lock-ups and stability**

| Math Channel Name | Math Channel Equation |
|---|---|
| Slip ratio (front left) | ('Wheel Speed FL' [km/h]) - 'Corr Speed' [km/h])/'Corr Speed' [km/h] |
| Partial lock-up (front left) | choose('Slip Ratio (Front Left)'<-0.07,1,0) |
| Front partial lock-up Integral | Integrate('Partial Lockup (Front Left)'+'Partial Lockup (Front Right)','Partial Lockup (Front Left)'>0 OR 'Partial Lockup (Front Right)'>0,range_change("Outings:Laps:Track Sections:Braking Zones:Throttle")) |
| Rear partial lock-up Integral | Integrate('Partial Lockup (Rear Left)'+'Partial Lockup (Rear Right)','Partial Lockup (Rear Left)'>0 OR 'Partial Lockup (Rear Right)'>0,range_change("Outings:Laps:Track Sections:Braking Zones:Throttle")) |
| Yaw rate smoothed (deg/s) | smooth('Yaw Rate' [deg/s],0.5) |
| Yaw rate smoothness (deg/s) | abs('Yaw Rate' [deg/s]-'Yaw Rate Smoothed' [deg/s])*100 |
| Steering smoothed | smooth('Steering Wheel Angle' [deg],1.0) |
| Steering smoothness | abs('Steering Wheel Angle' [deg]-'Steering Smoothed' [deg])*100 |
| Steering stability | integrate('Steering Smoothness' [deg],'Straight Line Braking' == 1,range_change("Outings:Laps:Track Sections:Braking Zones")) |
| Yaw rate stability | integrate('Yaw Rate Smoothness' [deg/s],'Straight Line Braking' == 1,range_change("Outings:Laps:Track Sections:Braking Zones")) |
| Stability KPI | 'Steering Stability'/'Yaw Rate Stability' |

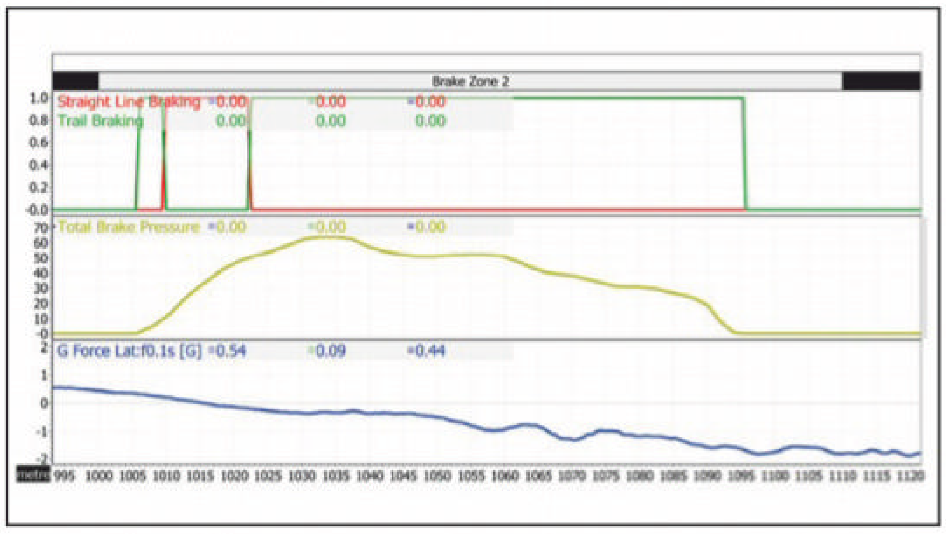



**Figure 1: The red section corresponds to where the driver was within the bounds for straight line braking analysis, green is where it's within the bounds for trail braking**

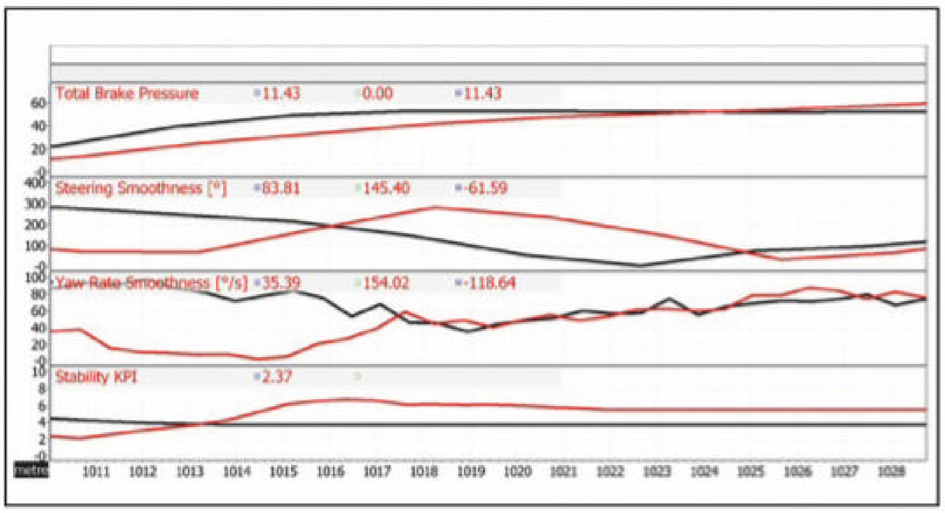



**Figure 2: A comparison of steering stability and yaw rate stability for two drivers in straight line braking. The black trace shows a greater variation in steering approach**

the slip could be considered a partial lock-up, as after the ideal slip ratio the tyres are now sliding more than they are allowing the vehicle to slip, as shown in **Table 2**. The partial lock-up is being used in this case to filter out any instances of high vehicle stability due to vehicle lock-up. In this case we are looking at the duration of time the lock-up occurred by using the integral function. With the channels generated, the three parameters can now be plotted and compared between two drivers. **Figure 2** shows the stability KPIs on a section of the track for two different drivers.

We will start by looking at two drivers of similar level but different driving styles running the same vehicle and similar set-ups going into an area of straight-line braking. In this braking zone, we see the black-trace driver had greater variation in steering input, indicating a higher steering smoothness. At the same time, the yaw rate stability was equally high for this driver, suggesting the car has a lower tendency to rotate and was less influenced by the steering inputs. When we combine the smoothness results into our KPI, we can now see that the red driver had a higher vehicle stability than his competitor.

We can consider the effects or partial lock-ups on stability negligible in this corner. Based on the stability KPI we can infer that the red driver was more stable than the black. Depending on the circumstances within a weekend we can now either make a set-up change or coach the first driver to use a more gradual braking method to keep the car more under control and mitigate some of the instability seen in the data trace. In this case we will consider that time is available to make a set-up change and that we do not want to have the black-traced driver change braking style, so we will look at this as a set-up change analysis. But before we start looking at set-up changes we will want to make sure that the issue was not related to the tyres or brakes not being uniformly up to temperature.

We will now look at the six-lap average for the stability KPI and partial lock-ups to see if the


-35mm
Worlds apart
Our technology centre is the most advanced in Europe.
That is how we can achieve a negative radius of up to -35mm. Extreme engineering and precision that other performance cam manufacturers in Europe cannot match. All our camshafts and ancillaries have been developed by the best to be the best.
№1
Kent Cams – the best in Europe:
No.1 for product development expertise
The greatest performance increase of any single modification
The widest range of camshaft ancillaries produced on site
The most advanced technology:
Negative radius to -35mm
CBN wheels with constant surface speed
Multi-angle lobes with CNC dressing
Marposs 3D C and Z axis position probe
Microphonic wheel dressing
Lotus Concept Valve Train software
KENT CAMS
HIGH PERFORMANCE ENGINEERING
www.kentcams.com
Cams + Pulleys, Belts & Chains
Valves & Valve Springs
Performance Cam Kits & Valve Spring Kits
Followers & Tappets


EVOLUTION MEASUREMENT
EvoScann®
P-Series
Digital Pressure Scanner
Serial No: 1113
www.evoscann.com
<<< Channels >>>
EvoScann®
P8-A
Pressure Scanning
REVOLUTIONised
P16-A
P64-D
P8-D
Smallest and lightest pressure scanners available
High accuracy multi-channel pressure measurement
Absolute & Differential measurement
Lightweight, carbon fibre external construction
Integral microprocessors
Direct digital output
CANbus communications
Comprehensive range of installation accessories
For a demonstration or a quotation call +44 (0)1264 316470 or email enquiries@evolutionmeasurement.com
EVOLUTION MEASUREMENT
www.EvoScann.com

# In order to use the traditional definition of vehicle stability we will need a tyre model that accounts for the tyre slip

stability was related to the tyre or brake temps. If the instability was temperature related, the number of partial lock-ups and the magnitude of the stability KPI should decrease with lap count. If it is set-up related, we can expect to see little trend between the stability KPI, partial lock-up quantity, and lap count.

**Figures 3** and **4** refer to the vehicle stability and the time that the driver locked up the front wheels. With the six-lap trends we see that the partial lock-up did not have a strong correlation to the stability KPI, especially during the earlier portions of the session. We do see that the black trace did become more stable later in the session, but given the large partial lock-up time during the third lap we can assume that after this the black-trace driver decreased the braking aggression. The lack of correlation to lap progression indicates that the stability issue was set-up related, probably not temperature related. To aid in the determination of which element to choose, we can go beyond standard practices of using driver feedback and data and introduce simulation tools to give a better idea of the magnitude of change.

## Using simulation

For our simulation analysis, we will be using the full vehicle simulation tool OptimumDynamics to help determine adjustments to the racecar. OptimumDynamics provides the ability to iterate multiple set-ups and perform a full vehicle simulation using on-track data or an acceleration dependent simulation. For this analysis we will generate a sensitivity study by creating a yaw moment simulation with just one small car body slip (or yaw angle) input, no steering input, and our peak longitudinal deceleration capability. We will then track the maximum stability value (in this case in per cent change compared to baseline set-up) generated during the simulation for each set-up change.

In order to use the traditional definition of vehicle stability we will need a tyre model that accounts for the tyre slip. Unlike the steering smoothness and the yaw rate, we are looking for a higher value of vehicle stability in this simulation corresponding to a more stable racecar. The results are shown in the bar plot in **Figure 5**.

The sensitivity case study being analysed in this instance shows the relative change in stability caused by changing the front or rear toe 0.1-degree out (+0.1-degree) or 0.1-degree in (-0.1-degree) per wheel, increasing or decreasing the front or rear spring rate by 25N/mm, or by increasing or decreasing the front braking torque ratio by 2.5 per cent. Note that for this case analysis the relative stability change is higher than may be seen on other vehicles due to a lower initial stability value. The relative changes will vary for each vehicle and should not be considered catch-all values for the set-up changes being considered.

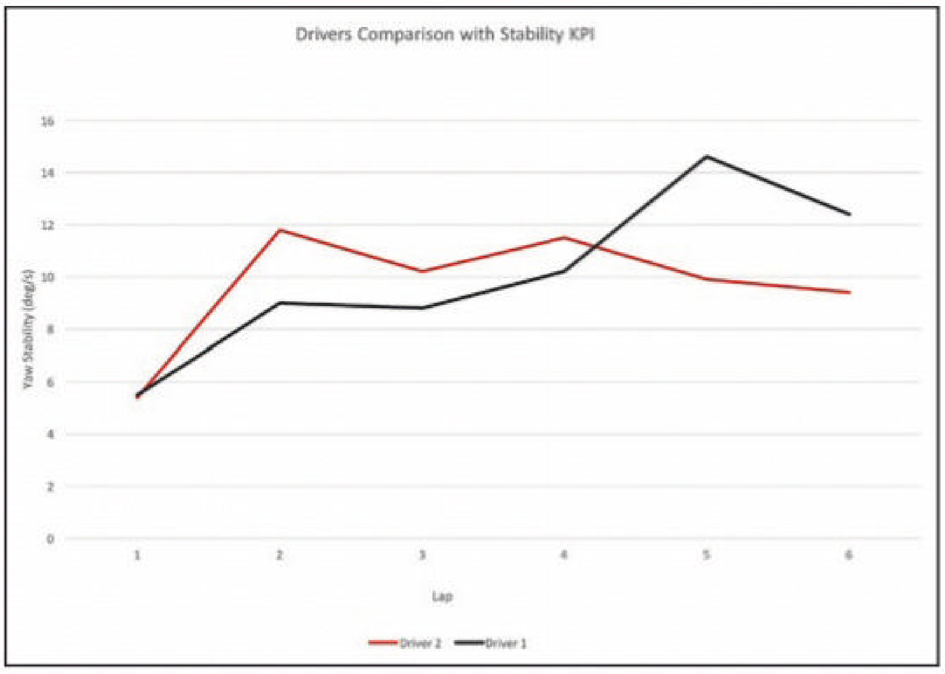



Figure 3: Driver stability trend across six laps. Black trace shows more stability later on

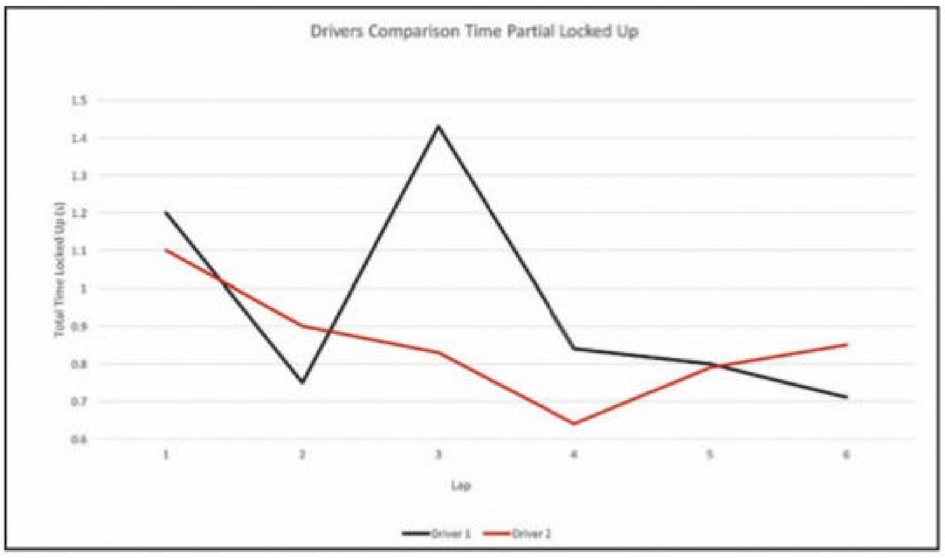



Figure 4: The driver lock-up trend across six laps. The data points to a car set-up issue

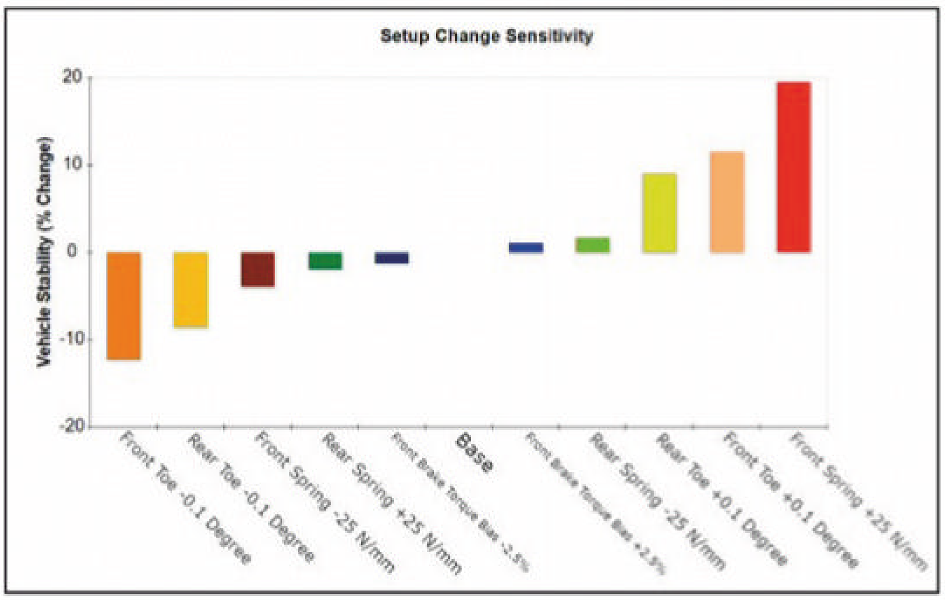



Figure 5: This graph illustrates racecar stability sensitivity to different set-up changes

In this case, we know we want to increase the stability under braking but minimise the effects on other aspects of vehicle balance. Based on this, we will avoid making changes to the spring rates and increase the front toe-out. Just by using a simple single state vehicle analysis we now have a list of options and a strong gauge of how to adjust our vehicle to suit our driver's needs.

## Conclusion

To sum up, by adding an analysis of steering and yaw rate under braking we can understand not only where a driver is braking but also how a vehicle set-up can be adjusted to suit the characteristics of a braking style by comparing the difference in driving styles using brake pressure and considering the variation in steering and yaw rate to gauge the stability of the vehicle in the braking state. With the braking stability KPI we can see how much the vehicle stability can vary for two different driving styles in a single lap trend and in a full session trend and how we can diagnose the problem even if the driver is not noticing the issue.

In combination with using simulation tools we can now have a better ability in predicting how the racecar changes are going to improve performance, and in diagnosing the issues the driver may face during an event.

**Slip Angle is a summary of Claude Rouelle's OptimumG seminars.**

**OptimumG offers a complete solution for testing, simulating, and improving the dynamic performance of your vehicle. All consulting services can be sub-contracted or we can simply guide your race team through our methodology.**

**CONTACT**
**Claude Rouelle**
**Phone:** + 1 303 752 1562
**Enquiries:** engineering@optimumg.com
**Website:** www.optimumg.com


Lane MOTORSPORT
WE CONNECT TECHNOLOGY
AVAILABLE FROM STOCK
NEW
SE28 / VG95343-5 FUEL RESISTANT
HEAT SHRINK TUBING
ALTERNATIVE TO TE RAYCHEM DR-25
+44 (0) 1403 790 661
LANEMOTORSPORT.COM
MOTORSPORT@FCLANE.COM
SOURIAU
CONNECTORS
Weald
ACCESSORIES
HellermannTyton
HEAT SHRINK BOOTS
ONLINE SHOP
FOR AFTER HOURS ORDERING


KRONTEC
HIGH PERFORMANCE COMPONENTS
WEINNOVATEMOTORSPORTINNOVATESUS
REFUELING COUPLING
HYDRAULIC SYSTEM
STEERING WHEEL QUICK RELEASE
QUICK DISCONNECT COUPLING
AIR JACK SYSTEM
FIRST CHOICE OF TOP-LEVEL MOTORSPORT TEAMS AND RACE SERIES
KRONTEC MASCHINENBAU GMBH
OBERTRAUBLING, DEUTSCHLAND
+49 (0)9401 - 52530
FOR MORE PRODUCT INFO
WWW.KRONTEC.DE
KRONTEC DESIGN LIMITED
SWINDON, ENGLAND
+44 (0)1793 - 422000

# A sticky end

Our britcar BMW M3 E45 wind tunnel study concludes with some front end tweaks, rake changes and lashings of good old race tape

By SIMON MCBEATH

Having previously raced his 3.2 BMW M3 E46 in the UK's Kumho BMW Championship and the CSCC New Millennium series, after sampling a Britcar Sprint race late in 2018 Piers Reid has now moved into the Britcar Dunlop Endurance series. We took the car to the MIRA full-scale wind tunnel to optimise its aerodynamic package.

As ever, the first runs in our session were illuminating. Planning, however, had allowed for most likely eventualities and a raft of modifications were made. The owner's primary objectives were to reduce the drag and also improve the aerodynamic balance. By the session's end we had achieved high downforce and low drag balanced set-ups that compared well with the dry weather baseline setting evaluated at the start of the session, as **Table 1** illustrates. Wing angle reduction and splitter end fences played key roles in early runs, as we highlighted in last month's issue, and from there we examined further front end changes to modify the aerodynamic balance.

## Get it taped

There aren't many aerodynamic devices that can increase downforce while simultaneously reducing drag, but the humble roll of race tape is definitely one of them. It's just a case of applying it in the right places. In this instance tape was used (with a couple of pre-fabricated aluminium offcuts) to mask off the front brake cooling duct inlets; to cover an opening in the centre, rear of the bonnet; to cover gaps above the headlights; and finally to secure some foam board behind the upper grille aperture to improve the seal to the engine airbox. The results are shown in **Table 2** in 'counts', where one count is a coefficient change of 0.001.

Covering the brake duct inlets, which simply fed air into the front wheel arches, was a useful drag reducer as well as an effective means of increasing front downforce. Taping over the aperture in the centre, rear of the bonnet made no difference to drag but contributed

**It's just a case of applying the race tape in the right places on the car**


Illustrations: Simon McBeath

The M3's owner using the smoke plume. The objective of the session was to reduce the drag and find a better aero balance

**Table 1: Baseline aerodynamic coefficients and optimised set-ups**

| | CD | -CL | -CLfront | -CLrear | %front | -L/D |
|---|---|---|---|---|---|---|
| Baseline | 0.462 | 0.589 | 0.205 | 0.384 | 34.8% | 1.275 |
| High downforce balanced set-up | 0.477 | 0.722 | 0.351 | 0.372 | 48.5% | 1.514 |
| Low drag balanced set-up | 0.430 | 0.603 | 0.295 | 0.309 | 48.9% | 1.404 |

**Table 2: The benefits of race tape**

| | ΔCD | Δ-CL | Δ-CLfront | Δ-CLrear | Δ%front* | Δ-L/D |
|---|---|---|---|---|---|---|
| Brake ducts | -5 | +14 | +13 | +1 | +1.1% | +45 |
| Bonnet aperture | 0 | +14 | +13 | +1 | +1.1% | +29 |
| Headlight gaps | -2 | +1 | +4 | -3 | +0.5% | +19 |
| Engine inlet | -2 | +23 | +29 | -5 | +2.7% | +55 |
| Total as % | -1.9% | +8.0% | +22.4% | -1.6% | +5.4% | +10.3% |

** Changes in %front are absolute, not relative.*

Using the race tape worked very well once again. Here the BMW's brake cooling ducts and its headlight gaps are covered exactly the same downforce increment as the brake duct covers. Back on the front panel again, covering the headlight gaps shaved off a little drag and added a small amount of front downforce while, curiously, reducing rear downforce a little too. And most effective of all, creating some prototype ducting to guide air entering the upper grille more effectively into the engine air airbox brought a small drag reduction and another very useful increment of front downforce. Overall the car gained over 10 per cent in aerodynamic efficiency, as given by the –L/D figure, and with a 22.4 per cent increase in front downforce the aerodynamic balance was shunted sufficiently forwards that the car was much closer to our target balance range of 47-50%front. Might be time to buy those shares in race tape manufacturers, then.

## Total downforce and drag both increased more or less linearly with rear ride height over this range, and reasonably efficiently too

**Table 3: The effects of raising rear ride height**

| | ΔCD | Δ-CL | Δ-CLfront | Δ-CLrear | Δ%front* | Δ-L/D |
|---|---|---|---|---|---|---|
| +10mm RRH | +3 | +24 | +30 | -4 | +2.6% | +41 |
| +19mm RRH | +4 | +21 | +10 | +11 | n/c | +32 |
| Total as % | +1.5% | +6.4% | +12.5% | +1.9% | +2.6% | +5.0% |

** Changes in %front are absolute, not relative.*

**Table 4: The effects of dive planes**

| | ΔCD | Δ-CL | Δ-CLfront | Δ-CLrear | Δ%front* | Δ-L/D |
|---|---|---|---|---|---|---|
| Fitting upper DP | +7 | +40 | +41 | -1 | +3.3% | +67 |
| Adding lower DP | +14 | +10 | +12 | -1 | +1.0% | -21 |

## Rake in the gains

As the BMW did not feature a flat floor panel or a rear diffuser at the time of our session, expectations were not especially high that increasing overall rake angle by raising the rear ride height would yield much benefit. However, **Table 3** tells a different story, as rear ride height was raised first by 10mm and then by a further 9mm using packers under the tyres.

Total downforce and drag both increased more or less linearly with rear ride height over this range, and reasonably efficiently too. That both increased can probably be ascribed to the increase in mass flow, and hence velocity, under the car as the rear was raised, leading to more head-on encounters between air and hardware (= drag) yet reduced pressure underneath the relatively flat underside (= downforce) of this typical modern production car. However, the story was not quite that simple, with front downforce gains tailing off quite significantly at the second adjustment. Splitter height had dropped as rear ride height was increased, and was now in the region where the wind tunnel stationary floor's boundary layer may have started to interfere with flow under the front.

At the rear the initial decrease in rear downforce reversed sufficiently to give a net overall gain. This may in part have come from the effective 0.4-degree increase in rear wing angle, which according to our wing mapping in last month's issue could account for 11 or 12 counts of rear downforce gain, so there must have been other gains and losses occurring as well. Nevertheless, increasing rake by 10mm brought the aerodynamic balance right into our target range at 48.5%front, and with the 19mm rear ride height increase the balance was identical and the downforce was the best of the session in a balanced set-up.

## Drag shaving

The last few steps in our session focussed on drag reductions by initially dropping wing angle to about two degrees shallower than previously run. This put the balance too far forwards at 55%front so front end devices were then exchanged or removed until the aerodynamic balance was reinstated. This process produced some useful data on the effect of the dive planes. Removal of the lower dive plane left the upper one in place; removal of the upper dive plane left no dive planes in place. The responses are in **Table 4** as the effects of successively fitting the dive planes.

We can see from **Table 4** that fitting the upper dive planes on their own produced very efficient gains, with 41 counts of extra front downforce for just seven counts of extra drag, yielding a tangible gain in efficiency (-L/D) and a very useful 3.3 per cent forwards shift in aerodynamic balance. Adding the lower dive planes to the upper dive planes however was inefficient, 12 counts more front downforce being accompanied by 14 counts more drag, with a drop in overall efficiency and just a 1.0 per cent shift in %front.

Removing the dive planes and leaving just the splitter end fences in place, along with the new low rear wing angle produced the low drag balanced set up highlighted in **Table 1**.

Next month Aerobytes will feature a brand new wind tunnel project.

Racecar's *thanks to Piers Reid.*

**Double dive planes were originally fitted to the BMW**

**Here the lower dive plane had been taken off the car**

**No dive planes; as featured in the lower drag set-up**

**CONTACT**
**Simon McBeath** offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk.
In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

Produced in association with MIRA Ltd
A HORIBA COMPANY MIRA
**Tel:** +44 (0) 24-7635 5000
**Email:** enquiries@horiba-mira.com
**Website:** www.horiba-mira.com


VAC MOTORSPORTS
VAC tilton
Clutch + Flywheel Kits
-Rally | Race | Carbon Clutches
-Lightweight Flywheel included!
-Twin + Triple Disc Clutches in 5.5"+7.25"
CP CARRILLO
Forged Pistons
-Pistons Avaliable From CP + JE
-Part of VAC Stroker + Turbo Kits
-Perfect For High Performance Applications
Dailey Engineering
Billet Dry Sump Kits
-Increases HP + Reliablity
-4-cyl | 6-cyl | V8 | V10 applications
-Full Kits with Pumps also available!
QUAIFE Drenth
Gearboxes + Differentials
-Rally | Drag | Hill Climb | Road Racing
-BMW | Ford | Chevy | Honda and more!
-Sequential + H Pattern Applications
VACMOTORSPORTS.COM
VACMOTORSPORTS
2501 Snyder Ave. Philadelphia, PA 19145
Mastercam
QUAIFE
SCHRICK
ARP
ARROW
ATI PERFORMANCE PRODUCTS
COMETIC
CP CARRILLO
Drenth
tilton


HEAT EXCHANGER SERVICES
Our ISO graded 'clean room' is available for complete core cleaning and particle cleanliness assessment on radiators, oil coolers and chargecoolers.
Core Cleaning
Ultrasonic, Power Flush, Pulsation, Agitation & Flow Bench
Particle Assessment
ISO 16232, Microscopic & Optical Analysis, Size & Count
Calorimetric, Flow & Pressure Testing
Radiators, Oil, Gearbox, KERs & Chargecoolers
Core Race Preparation
Cleaning, Filtration, Drying
Oil Conditioning and Sealing
www.youngcalibration.co.uk
+44 (0)1273 455572
Unit 4, Ham Business Centre, Brighton Road, Shoreham by Sea, BN43 6RE


All the cars in Formula E, pictured at season five's Berlin round, now run with single-speed transmissions; a far cry from the conventional Hewland 5-speed spec racing gearbox the series started out with back in season one

# Who let the cogs out?

**They may only have one gear ratio but, as our in-depth study into the technical evolution of these transmissions shows, there's absolutely nothing that's low-tech about Formula E gearboxes**

**By GEMMA HATTON**

'Developing a Formula E gearbox is a very long process because we are not optimising a known architecture'

# 'We have to lose as little energy as possible through the transmission to maximise the transfer of torque from the motor to the wheels'

If you were to ask anyone which technologies have progressed the most throughout the first five seasons of Formula E, they would probably reply 'motor efficiency and battery capacity', and they would be correct. But this enhanced capability of the motors, together with the increased freedom of the regulations, has also driven significant developments within the transmission, and today's single-speed Formula E gearboxes are now achieving incredible efficiencies and are a world away from the regulated 5-speed unit that was first introduced in season one.

'It's interesting to analyse the transmission because most of the time in Formula E we talk about the progress on the electrical side,' says Thomas Chevaucher, technical director at DS Techeetah, which won the 2018/19 drivers' and teams' championships. 'But the transmission has evolved a lot throughout the history of Formula E and it is difficult to imagine the steps of development that have been made so far. The main reason for this is because the improvements in electric technology have allowed the transmission to progress. At the level we are now at in Formula E, what you gain or lose in the transmission is more than what you can gain or lose on the electric side, so the transmission is an important part of the overall powertrain performance.'

## 'Box of tricks

A transmission effectively transmits the input torque from the engine or motor to the wheels. It achieves this through several gear ratios which provide the precise amount of torque to the wheels to allow the vehicle to accelerate whilst remaining within the most efficient RPM range of the engine or motor.

'We know the location of the motor axis and the location of the differential axis and the gearbox essentially joins these two together,' says Steve Blevins, project manager at FE gearbox supplier Ricardo. 'It's just a question of joining those two points with the reduction ratio we want, in the most efficient manner possible.'

For a conventional internal combustion engine the most efficient rev range is termed the power band and this is where the engine speed produces the right amount of usable torque for the engine to perform within its optimum condition. For electric cars, this rev range relates to the torque band, which is where the motor operates at its highest efficiency.

'The DNA of Formula E is to improve efficiency,' says Chevaucher. 'This is because we have a limited amount of energy from the battery at the beginning of the race, and that is not enough to complete the race at full pace. So, we have to make the best use of the energy that has been made available to us by the FIA. Every single percentage of efficiency or kilowatt of energy that you save, allows you to go quicker. In an electric car the main areas where you lose energy is in the power electronics, motor and transmission, which is why the transmission is such a crucial thing to optimise in Formula E. There is also a secondary effect. If you have a loss, you have to use more energy from the battery to achieve the same speed. So, poor efficiency has a double disadvantage.'

## Efficiency drive

It is this drive for efficiency that has been the focus of powertrain development since the regulations opened up in season two. This has led to an influx of investment, resource and effort to try and minimise any losses within the driveline, maximising performance and efficiency. 'To give an idea of the progress that has been made on the global powertrain, the efficiency of the overall powertrain in season one was approximately 90 to 92 per cent, which was already impressive,' says Chevaucher. 'For season five, I would say we are now above 95 per cent, while the efficiency of the global transmission is close to 100 per cent.'

In terms of motors, the high spec examples we have today are capable of achieving peak efficiencies of up to 98.5 per cent, which has consequently unlocked significant developments in gearbox technology. The challenge right now is to try and operate the motor within this peak efficiency band throughout the range of motor speeds, and this is the job of the transmission.

'We have to try and lose as little energy as possible through the transmission and so maximise the transfer of torque from the motor to the wheels,' Blevins says. 'Therefore, we need to achieve high gearbox efficiencies. What we are also aiming to do is match the range of gearbox efficiencies to where the motor is most efficient. If we can match the gearbox efficiency at that point where the manufacturers are running their motors most efficiently then that maximises the overall performance of the driveline.'

As a result of this relentless drive for efficiency, Formula E transmissions have evolved from 5-speed boxes in season one to single-speed boxes in season five. To understand why it's worth taking a look at a conventional IC engine. **Figure 1** is the torque curve for a typical IC-engined racecar, which, as would be expected, has the traditional peaked shape. The question is, how many gear ratios will allow the transmission to maximise the amount of tractive effort applied to the track surface?

## Thrust curves

To analyse the above we need to take a look at the thrust curves. These essentially show the actual amount of tractive effort available at the tyre contact patch throughout the speed range of the vehicle. **Figure 2** illustrates the typical thrust curves for a 5-speed gearbox for the IC-engined racecar. The blue line illustrates the maximum speed limit of the racecar dictated by aerodynamic drag.

'The actual power the car is able to put down onto the ground relates to the number of ratios within the gearbox,' Blevins says.

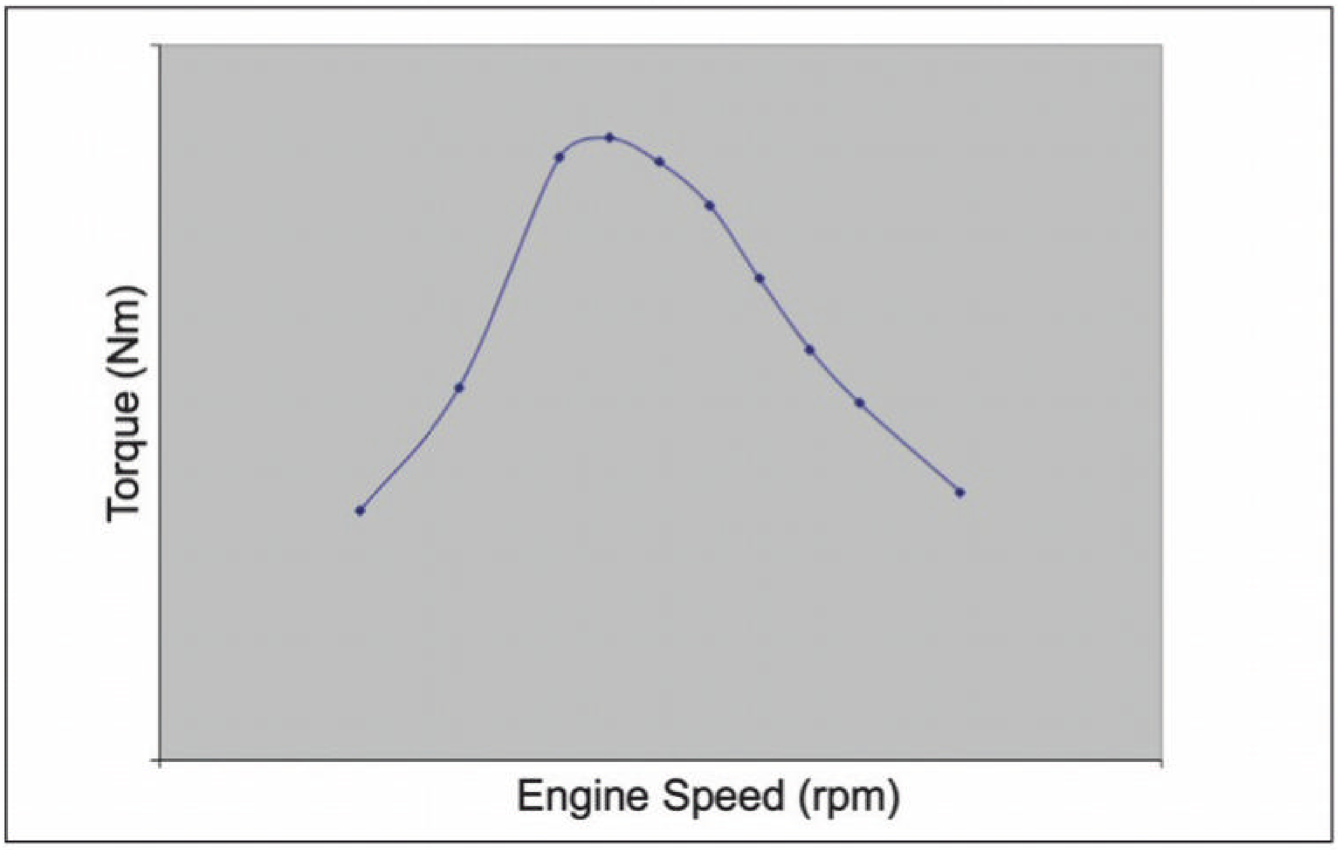



**Figure 1: The torque curve for a typical internal combustion engine showing the familiar peaked shape**

'Therefore, the aim is to use the number of ratios that get the thrust curves to maximise the space underneath the power curve as this means that the maximum amount of power is getting transmitted to the ground. First gear is a large reduction and so transmits a large amount of torque, which is why the tractive effort is off the chart. By the time you get to fifth gear the peaky shape of the thrust curves have levelled out. The red sections highlight areas under the power curve where you are not getting the maximum tractive effort available, which therefore presents an opportunity.'

**Figure 3** shows the thrust curves for a 6-speed gearbox and as you can see, although still evident, the red areas are much smaller. Therefore, in the case of this IC-engined racecar, switching to a 6-speed gearbox maximises the amount of power transmitted to the track; improving performance compared to a 5-speed gearbox. However, this also comes with the compromise of not only having to carry more weight around, but also having more gearshifts for the driver to make, which introduces torque-interrupts during acceleration.

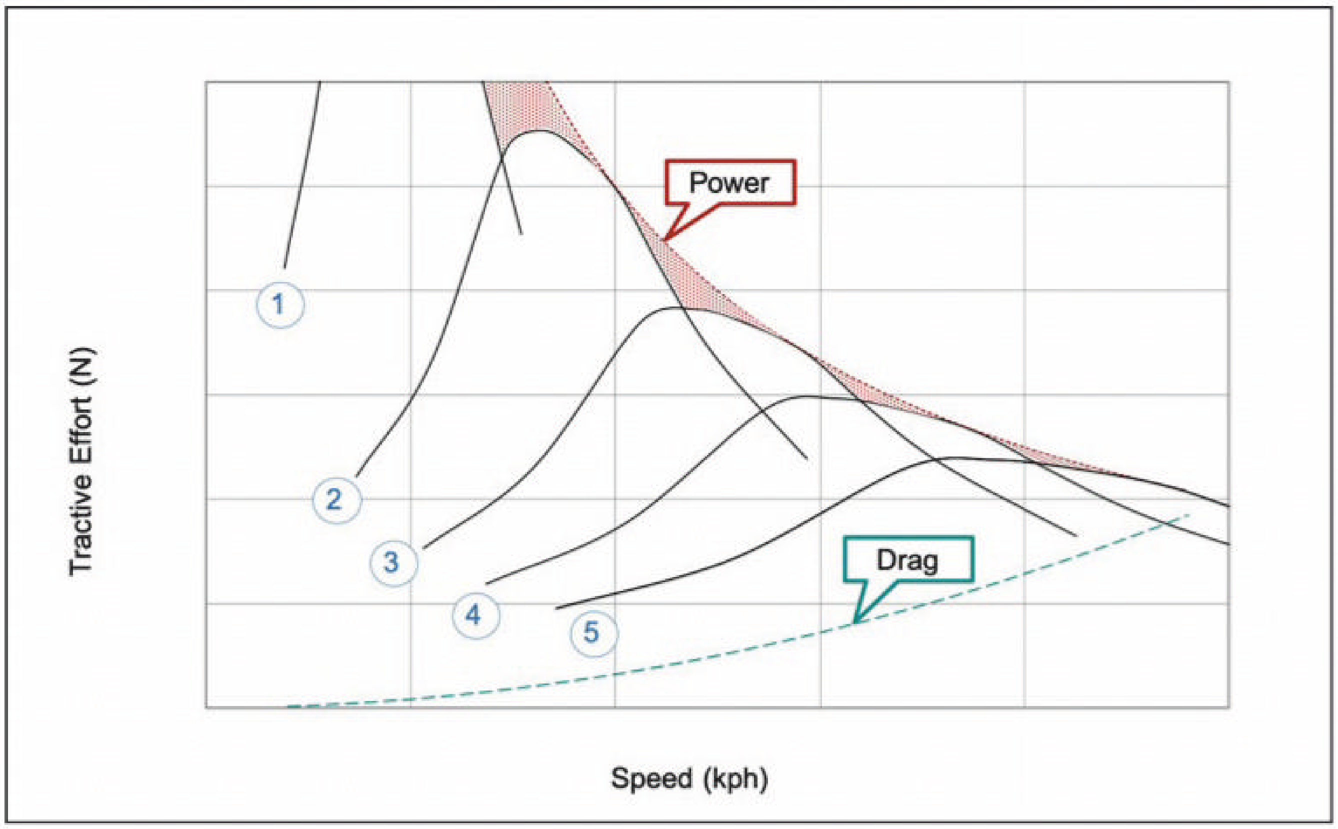



**Figure 2: Thrust curves for a 5-speed gearbox. Blue line illustrates the maximum speed of the car dictated by drag**

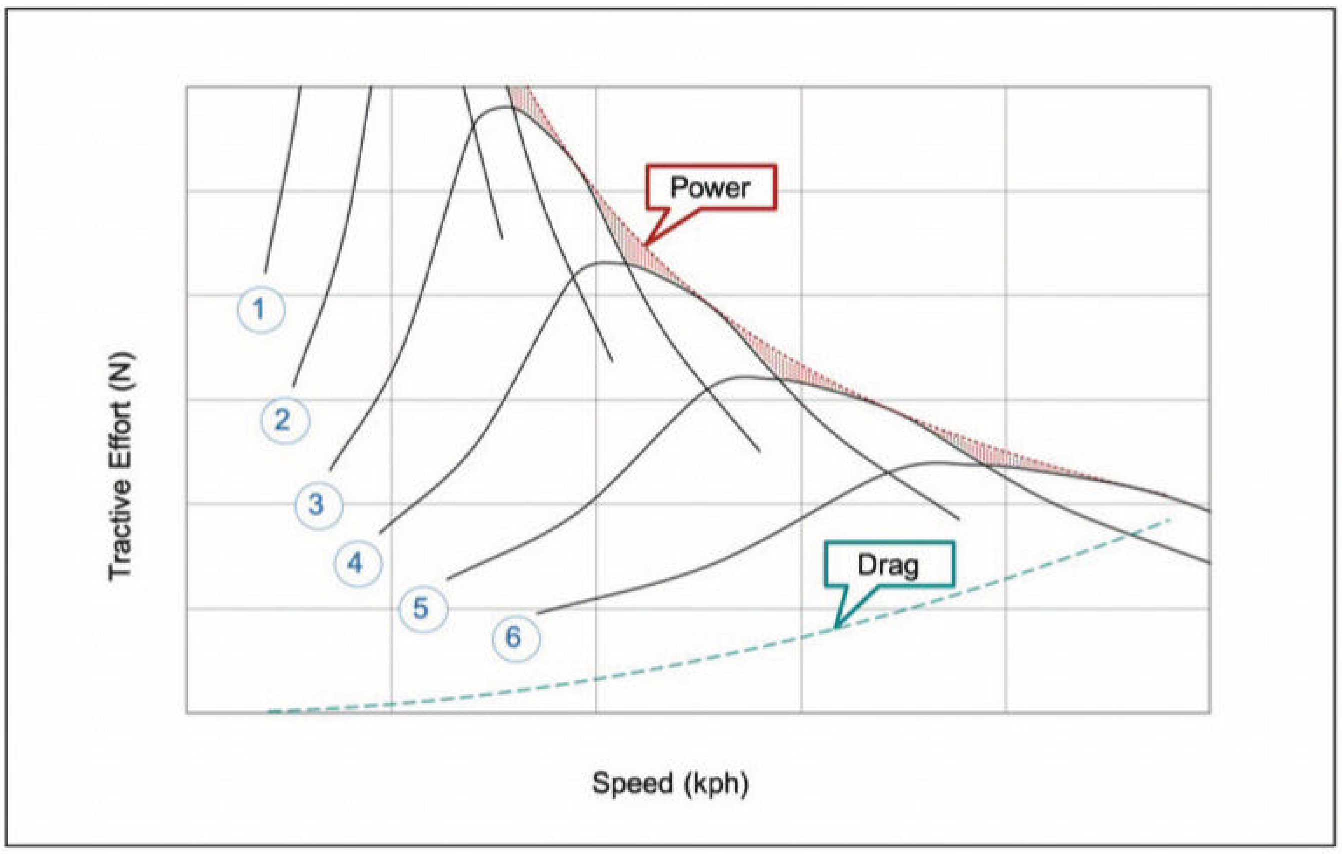



**Figure 3: Thrust curves for a 6-speed gearbox. Note that the red areas are much smaller compared to Figure 2**

**A higher number of gears is counter-intuitive in Formula E because the peak torque curve for an electric motor is a completely different shape to that of an IC engine**

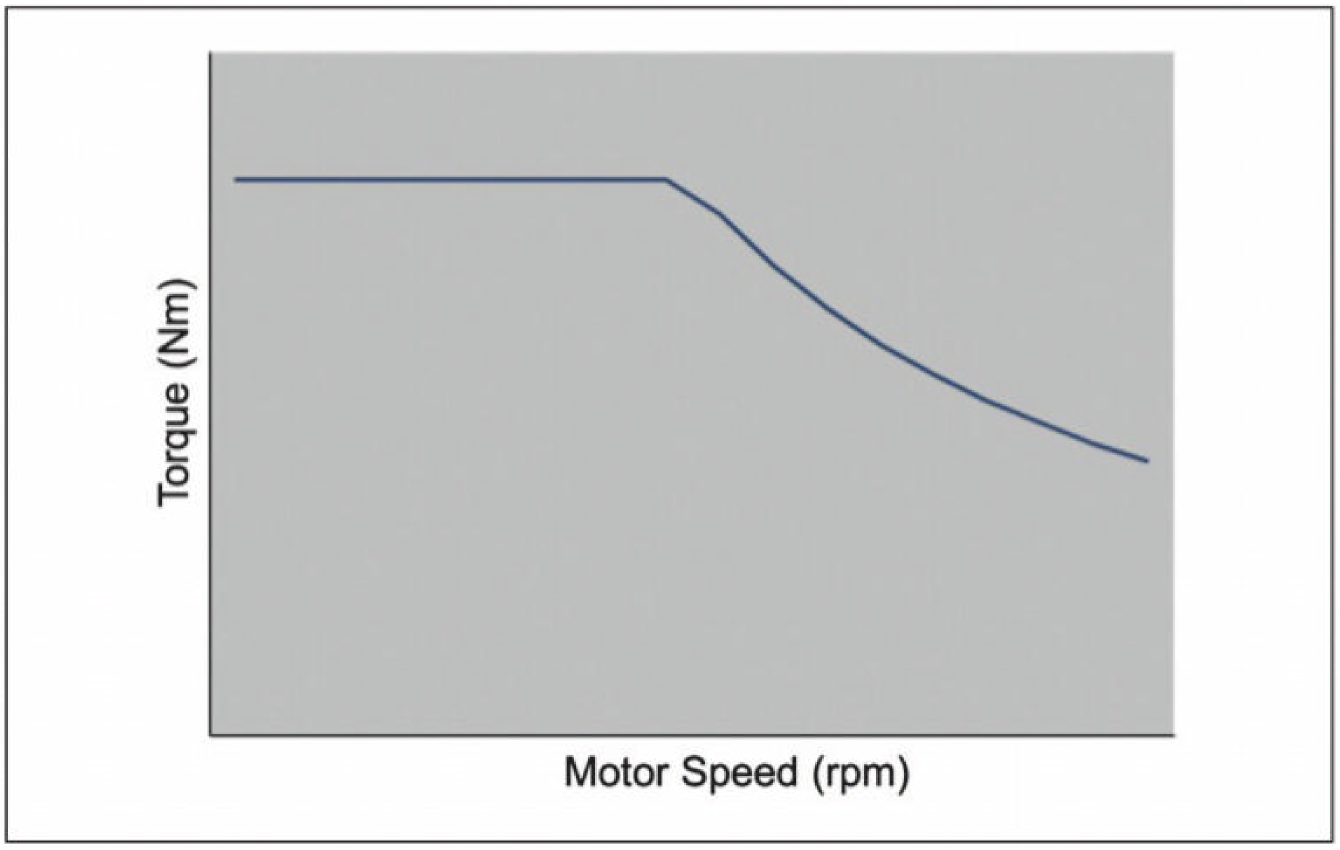



**Figure 4: Peak torque curve of an electric motor. Note gradual decline as the unit becomes power limited**

However, a higher number of gears is counter-intuitive in Formula E because the peak torque curve for an electric motor is a completely different shape to that of an engine, as illustrated by **Figure 4**. Peak torque is instantaneous and then continuous for approximately 50 per cent of the speed range, gradually decreasing throughout the rest of the rpm range as the motor becomes power limited. If we then plot the thrust curves for the season one 5-speed gearbox, we get **Figure 5**.

## Sparked into life

The first season of Formula E ran from 2014 to 2015 and was effectively a spec series. The Gen1 car (STR01) produced by Spark Racing technologies featured a standard 28kWh battery from Williams Advanced Engineering.

## 'This concept requires a large reduction ratio, so we have had to split the reduction up so that it is a two-stage single-speed gearbox'

Drive was provided by a single motor that was mounted longitudinally within a cast aluminium bellhousing and the inverter was mounted above the battery, with both the motor and inverter supplied by McLaren Applied Technologies. Torque from the motor was transferred to the wheels via a Hewland 5-speed gearbox complete with pneumatic paddleshifting. Under race conditions the maximum available power from the motors was limited to 150kW, as per the regulations.

'You can see [in **Figure 5**] that at around 100km/h, the overlap of the curves show that you could effectively either be in first, second or third gear and yet still put the same amount of tractive effort down to the ground,' says Blevins. 'So, you're carrying around parts in the transmission that you don't necessarily need.'

## Second gear

For season two the battery remained fixed, but the regulations opened up to allow development of the powertrain parts downstream of the battery such as the motor, the gearbox, differentials and casings. This saw the introduction of a wide variety of transmission concepts, with some of the teams shifting to 3- and 4-speed gearboxes, with the motor either longitudinally or transversely mounted, while other teams stuck with the original season one hardware.

Only a few new powertrain regulations were introduced for season three, the rest of the rules stayed the same. This allowed a year of progression for Formula E, rather than one of redesign, which enabled teams to evolve their season two concepts. Although by this season all of the teams had moved away from the original 5-speed gearbox.

'We actually switched to a single ratio gearbox in season two, but this was mainly for simplification as there was not much time available for us to develop a more complex unit,' Chevaucher says. 'Everyone knows that at that point [season two] our car was good, but heavy, so for seasons three and four we moved back to a multiple ratio gearbox to work on optimising the performance of the motor.'

The next major step came in season four when the regulations increased the available power from the motors to 180kW. This effectively extended the power curve towards the right, as shown in **Figure 6**. At this point the majority of teams switched to a 2-speed gearbox to reduce the tractive effort overlap between the ratios when compared to **Figure 5**. However, there is still an overlap, in this configuration at around 150km/h you can either be in first or second gear, giving the driver a degree of flexibility as to when to

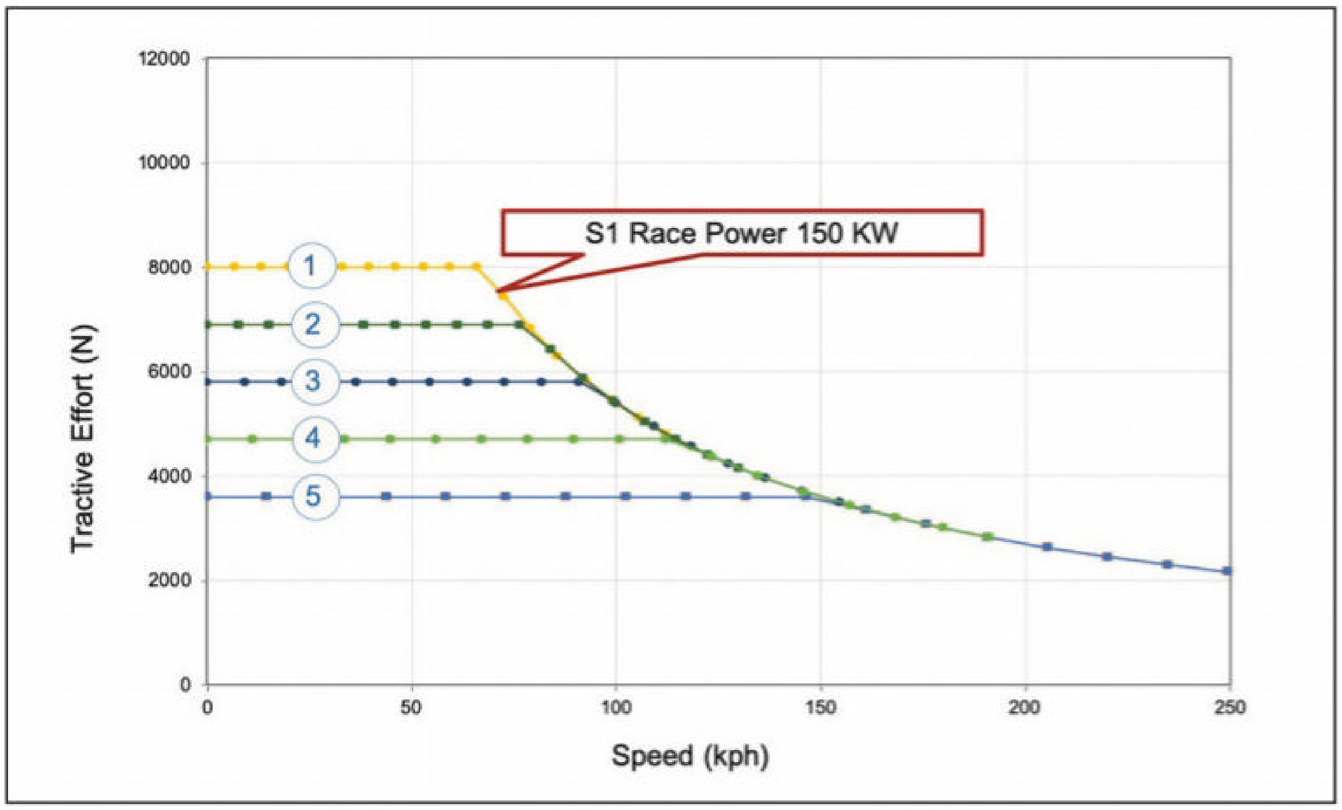



Figure 5: Thrust curves for the season one 5-speed gearbox. At around 100km/h you could use first, second or third gear

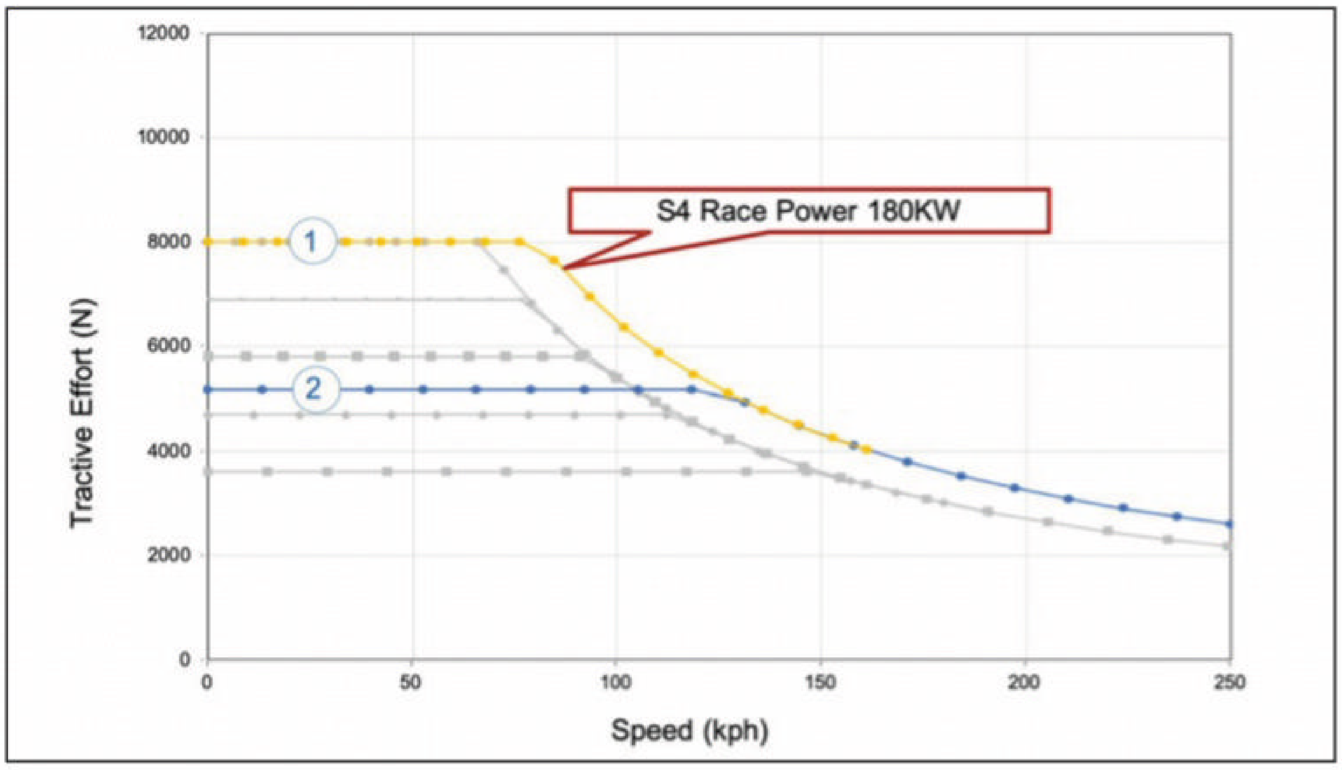



Figure 6: Motor thrust curves for season four. At this point the majority of the FE teams had switched to a 2-speed gearbox

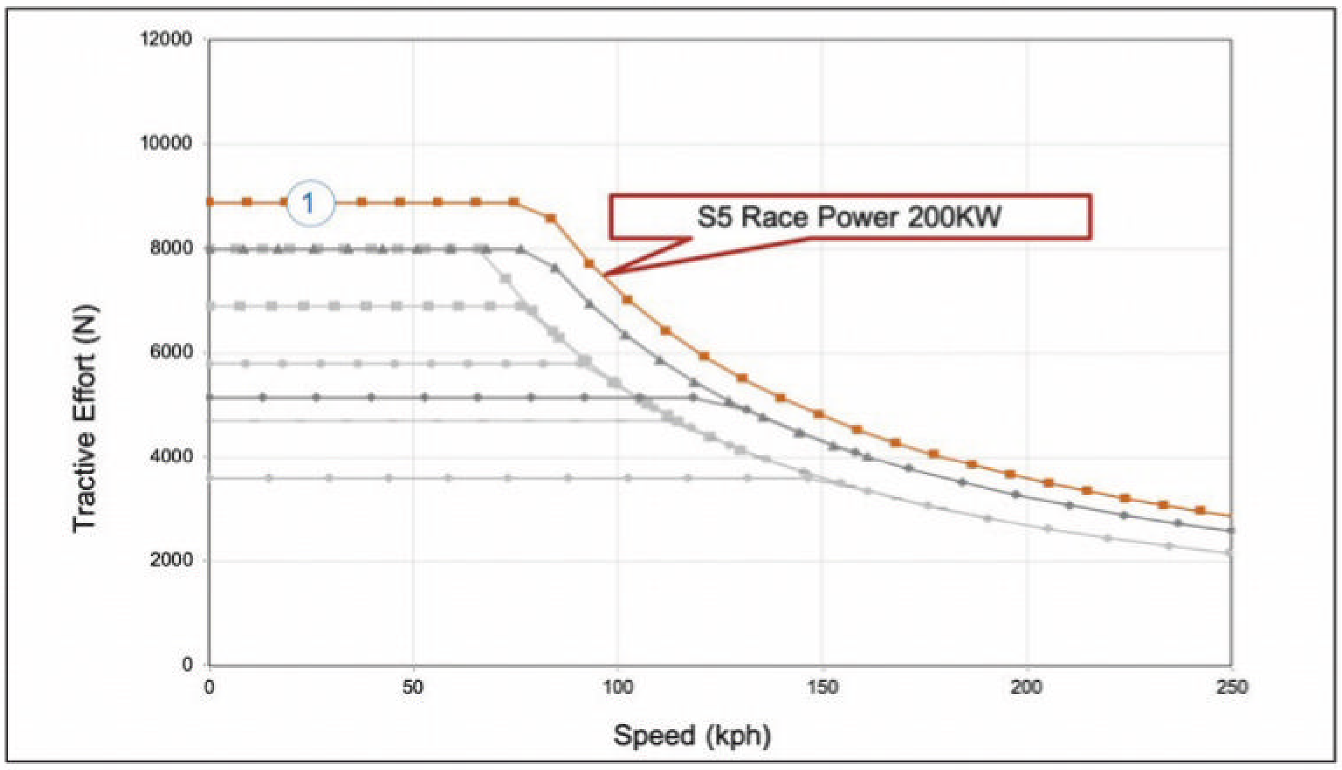



Figure 7: Motor thrust curves for season five. Power is up and single ratio gearboxes are now used by all the teams


KAISER®
RACE TECHNOLOGY
SOLUTIONS MADE OF PASSION
HIGH TECHNOLOGY FOR WINNERS
Formula 1 is the greatest challenge a manufacturer of mechanical components may ever be confronted with. We have embraced this challenge and have attained the status of top supplier with our high tech products.
At Kaiser we manufacture the Chassis-, Engine-, and Gearbox Components our customers require.
... JUST GOOD IS NOT GOOD ENOUGH FOR US!
www.kaiser-wzb.de
F1 RACE PARTS
WEC RACE PARTS
WRC RALLY PARTS
AERO SPACE PARTS

**‘Controlling how oil moves around inside the gear-case is important; it obviously provides lubrication, but it also helps with gearbox cooling’**

shift gear. Unfortunately, the motor performance wasn’t quite there to allow accelerating from zero to maximum speed without a gear shift being required resulting in a single torque-interrupt event.

‘The biggest step so far was between seasons four and five,’ says Chevaucher. ‘Developing a Formula E gearbox is a very long process because we’re not optimising a known architecture like you are for other categories of racing. We are building new architectures which means there are lots of possible routes of development that are not usually possible in conventional IC engines.’

## Fifth gear

Season five saw the introduction of the Gen2 car as well as an increased battery capacity, allowing the race to be completed with a single car (before this they were changed mid-race). The amount of available power and speed from the motors was also increased, power to 200kW in normal race configuration, and as a result, the power curve extended even further to the right. This led to most teams having to effectively start their transmission design from scratch, and all converged on a single-speed transmission.

‘The improved torque and speed range of the motor means that you can now cover 0-200km/h in one gear,’ says Blevins. ‘During the first season of Formula E, you had to carry five gears around to achieve that performance, but now we are able to achieve a better performance envelope with just one ratio. That’s essentially why everyone has now converged towards a single-speed driveline. However, this concept requires a large reduction ratio which is too much to do on a single gear pair, so we have had to split the reduction up so that it is a two-stage single-speed gearbox.’

With all teams now converged on to the same single ratio concept, large performance gains are difficult to make. Therefore, the teams and their suppliers are now having to chase tiny percentages to improve efficiency in an attempt to beat the competition. So, which areas are Formula E transmission suppliers focussing on now? Well, to determine the areas of potential improvement, you first need to identify where the losses are.

‘One area of loss comes from the gear mesh itself,’ Blevins says. ‘Theoretically there is a perfect gear alignment which can be achieved by using the ideal shape of a gear tooth which is a true involute. Gears should roll together, rather than slide and when the shape of the gear teeth migrates away from that true involute you start to induce sliding. This sliding effect can also be caused by shaft deflection, as the gear centres effectively increase under load. Under this condition the tip of the tooth can also begin to interfere with the mating gear creating a further transmission loss. We can predict this and refine the micro geometry of the gear by adding tip relief. But that assumes a degree of deflection, which will change with the level of torque transmitted. Using our experience, and a duty cycle supplied from our customer, we can calculate what average torque the gears are transmitting, allowing us to optimise the amount of tip relief required.’

**Optimising the meshing of two gears depends on everything from tooth geometry to shaft deflections and case design**

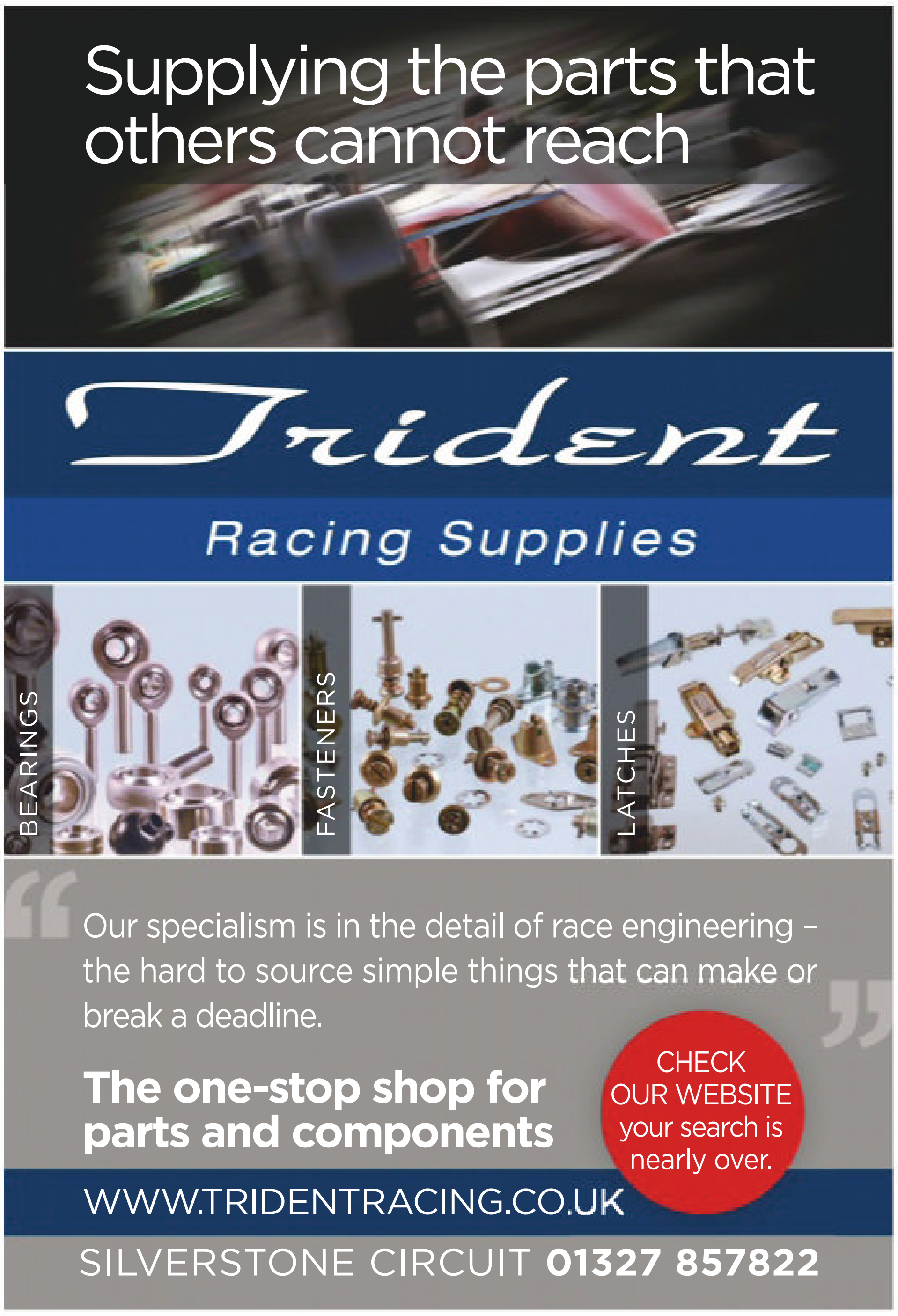
## Oily drag

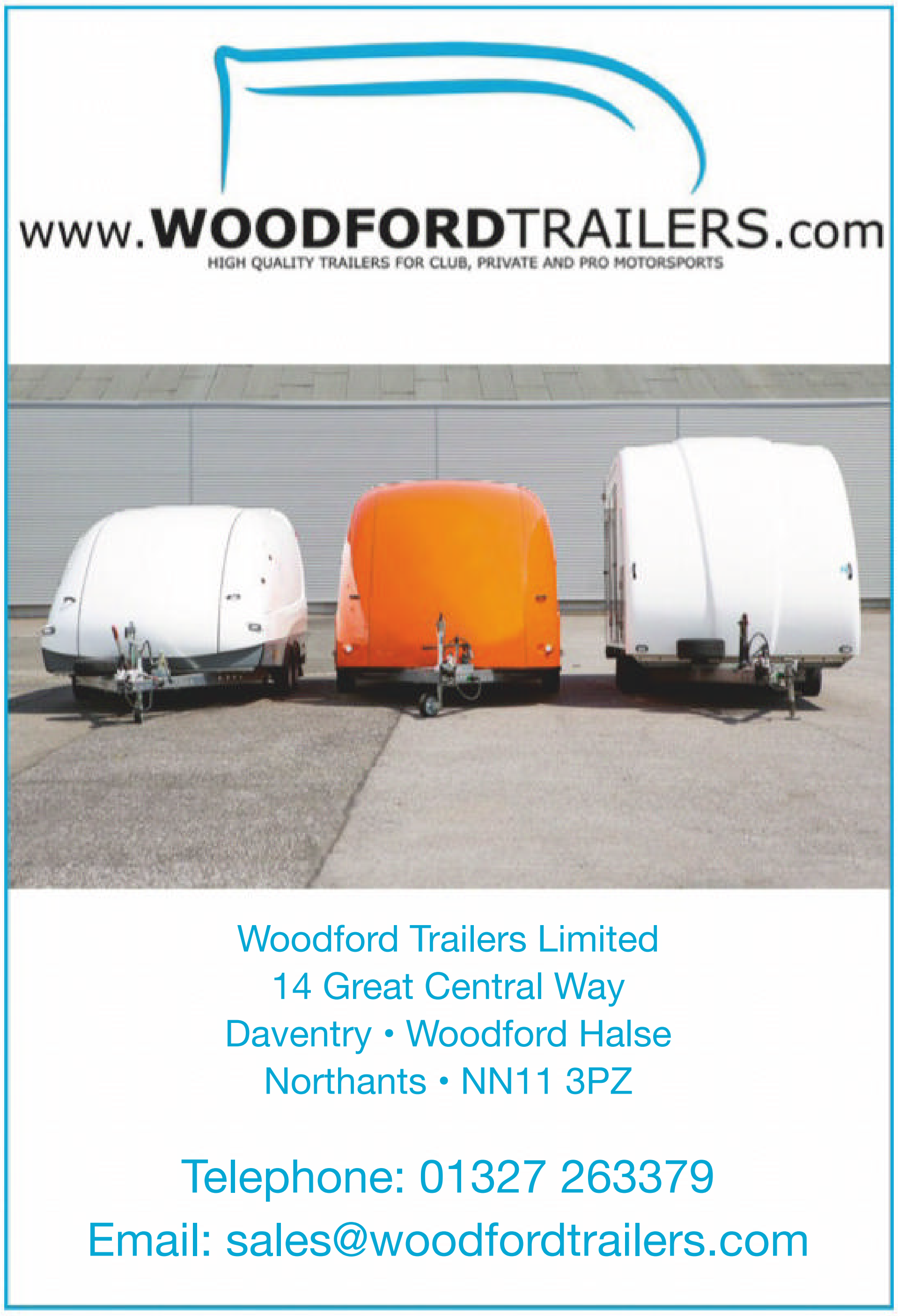
There are also losses associated with the gearbox oil. If the gear assembly is dipped into a sump then the gear teeth have to be dragged through oil as the gear rotates. Therefore, the gearbox layout, gear geometry, case design and oil management are all optimised to minimise this drag. With the mandated multi-speed gearboxes in season one these features were previously not as important, but the competitiveness of current Formula E is forcing suppliers to focus on developing these finer details.

Temperature is another enemy of efficiency and is the second function of the oil. Typically, Formula E transmissions run cooler than, say, a GT gearbox simply because the fewer number of ratios means there are fewer gears meshing together. Also, relative to GT, Formula E boxes are usually transmitting less power. These lower transmission temperatures mean that fewer and smaller oil coolers are required, reducing weight and aiding packaging.

‘We take oil management very seriously,’ Blevins says. ‘Controlling how the oil moves around the inside of the gear-case is very important; it obviously provides lubrication, but it also helps with gearbox cooling. We therefore aim to introduce oil only where it’s needed; trying to keep it away from rotating components elsewhere to minimise any churning losses. We have also done a lot of


Cyprium
MOTORSPORT SYSTEMS
SUPPLIERS OF HIGH QUALITY ELECTRICAL HARNESS SYSTEMS
Cyprium designs product for the Global motorsports industry with our in house expertise, knowledge and know how generated by over 25 years of experience.
TEL: 01379 897262
Contact: Chris Hart chrishart@cyprium.co.uk
or Nigel Barber nigelbarber@cyprium.co.uk
www.cyprium.co.uk


Supplying the parts that others cannot reach
Trident
Racing Supplies
BEARINGS
FASTENERS
LATCHES
Our specialism is in the detail of race engineering – the hard to source simple things that can make or break a deadline.
The one-stop shop for parts and components
CHECK OUR WEBSITE your search is nearly over.
WWW.TRIDENTRACING.CO.UK
SILVERSTONE CIRCUIT 01327 857822


www.WOODFORDTRAILERS.com
HIGH QUALITY TRAILERS FOR CLUB, PRIVATE AND PRO MOTORSPORTS
Woodford Trailers Limited
14 Great Central Way
Daventry • Woodford Halse
Northants • NN11 3PZ
Telephone: 01327 263379
Email: sales@woodfordtrailers.com


PEGASUS
Stocking distributor of silicone hoses
Most comprehensive stock (and most helpful sales staff) of AiM automotive data acquisition products in the USA
Distributor of genuine Red Head push-pull refueling valves
US importer of Jabroc® skid plate sheets
Stocking distributor of MS21071 Apex Joints (all sizes, ¼" to 1 ¼")
... and much more!
Pegasus Auto Racing Supplies • New Berlin, WI USA
800-688-6946 • 262-317-1234
PegasusAutoRacing.com
Racers serving racers around the world since 1980

## 'With the input shaft spinning at up to 30,000rpm you need some pretty trick technologies to reliably survive a season of racing'

work with our customers and suppliers on specifying alternate oil seals and bearings. With the input shaft spinning at up to 30,000rpm you need some pretty trick technologies there to reliably survive a season of racing.

'We've also seen step changes in technology in these components over the last three to four years,' Blevins adds. 'Refinements in the design of these components have helped reduce their losses, adding further fractions of percentage points to your overall transmission efficiency.'

## Case study

Gains can also be made in the design of the gearbox case. Traditionally, these were cast, but for Formula E they are now fully machined from billet aluminium. This means that wall thicknesses are now down to 1.5 to 2mm thick and these are consequently heavily ribbed to help take the gear loads. 'Really [the casing] wall is now just a shroud to stop the oil from leaking out,' Blevins tells us.

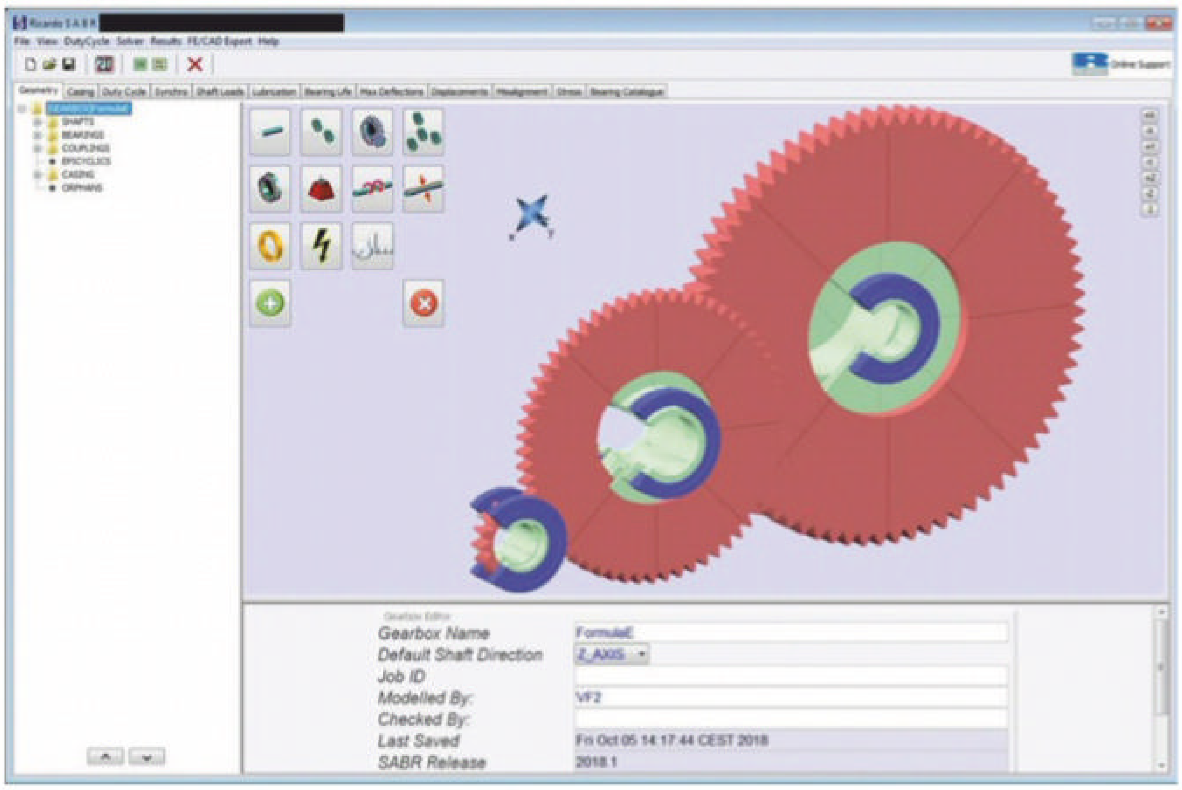
The potential gains of optimising all these aspects of the transmission are modelled and then combined to predict the overall efficiency of the Formula E transmission. This is achieved through two simulation tools specifically developed by Ricardo. The first is called SABR, which models the driveline to determine the shaft deflections and bearing loads, which can then be used to start predicting the potential efficiency of the gearbox.

'Shaft deflections can potentially misalign the bearings and also affect the meshing of the gears,' Blevins says. 'But there may be a case where you will allow the shafts to deflect as increasing their stiffness may force you to add extra weight. Take the example of a simple shaft with a gear in the centre and a bearing either side. When you subject that to a torque, the natural reaction is for the gears to start to separate, so you effectively 'banana' the shaft away from the gear mesh. This will twist the bearings and introduce bearing drag because the inner race and rollers are running misaligned to the outer race. Our experience then tells us what we can do to minimise this effect, either through modifications to the bearing or refinements in the case design.'

## Tooth and nailed

All this is simulated by SABR, which then feeds into another piece of software called GEAR. This analyses everything to do with gear teeth and tooth micro geometry. SABR and GEAR work together in an optimisation loop, running simulations that determine the effect of shaft deflection on the gear meshing and then modify the geometry to account for this. The result is an optimised transmission efficiency prediction which can then be simulated for a range of motor speeds, generating a percentage power loss matrix which is used to support and guide further development.


**CNC gear-cutting equipment at Ricardo. Modern machinery allows the manufacture of extremely complex cog geometries**




**SABR and GEAR are simulation tools developed by Ricardo which work together to optimise gear design**

'The benefit of SABR and GEAR is that they talk to each other,' says Blevins. 'For example, we may be able to save some weight by increasing the bore diameter of a shaft but then that might allow the shaft to deflect too much, which could then misalign the gears and bearings. So, we might have saved 200g in gearbox weight, but SABR and GEAR will show that we have lost maybe 0.5 per cent efficiency because the gears are now running out of position.'

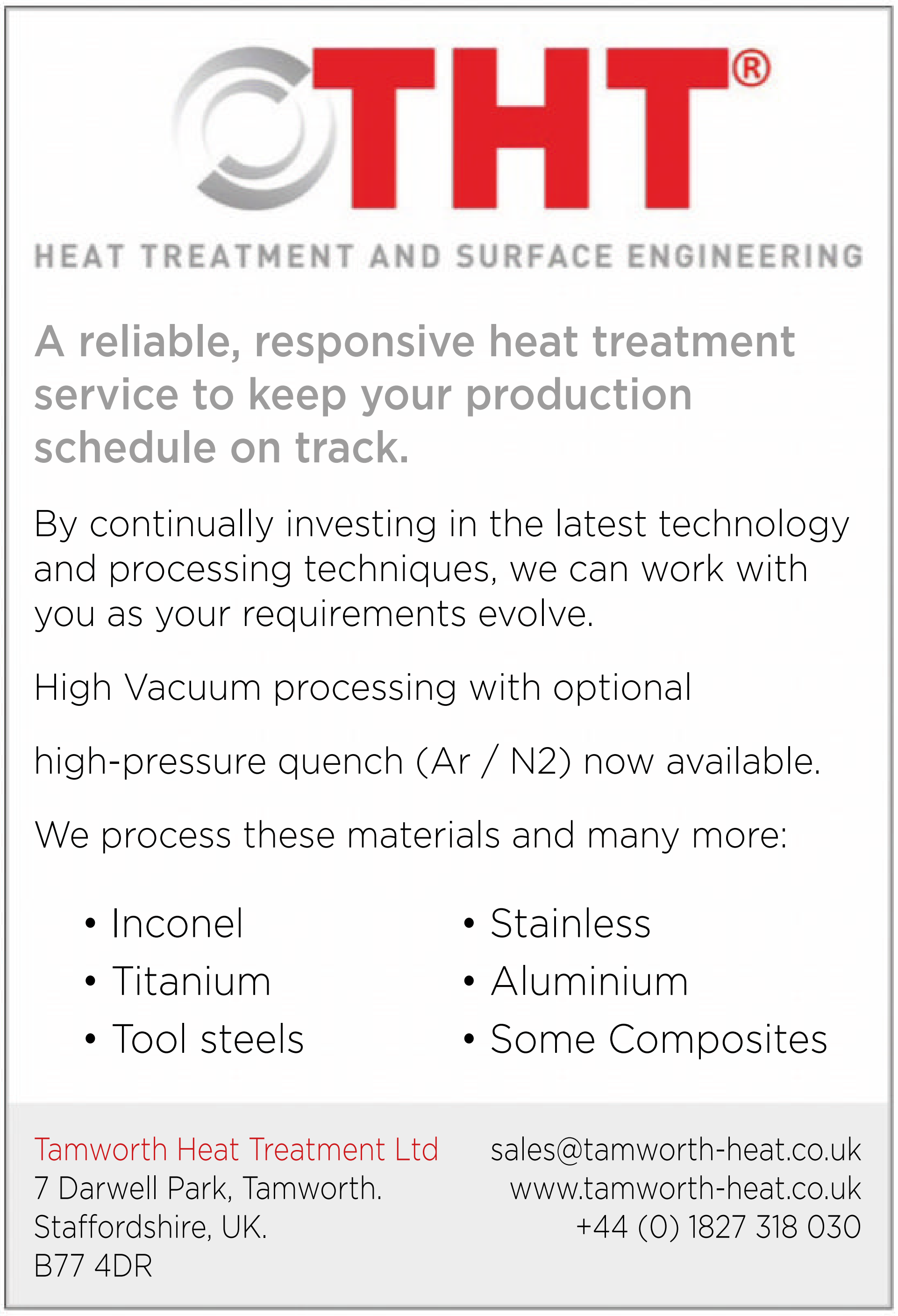
However, there is no substitute for physically making and testing parts, which is why Ricardo has also developed a transmission rig specifically for Formula E gearboxes. This allows it to run the transmission at maximum torque, low speed and low torque, maximum speed and everything in between to determine at which rpm range the gearbox is most efficient. 'Typically, a gearbox is signed off with a number of points within that matrix spread throughout the full torque and speed range of the motor,' says Blevins.

With the season six regulations retaining the same levels of available power from the motors, it is likely that we will see an increase in these impressive efficiencies as the teams in Formula E, and their suppliers, continue to chase the smallest of gains.

Setrab
ProLine
Oil coolers and Intercooler cores
Reliability
Flexibility
Know-how
Visit us at www.setrab.com/proline


KINSLER
We supply systems to Indy, IMSA, NASCAR, World Of Outlaws, USAC, and the list goes on...We offer the same Professional Level Technology to YOU !!!
Precision machined and fully CNC ported for 2 or 3 bolt heads.
Championship Technology for YOUR 911
ed.pink RACING ENGINES
Kinsler GT Porsche ITBs
All linkage is high quality Billet Aluminum...
Our throttle plates are easy to adjust and STAY Synchronized!!!
Throttle shafts supported by bearings, integrated lip seal to protect from dirt.
We partnered with Ed Pink Racing Engines to design a "Direct To Head" ITB package.
Many MORE unique features
Call 248-362-1145 or visit kinsler.com
Kinsler's unique mechanical progressive linkage enhances the driving experience by giving the driver superior throttle control.
Monster Mesh™ Filter
©
EFI Injectors, Lucas Metering Units, and all makes of Pressure Relief Valves need 3 micron protection, but 3 micron filters plug up too quickly, so most racers use 10 micron, which is too coarse. We made this new element for NASCAR Cup cars: 10 micron premium paper top layer to take out 95% of the dirt, with a 3 micron precision Fiberglass lower layer.
Details: Kinsler.com home page.
10/3 Element
K-140 Pressure Relief Valve
Used on 95% of NASCAR Cup and INDY 500 cars
(248) 362-1145
Troy, Michigan USA
sales@kinsler.com


mjtech limited
With a wealth of knowledge we are specialists in motorsport transmissions covering rebuilds, design and reverse engineering of parts for all types of gearboxes and axles.
Supporting teams in the World Endurance Championship, European Le Mans Series, Blancpain, Masters Historic Championship and Formula E.
On completion, gearboxes are run on our spin rig to check oil temperature, oil pump pressure and oil flow as well as input and output rpm.
M J Tech Limited are also Aerospace certified in Non Destructive Testing (NDT) using the Magnetic Particle Inspection and Dye Penetrant Inspection methods.
All internal components and casings are crack checked on strip down and reported on prior to rebuild.
NDT of suspension and driver controls for teams in Historic championships for scrutineering passports.
Tel: 01525 240022 • Email: enquiries@m-j-tech.com
Web: www.m-j-tech.com • M J Tech Limited

THT®
HEAT TREATMENT AND SURFACE ENGINEERING
A reliable, responsive heat treatment service to keep your production schedule on track.
By continually investing in the latest technology and processing techniques, we can work with you as your requirements evolve.
High Vacuum processing with optional
high-pressure quench (Ar / N2) now available.
We process these materials and many more:
• Inconel
• Titanium
• Tool steels
• Stainless
• Aluminium
• Some Composites
Tamworth Heat Treatment Ltd
7 Darwell Park, Tamworth.
Staffordshire, UK.
B77 4DR
sales@tamworth-heat.co.uk
www.tamworth-heat.co.uk
+44 (0) 1827 318 030

The Bloodhound project has been rescued from the financial brink and the Land Speed Record car is set for high speed test runs in South Africa in the autumn

# Flying low

**The aero wizard behind the recently resurrected Bloodhound Land Speed Record project, and its driver, explain why you shouldn't think solely in terms of high speed car *or* aircraft aerodynamics when it comes to the stability and control of supersonic vehicles**

**By RON AYERS and ANDY GREEN**


## The dynamic yaw response of Bloodhound will probably feel like that of a supersonic hovercraft or hydrofoil, if such things existed

Is it a high-speed car? Or is it a very low flying aeroplane? When considering the stability and control of very high velocity cars, the answer is: neither. These vehicles have unique characteristics and their stability must be analysed from first principles.

Much has changed since the early jet cars of the 1960s. Access to computational fluid dynamics (CFD), CAD systems and low-cost instrumentation has transformed the field of Land Speed Record (LSR) attempts, and it is now feasible to design record cars that will exceed the velocity of sound.

This piece is a summary of lessons learned from Thrust SSC and the JCB Dieselmax, which are being employed in the design of Bloodhound, the project that aims to break the 1000mph barrier and is due to undergo high speed testing at Hakseen Pan, South Africa, this autumn, where 500mph is being targeted. The project has been relaunched recently after being saved by businessman Ian Warhurst.

Dieselmax is included here because at its top speed of 350mph the flow around the wheel-to-ground contact points locally exceeded the velocity of sound. Thus, Dieselmax genuinely qualifies as 'transonic', since this is actually defined as 'locally experiencing both subsonic and supersonic flows'.

We'll start this examination by looking at wheel loads. As a vehicle running by itself on a smooth surface without obstacles, there is only one object with which the LSR car can have a collision, and that is the track surface – there is nothing else to crash into. Therefore, to avoid such a collision, the primary safety of the vehicle comes down to keeping all of the wheels on the ground, all of the time. You can't have a crash with something you're already resting on.

In the case of Bloodhound we aim to ensure that the download (due to gravity plus aerodynamic up/downloads) is predicted to be never less than 10kN (kilonewtons) on each wheel. Thus, there is a margin to ensure that unexpected and transient loads (for example, due to crosswind gusts, or steering inputs, irregularities on the track surface, etc.) will never result in a wheel leaving the ground.

# In a perfect world the wheel downloads would remain constant throughout the speed range, but in reality this is not possible

In a perfect world the wheel downloads would remain constant throughout the speed range, but in reality this is not possible. Instead, the wheel loads need to remain positive (to avoid leaving the ground) and bounded (to avoid structural overload of the chassis or indeed the surface). The generic target we identified for Bloodhound was to bound the wheel loads to between 50 per cent and 150 per cent of the load due to gravity (from which the above 10kN minimum is derived). This target is simple to express but extraordinarily difficult to achieve across a speed range from zero to Mach 1.4 (1000+ mph). Nonetheless, it provided the essential objective that drove the five years and more of aerodynamic research that went into establishing Bloodhound's basic shape.

An alternative approach to bounding wheel loads is to trim the vehicle using active aerodynamic surfaces (such as winglets) to adjust the vertical loads during the run. But having assessed the complexity of a suitable system to achieve this, and the huge negative implications for safety if it malfunctioned in any way at high speeds, we decided to take the longer route for Bloodhound, and to find a shape that would stay on the ground by itself without active aero trimming.

## Static stability

Now we will consider static stability in pitch. Static stability is the tendency to return to the neutral position when the vehicle is displaced. Put simply, if a displacement caused the vehicle to diverge, it is statically unstable, while if it returns to the neutral position, it is said to be statically stable. In theory, a vehicle will remain on the ground if the total vertical down-load (the sum of gravity, aerodynamic forces, pitch due to thrust, pitch due to drag, etc.) acts anywhere within the trapezium shape defined by the wheel/ground contact points. In practice more stringent criteria apply, and the centre of download should act somewhere near the mid-point of the wheelbase or problems of stability and control are likely to result.

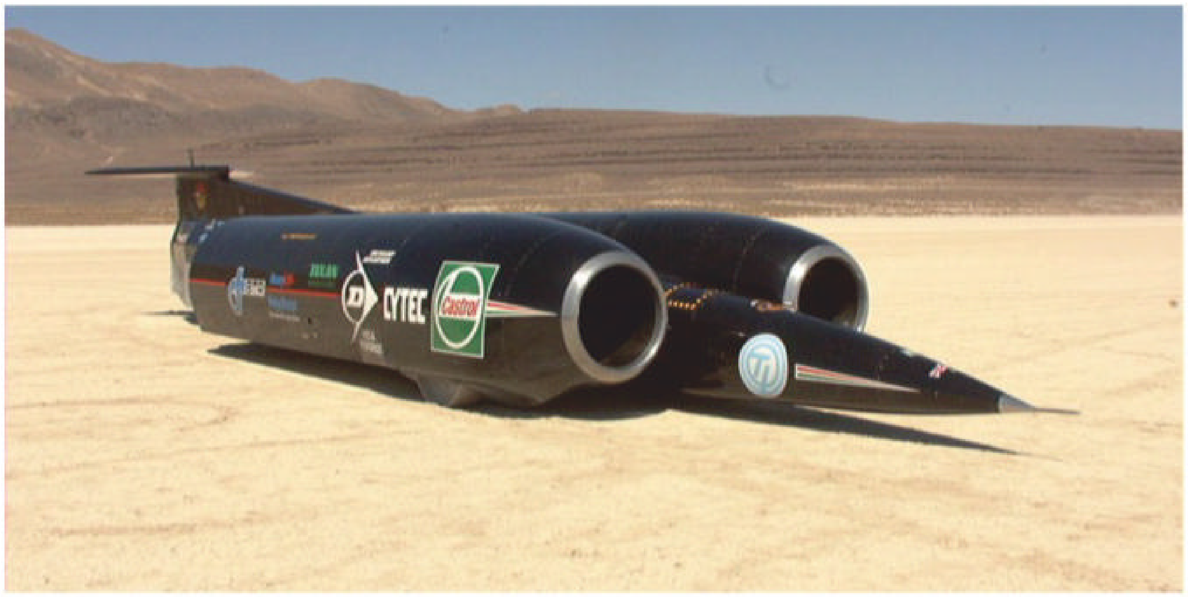
It is sometimes stated, erroneously, that it is the aerodynamic centre that controls pitch stability. The aerodynamic centre does indeed have significance, but in connection with dynamic stability (of which more later).

But it's with stability in yaw where the differences between automobile stability theory and aircraft stability theory really become apparent. An automobile is said to be stable if the centre of download is behind the centre of gravity as in **Figure 1** (here the rear axle is experiencing more download than the front axle, generating more lateral grip and ensuring the car has understeer).

An aircraft is considered stable if the yaw centre of pressure is behind the centre of gravity (like an arrow), as in **Figure 2**.

For a high-speed record car both are significant, as automobile stability dominates at low velocities (since the aerodynamic forces will be small) but aircraft stability is massively dominant at high velocities. And there will also be intermediate velocities, likely to be in the region of 200mph to 400mph, where they will each make a significant contribution.

However, there could be a problem with the automobile component of stability of jet




Thrust Programme Ltd

**Thrust SSC broke the Land Speed Record with 763mph in 1997, making it the first supersonic land vehicle**


**While Dieselmax was not jet-propelled it was technically transonic – in that localised parts of it experienced both supersonic and subsonic flows**

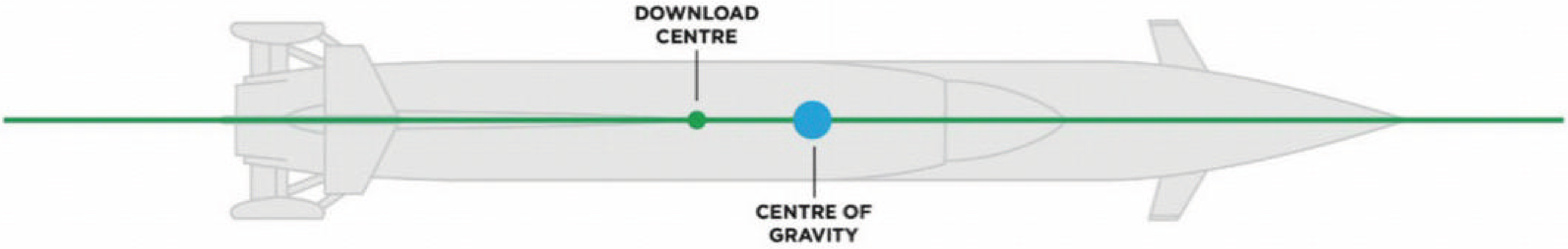



**Figure 1: The rear axle is experiencing more download than the front, generating more lateral grip and causing the 'car' to understeer**

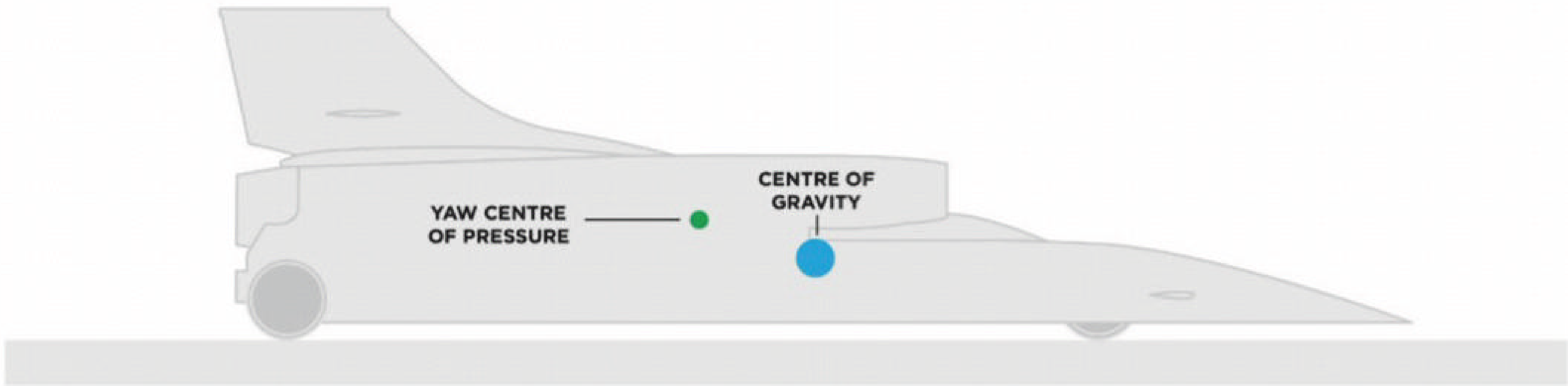



**Figure 2: An 'aircraft' is considered to be stable if the yaw centre of pressure is behind the centre of gravity, like an arrow**

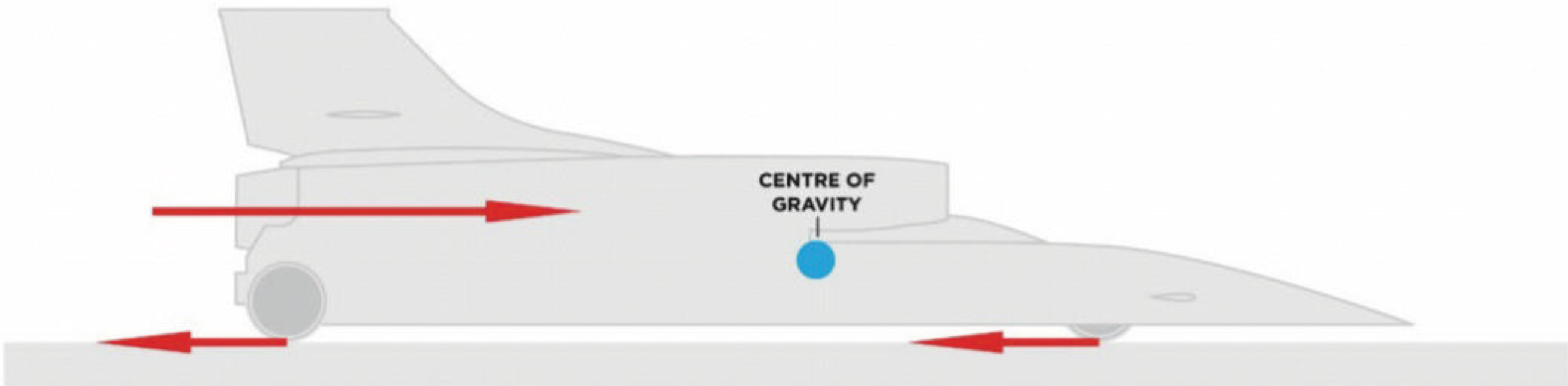



**Figure 3: The stability can be negative in the sense that the thrust-line of the jet engine is higher than the vehicle's centre of gravity**

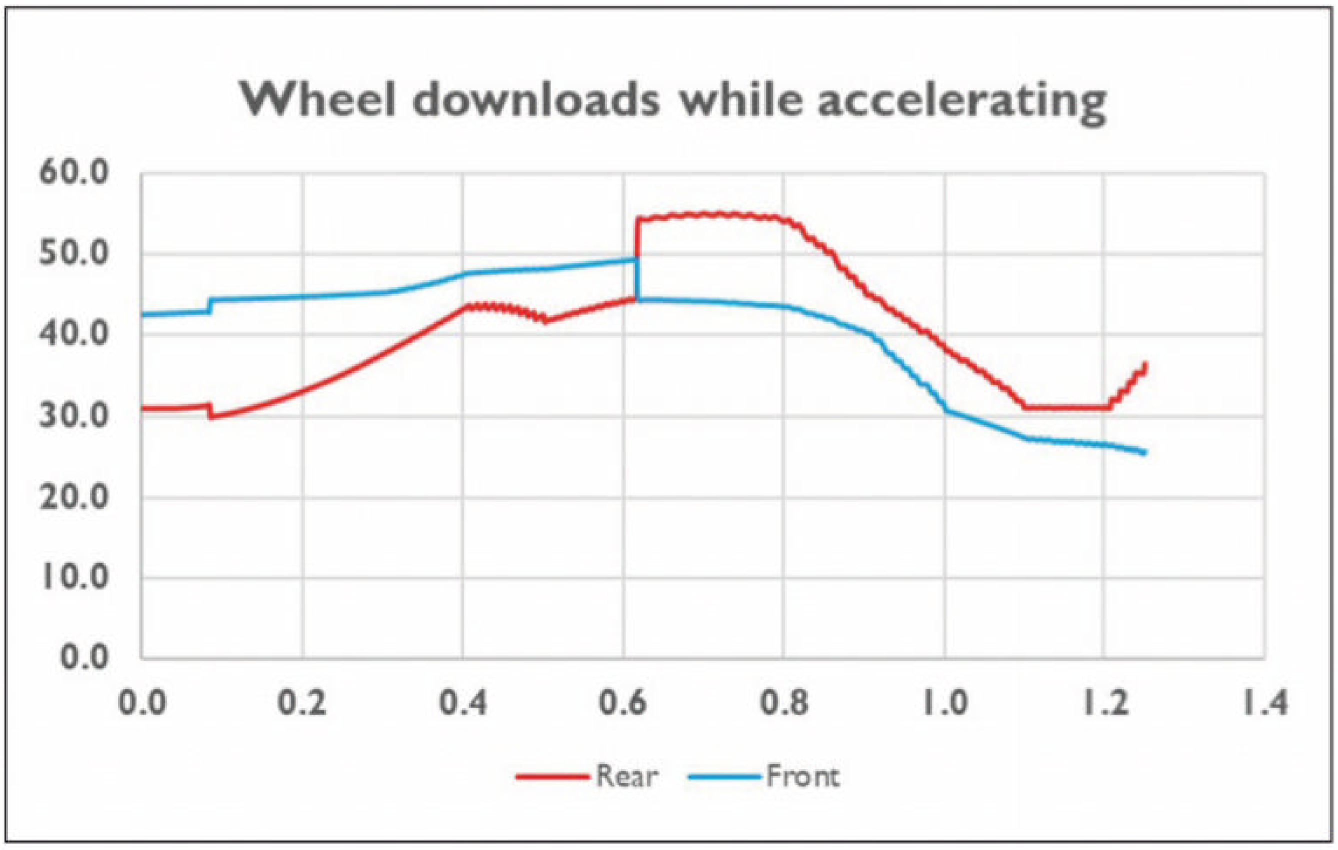
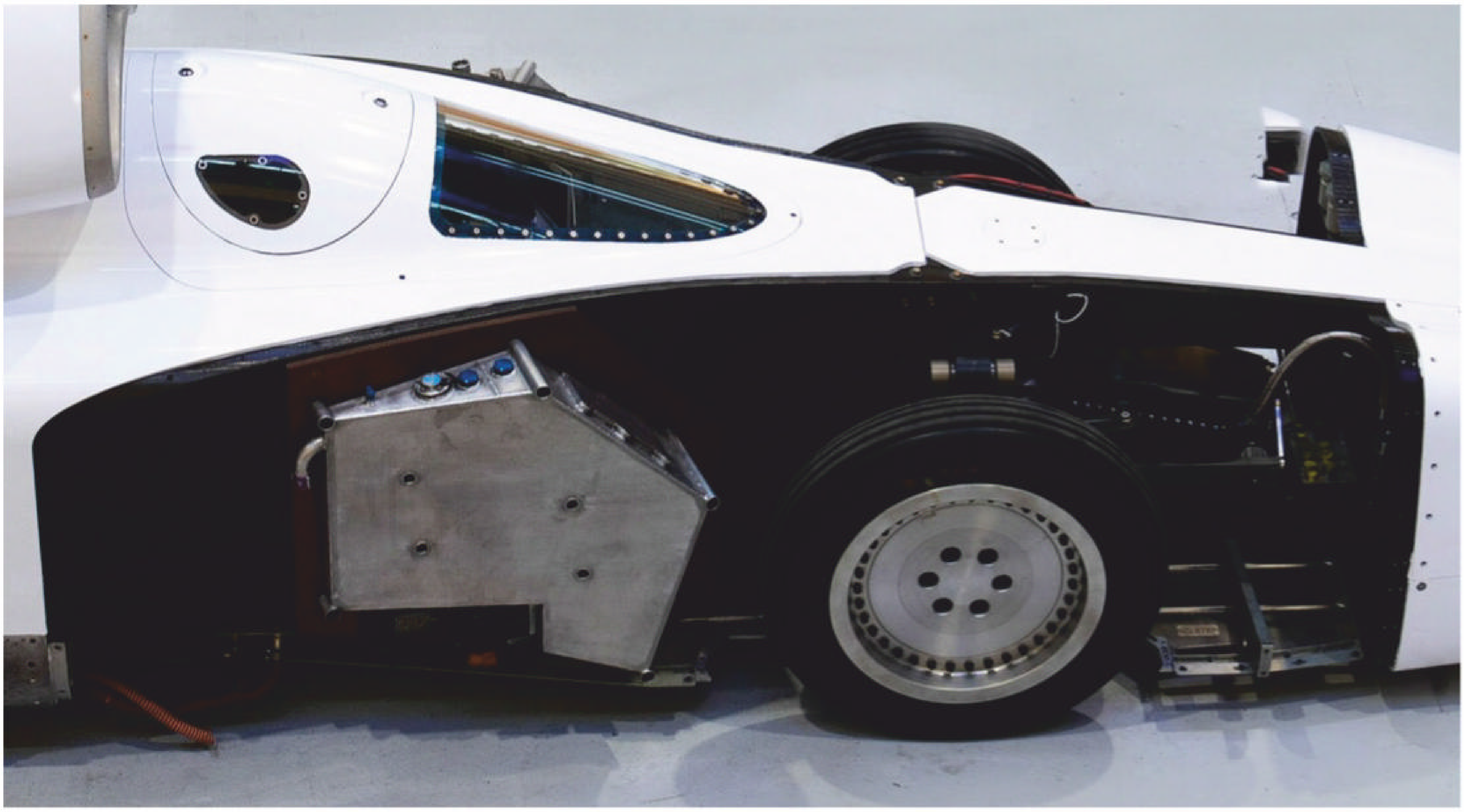



**Figure 4: Here the *Y* axis shows downloads in kN, *X* is Mach number. At Mach 0.62 the rocket in the tail of the car ignites**

powered cars. Namely, that the automobile stability can be theoretically *negative*, so at first sight they should be difficult to drive at low velocities. The stability can be negative in the sense that the thrust-line of the jet engine is higher than the vehicle centre of gravity (since much of the vehicle mass is in the chassis and the wheels) thus generating a nose down pitching moment, so giving more download on the front wheel than on the rear. This nose-down moment will be increased by the influence of wheel drag on the surface making the car even more unstable (**Figure 3**).

The graph (**Figure 4**) illustrates the influence of the thrust line-of-action for Bloodhound. It shows the computed downloads for the front and rear pairs of wheels (in kilonewtons) against Mach number as the car accelerates up to a Mach number of 1.35. At Mach numbers below 0.62, front wheels experience greater downloads than the rear wheels due primarily



For runway testing Bloodhound has used regular rubber tyres but for the high-speed desert tests and the Land Speed Record attempt itself solid aluminium wheels will be fitted

to the high thrust line of the jet. According to the theory of stability for cars, this is clearly destabilising. At M = 0.62 the rocket ignites and its lower thrust-line restores the (download-related) stability for the rest of the acceleration.

## Instability theory

The question arises, does this theoretical instability matter? At low Mach numbers, say below about 0.2, the fin will not be providing much positive stability so one might expect the automobile instability to cause steering problems. However, we have personally met or communicated with drivers or designers from most of the jet/rocket powered cars since they began breaking records in the 1960s and none of them referred to problems of directional instability on deserts (with one exception; Thrust 2 did suffer serious steering problems when its metal wheels were badly affected by conditions on a rutted Bonneville salt surface, but no steering problems were subsequently experienced on Black Rock Desert's more compliant dry mud lake bed). We infer from this that the rate of divergence of these very long vehicles is sufficiently slow that the driver's reflexes can correct for any steering deviation – probably without the driver even realising that the car is unstable. Thus, we appear to be in the region described as 'unstable but controllable'. A bicycle is another vehicle that is unstable but still controllable even at low speeds.

But will yaw instability present a difficulty for Bloodhound in this velocity range? With a wheelbase of 8.9 metres there should not be a significant problem. But the first runs into this velocity range will still be treated with appropriate caution – just in case.

As the velocity increases, the aerodynamic component of yaw stability becomes increasingly dominant. At this point, the key parameter for yaw is the yaw static margin, i.e. the distance between the centre of gravity and the aerodynamic centre in yaw. It is essential that the yaw static margin is positive as speed increases – if the static margin is negative, the vehicle will try to swap ends, an effect that would increase with speed until it overwhelms all other forces and the driver loses control.

What is the ideal value for yaw static margin? For Dieselmax we aimed for two to three per cent of the wheelbase. This worked well in a gusty crosswind and is also the target figure for Bloodhound. But this may not be easy to achieve since yaw static margin varies significantly during the course of a run due to the fuel consumption moving the centre of gravity and the yaw centre of pressure varying with Mach number. Experience will show us what works best.

The above analysis makes no reference to the type of surface the vehicle is traversing, but solid wheels on a desert will have very different characteristics from rubber tyres on a road. For instance, the unyielding shape of the aluminium wheel must sink into the desert surface. Experiments have shown that Bloodhound wheels will sink about 7mm to 8mm into the Hakskeen desert surface (the South African venue for the attempt) at low velocity. Computations show that at 1000mph the wheels will 'plane' at a depth of about 3mm, so surface compliance will provide little assistance to the suspension. Rolling resistance will be some two to three times greater than for rubber on tarmac throughout the velocity range.

## Fluid deserts

The lateral constraint on a solid wheel by the desert is still a matter of conjecture, but clearly it will be much less than for a rubber tyre/tarmac contact. Crude experiments at low velocity show that the desert structure breaks away for any lateral load greater than about 0.35*g* to 0.4*g*. At still lower sideloads, it is not clear whether lateral constraint will exhibit the characteristics of viscous friction or of some other compliance law. As the record car accelerates towards the 600mph mark the desert fluidises at the wheel contact points, which clearly will reduce the lateral grip still further, so the handling characteristics will be constantly changing.

Rubber tyres on tarmac generate increased lateral grip as the download increases. It is quite possible that solid metal wheels running on a desert race track will also create higher

**Automobile stability dominates at the lower velocities, but aircraft stability is massively dominant at higher velocities**

## As the record car accelerates towards the 600mph mark the desert actually fluidises at the wheel contact points

lateral grip at higher downloads, but this effect is not quantified, or indeed certain. It is quite likely that the extra lateral grip generated by increased download is relatively small – this may provide part of the explanation to why 'unstable' LSR cars described above do not appear to be difficult to drive, as the destabilising forces involved could be relatively small.

The performance of Thrust SSC (which became the first land vehicle to officially break the sound barrier in 1997) was actually severely impaired by spray drag caused by an underbody shockwave penetrating the porous desert and kicking up loose sand, which impinged on the rear structure and suspension. Bloodhound has been designed to minimise this problem.

### Wheel-driven

It is worth noting here that wheel-driven Land Speed Record vehicles suffer an additional complication, in that the driven wheels are providing some (possibly all) of their grip to traction, leaving nothing for lateral stability. This was not a major concern for Dieselmax as it was four-wheel drive. To provide further confidence, the power to the rear wheels was limited to make sure that rear wheel RPM did not exceed front wheel RPM, to avoid the possibility of spinning up the rear wheels and producing an oversteer moment. Clearly this is not a solution for two-wheel drive record vehicles, which will always have to face stability challenges at high power settings.

Of course, gust sensitivity and yaw stability must also be explored. When travelling at supersonic velocities any crosswind gust would be experienced as being sharp-edged. Too much stability would jerk the car head-to-wind so can be just as problematic as too little stability. In considering the yaw static margin above, it is therefore not enough for it simply to be positive. It also needs to be carefully bounded, which leads to the above target being set at two to three per cent.

The problem is that yaw static margin is difficult to assess, without extensive (and expensive) computer modelling. Worse, it is almost impossible to measure objectively once the vehicle has been built and is running. However, experience with Bloodhound itself suggests a test approach that may be of use.

### Runway success

During the runway testing of Bloodhound in 2017 the car was tested at an airport and at a time of the year where gusty crosswinds were the norm. In addition, the initial car testing was conducted without the tail-fin fitted. Without the fin, the yaw static margin would clearly be negative. This was deemed acceptable, due to the low speeds (under 200mph) and high-grip rubber tyres being used on the runway. Once the fin was fitted, the static margin became positive. The difference could clearly be seen in frame-by-frame post-run analysis of in-cockpit video. Without the fin, the crosswind gusts were blowing the nose downwind, followed rapidly by driver corrections on the steering wheel. Once the fin was fitted, gusts would cause the nose to move into the wind, with the driver's corrections now in the opposite direction, downwind, to correct.

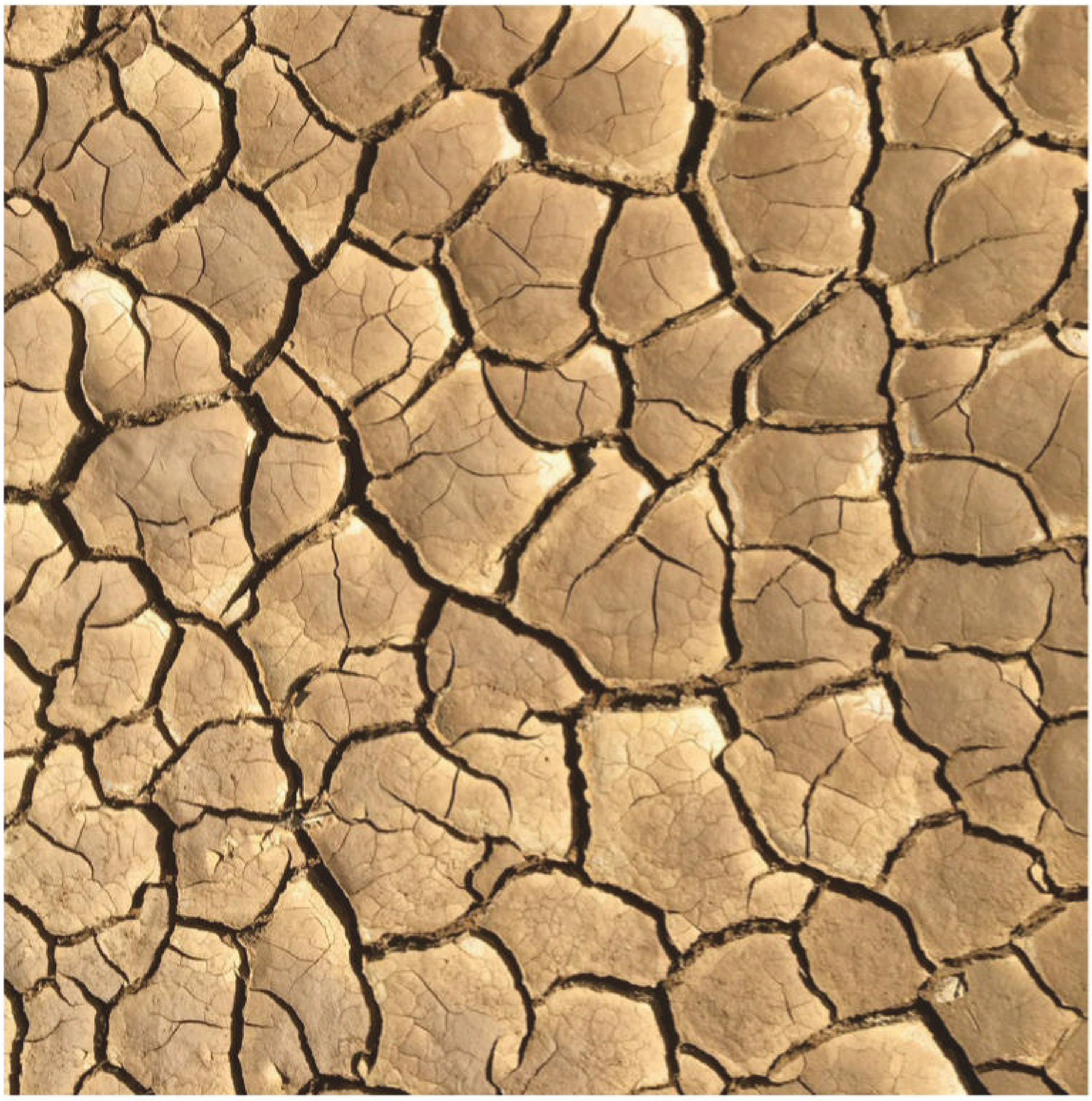
This use of in-cockpit video provides a cheap way to assess the yaw static margin throughout the speed range (which is otherwise actually pretty much impossible to measure), based on the way the car handles as the crosswind varies. For test runs without a crosswind, the effect can be simulated by putting a small 'kick' into the steering, to see how the car responds. We plan to use this technique, which is similar to methods for measuring aircraft stability, during the high-speed testing of Bloodhound.

If crosswind effects are a concern, then one obvious precaution is to operate at times of the day when calm conditions may be expected – such as early in the morning. On a long track, local observers will also be needed to warn of local weather conditions along the track (in addition to ensuring that the track remains clear of people and animals). However, limiting the yaw static margin (and thus limiting the gust response) remains highly desirable, as it increases the range of conditions in which the record car can safely be run.

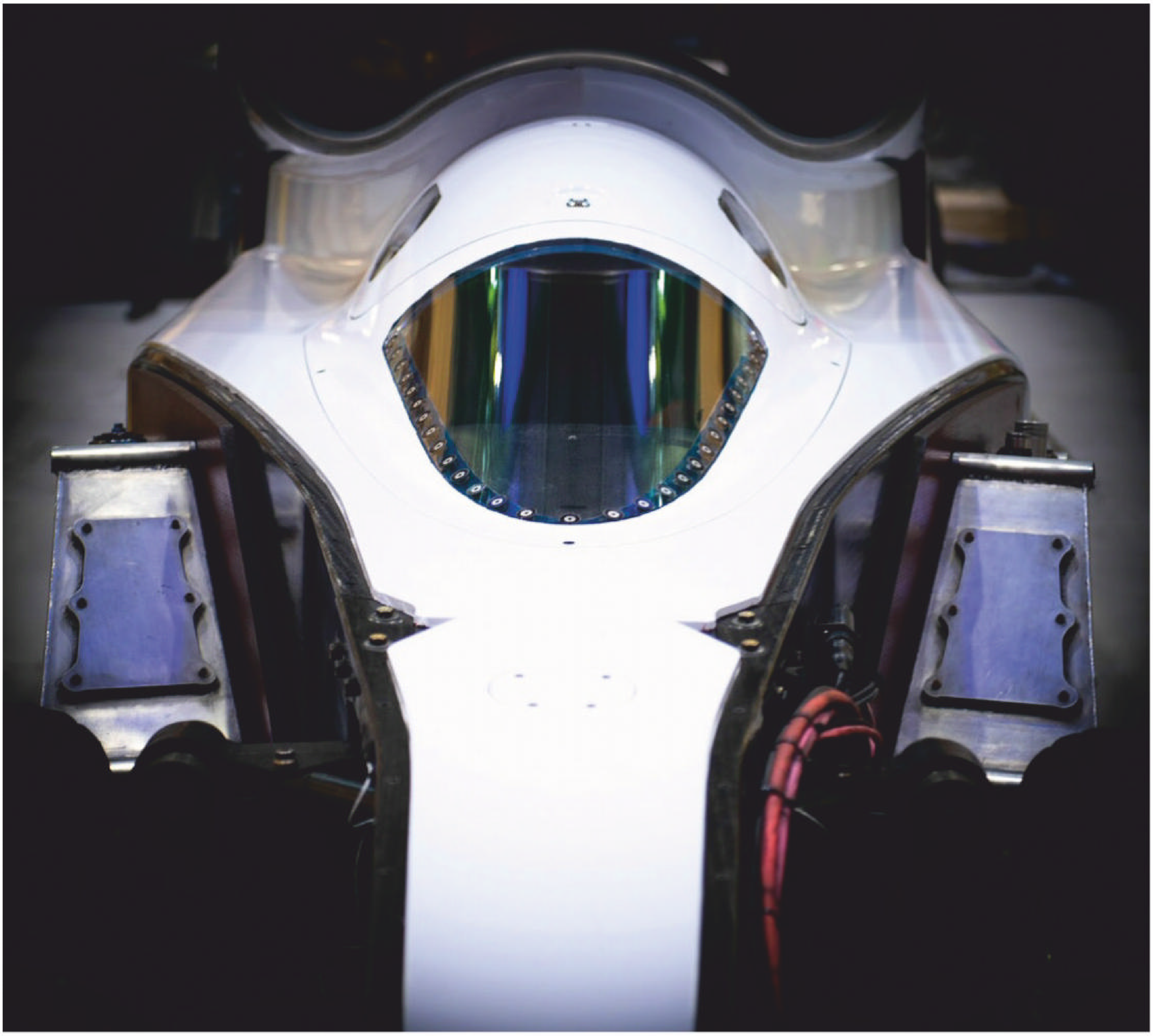
### Dynamic stability

While static stability is a measure of whether a vehicle will return to a neutral position, dynamic stability is the measure of how it will do so. If it settles straight back to equilibrium it is said to be dynamically stable, if it oscillates about the neutral point it has neutral dynamic stability, and if it suffers divergent oscillations it is dynamically unstable.

The two possible modes of dynamic pitch instability are *heaving* and *porpoising*. The names are self-explanatory. Normal suspension



**The arid ground of Hakseen Pan in South Africa. At lower speeds the solid wheels will sink 7mm to 8mm into this surface**



**The cockpit in which driver and co-author of this feature Andy Green will sit. At high speeds steering will be via aerodynamic effects on the front wheels, rather than lateral forces**

damping should cater for these problems, but it is also nice to know that these possible modes of instability are not being forced. We understand that heave has been experienced by Formula 1 cars, but although porpoising is a theoretical possibility we do not know if it has ever been recorded in practice.

Heave instability is controlled by the heave derivative (which is the measure of how vertical aerodynamic load changes with vertical chassis movement), which we have computed using our CFD capabilities. In the case of Bloodhound, the heave derivative is actually extremely small, so forcing would not occur.

Porpoising is controlled by the pitch derivative (the measure of how vertical load changes with pitch angle). For Bloodhound, our CFD shows that the point of action of lift increment due to a change of pitch attitude (that is, the aerodynamic centre) is well behind the centre of gravity and so is stabilising.

Although there is a need to fit front winglets to cope with any possible front-end trim problems, they must not be larger than is necessary as this could lead towards porpoising instability.

It is also interesting to note that for an aeroplane, having a positive static margin (with the aerodynamic centre behind the centre of gravity) provides static stability but on the suspension-constrained Bloodhound, it provides dynamic stability.

## Car or plane?

In the introduction to this piece the question was posed as to whether, at supersonic velocities, Bloodhound will behave like a high-speed car or like a very low flying aircraft. It is neither of these. At high velocity, the desert surface will fluidise under wheel contact so lateral wheel forces are expected to be minimal. Steering will be provided by the aerodynamic forces on the steered front wheels, while the fin provides the yaw stability. Thus, the dynamic yaw response of Bloodhound will probably feel like that of a supersonic hovercraft, or a supersonic hydrofoil, if such things existed. As they certainly do not, we will have to explore the handling characteristics in step-by-step testing, with gradual speed increases to limit the magnitude of any changes, just as we did with Thrust SSC.

Provided we remain focussed on maintaining our key requirements of positive and bounded wheel downloads, and a positive and bounded yaw static margin, we can ensure that the car will remain firmly on the ground and pointing in the right direction.

This in turn will enable us safely to explore (and refine) the performance and handling characteristics of our supersonic record car. In this respect, any suitably cautious attempt to set a new world Land Speed Record combines the best of experimental research with the ultimate in motor racing.

# Natural selection

**With environmental credentials so important in modern motorsport might high performance materials made from natural fibres be the perfect solution? *Racecar* spoke to industry specialist Bcomp to get the facts on all things flax**

**By GEMMA HATTON**

Up to 85 per cent of a Formula 1 car is made from carbon fibre composite components, yet these only account for roughly 20 per cent of the car's overall weight. With the minimum weight now regulated to 740kg without fuel or driver, this equates to around 148kg of carbon fibre on each car. Research shows that the manufacture of one tonne of carbon fibre material results in approximately 29.5 tonnes of $CO_2$ emissions. Therefore, to produce the carbon fibre required for one F1 car, approximately 2960kg of $CO_2$ is released into the atmosphere. Furthermore, carbon fibre currently lacks viable end-of-life options, hence waste volumes are growing rapidly, and toxic carbon dust can cause hazards within the working environment.

## Green flag

In comparison, one tonne of natural fibres has a carbon footprint of around 0.7 tonnes. So theoretically, if all the carbon fibre in an F1 car was replaced with natural fibre composites, 97.6 per cent less $CO_2$ emissions would be produced (103.6kg). Now, these are extremely crude figures, which only look into the manufacture of the materials themselves, not the manufacture of the components. There are also countless ways of calculating the carbon footprint of a material and natural fibre materials are unlikely to replace all the carbon components on a racecar. However, these rough calculations *do* offer an insight into how much more environmentally friendly natural fibres can be compared to the likes of carbon fibre.

Composites are made up of a polymer matrix, such as epoxy or other thermosets, and a reinforcing agent, such as a fibre. Fibres carry load along their length, providing strength and stiffness in one direction. Therefore, by adjusting the orientation of the fibres the mechanical properties can be tailored to suit the direction of the applied load. The polymer not only acts as an adhesive, bonding all the fibres together, but also transfers the shear stresses and loads between the fibres helping to optimise the distribution of external loads across the material. Composites are also lightweight with a high strength to weight ratio.

The most popular composites include carbon fibre and glass fibre. As the name suggests, carbon fibre is made up of fibres containing mostly carbon atoms bonded together to form a long chain. These strands are thinner than a human hair and they are twisted together to form a yarn. These yarns are then woven together to form a cloth. Carbon fibre is around five times stronger than steel, with twice the stiffness.

## Moral fibre

Glass fibres are made from flowing molten glass through small orifices which then solidify to form a flexible fibre. These are then bundled into a 'roving' and then woven into a cloth. High performance natural fibres are fibres extracted from the stem of specific plants, flax being one of the most popular for composite materials.

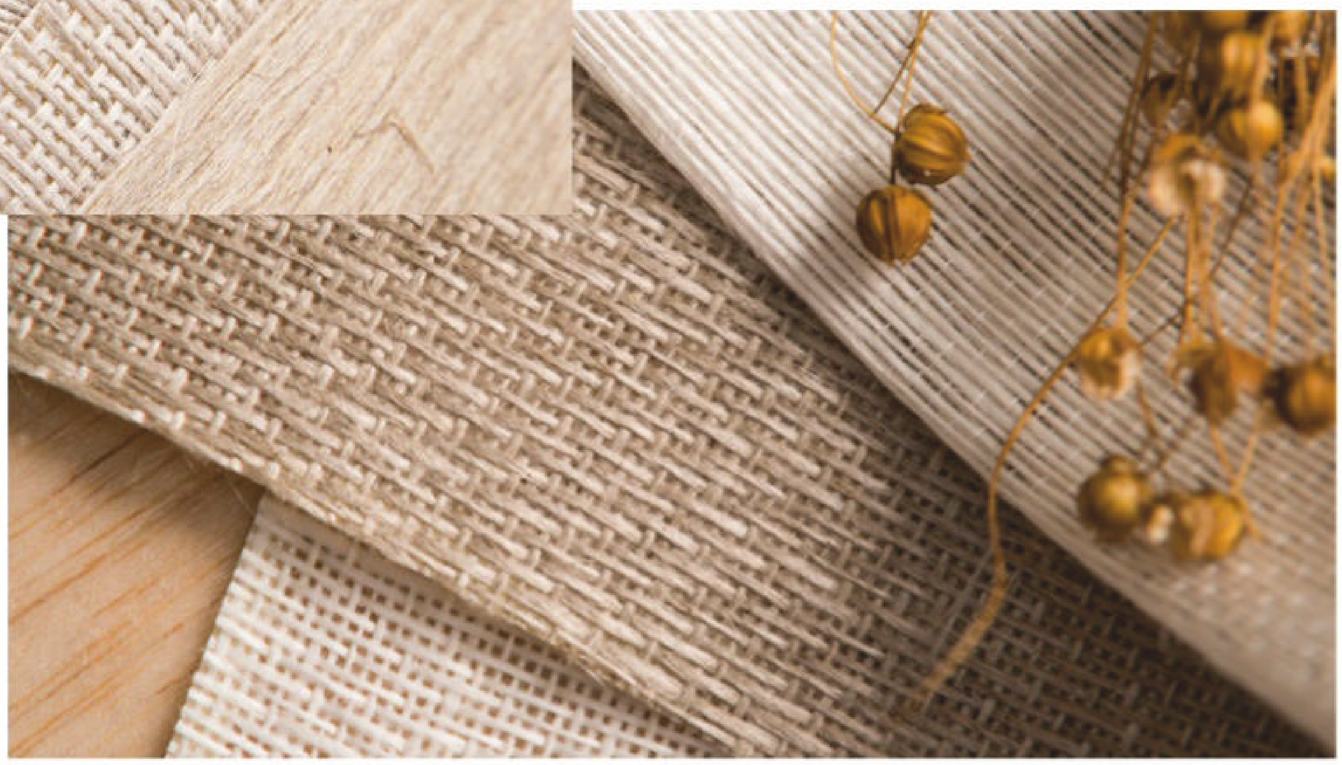
Flax fibres are extracted from the linum usitatissimum plant and are predominantly used in linen clothing. However, flax can also be woven and impregnated with resin to form a composite, which can match the performance of carbon composites in certain applications, have a smaller environmental footprint, five times higher vibration damping, and high radio-transparency; but these are also more sensitive to changes in humidity than carbon.

'We work with flax because its supply chain has the required maturity to provide consistent quality over the years and it has the best mechanical properties per unit weight within the natural fibre group,' says Christian Fischer, CEO at Bcomp, a specialist in high performance materials that are produced from natural fibres. 'Although these intrinsic properties are not comparable to carbon [fibre], if we compare to glass [fibre], we have a similar modulus of 65GPa with almost half the density at 1.45gcm$^3$. So we're starting with a material that has high specific stiffness.

**If all the carbon fibre in a Formula 1 car was replaced with natural fibre composites there would be a 97.6 per cent reduction in the $CO_2$ emissions produced**

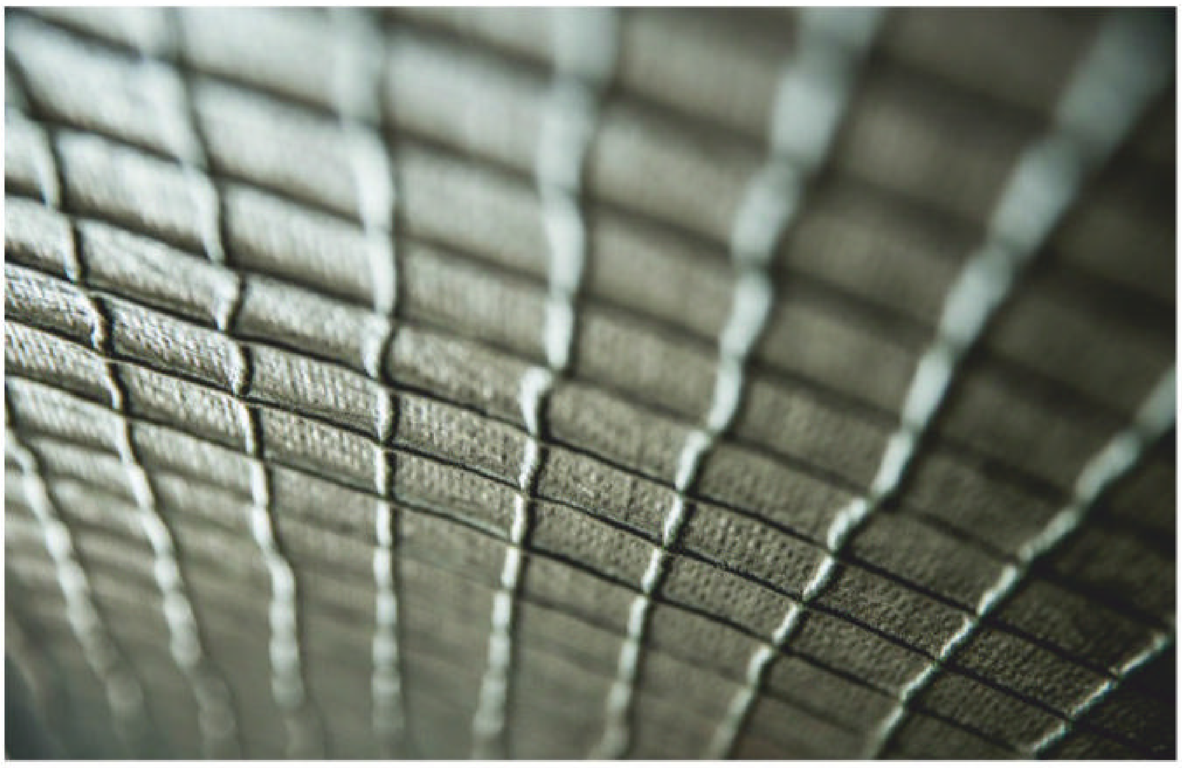
Electric GT's Tesla was the first car to feature Bcomp's materials, helping to achieve a 500kg weight saving compared to the original road car

> **'We work with flax because its supply chain has the required maturity to provide consistent quality over the years'**



Bcomp uses natural flax fibres to create its AmpliTex range of fabrics. These are able to match the performance of carbon fibre in certain applications

To bolster its mechanical properties the AmpliTex fabric can be reinforced with a grid structure which is called PowerRibs



'The requirements to reinforce a composite structure are very different to those required to make a linen shirt,' Fischer adds. 'This is why we have put a lot of development into how we spin, twist and weave the yarn to achieve the perfect surface coverage with a strong bond between the fibre reinforcement and the matrix.'

## Tailor made

These different twisting and weaving techniques tailor the mechanical properties of each fabric to its specific application, whether that happens to be a surfboard, a pair of skis or a piece of a racecar bodywork. 'This gave birth to our AmpliTex range which are very efficient reinforcement materials based on the same building blocks as other reinforced materials using synthetic fibres,' Fischer says.

Just like a ply of carbon fibre, AmpliTex is a range of flexible flax fabrics, each exhibiting a variety of different weaving patterns to achieve specific properties. But although AmpliTex can outperform glass fibre, how can its stiffness be increased to compete with the likes of carbon fibre? 'For us, it's not enough to compete with glass fibre,' says Fischer. 'On top of the high specific properties of flax, you also have a low absolute density, which provides us with a great material to build stiffness in thin-walled applications. If instead of smearing the material into the surface, you can organise it in a 3D rib structure, you further emphasise this singularity and boost the bending stiffness.

'It's like the veins on a leaf that reinforces the membrane; achieving maximum stiffness with minimal material,' Fischer adds. 'Benchmarking this against carbon, we can match the performance in terms of specific bending stiffness for thin-shelled components even though we have a material with lower intrinsic properties, because we create this rib structure, or PowerRibs as it is called.'

The PowerRibs reinforcement effectively adds a backbone to the AmpliTex flax fabric. PowerRibs is made by the unique twisting of flax fibres which then forms a thick yarn. This yarn is used to create a grid which is then bonded to the AmpliTex fabric.

## Material world

Carbon fibre is incorporated into racecars in several ways. For bodywork and aerodynamic elements, plies of carbon fibre are bonded together in different orientations to form a laminate. Whereas, for more structural parts such as the chassis and anti-intrusion panels an aluminium honeycomb or foam core is sandwiched together between two skins of carbon fibre to satisfy these higher load cases.

'When you want to maximise performance per weight there are physical limits given by the


NEW
The Kenwood
NX3000 Range
Autotel
Digital Race Radio
Professional Team Radio Systems.
Full ELMS and Le Mans 24 Support.
Sales and Rental Packages.
First season sponsorship deals available.
Autotel Race Radio 0044(0)1508 528837 Email sales@autotel.co.uk
www.autotel.co.uk


Woodward.
Euros, pounds or dollars,
we give you more
engineering for your money.
Power steering racks for left or right
hand drive, front or rear steer, in an
almost infinite variety of dimensions
...with a 3 to 4 week lead time.
WOODWARD
HYDROLINE
Download a Type CF design worksheet at woodwardsteering.com


www.ProFabrication.com
"Quality that Wins"
Custom Headers
Mandrel Bends
Merge Collectors
Straight Tubing
Mufflers
PRO FABrication
Headers and Exhaust
704-795-7563
Tailor Made Exhaust From CAD to Manufacturing


DOCKING engineering
Advanced Cooling Systems
Water Radiators
Intercoolers
Oil Coolers
Heat Exchangers
System Design
Ancillary Products
Manufactured to your requirements
by the UK's leading supplier.
Email info@dockingengineering.com
Tel +44 (0) 1327 857164
Fax +44 (0) 1327 858011
Web www.dockingengineering.com
Certified to CAA & AWS
Welding Standards
Unit 15 Silverstone Circuit
Silverstone, Northants
NN12 8TL, United Kingdom

## ‘I want our materials to be fitted on to the rear wings of racecars, because this will show the world that this is tomorrow’s tech’

intrinsic properties of the fibres,’ says Fischer. ‘These properties mean it does not make sense to build a chassis out of natural fibres, because carbon fibre sandwich composites are so effective. We focus on thin-shelled parts, typically monolythic single-skin or thin sandwich applications up to 2mm thick for which our solution provides the equivalent stiffness of a sandwich core.

‘Where we see significant potential is in the non-critical, semi-structural areas of a racecar, such as the bodywork,’ Fischer adds.

For certain applications, AmpliTex and PowerRibs can also be combined with carbon skins to create a hybrid structure which then outperforms pure carbon fibre whilst achieving a weight saving of up to 25 per cent.

A natural fibre composite door panel for a VLN Porsche; these materials are best suited to semi-structural areas on the car

### Laying up

The manufacturing processes that use AmpliTex and PowerRibs are similar to those of carbon fibre, if not easier. When using prepregs, a layer of fabric pre-impregnated with pre-cured resin, ubiquitous to composite manufacturing, the PowerRibs can simply be added dry on top of the laminate, and the processing pressure will drive the liquid resin from the substrate for complete impregnation. In vacuum infusion the dry PowerRibs act as their own flow media to help with the infusion of larger surfaces, removing the need for ad hoc, wasteful consumables such as those commonly used in carbon fibre manufacturing.

The first racecar that featured Bcomp materials was the Electric GT Tesla P100DL, which has bodywork made from AmpliTex and PowerRibs that has helped to achieve a 500kg weight saving compared to the road car version. There was also a full-natural fibre bodied car, the Gillet Vertigo, which raced up Pikes Peak in under 11 minutes in 2018.

### Splinter resistant

To compete in high level motorsport, materials have to pass the FIA crash safety tests, and this is another advantage of the Bcomp products. The nature of flax fibres, with the structure of PowerRibs, means that these composites do not splinter like carbon, which can causes all sorts of issues on track such as tyre punctures. ‘During the drop tower tests where a 2.2kg steel ball is dropped from two metres, the carbon composite plate shatters, generating sharp debris,’ says Fischer. ‘Whereas the composite of AmpliTex and PowerRibs is not as fragile, and while it still breaks, the softer debris remains attached to the main structure with the help of the PowerRibs, which help dissipate the energy.

Therefore, flax composites can, in a sense, be deemed ‘safer’ than carbon fibre. This has caught the eye of GT race promoter SRO and it is now in the regulations that any GT4 cars homologated after January 2019 must feature bio-based composites within the aero package, with synthetic foam cores banned.

As Bcomp’s materials continue to integrate into the motorsport sector, its also implementing light-weighting solutions into road cars as well. Natural fibre composites are now used in some interior panels, with the use of PowerRibs reducing weight by around 40 per cent as well as reducing the use of plastics by 80 per cent, when compared to a standard injection moulded panel.

‘People sometimes say: “Christian, you’re building this green tech story, but then you go into motorsports” and I say “Yes, because motorsport is still the platform of tomorrow’s technologies”,’ Fischer says. ‘I believe that whenever you can play in the Champions League, then you go play in the Champions League. So I want our materials to be on the rear wings of racecars, because this will show the world that this is tomorrow’s tech.’

‘But customers shouldn’t have to pay a premium for going green,’ Fischer adds. ‘You buy an organic apple because it’s good for you and your conscience but if it doesn’t taste good, you’re not going to buy it anymore. This is why our materials have to out-perform carbon and glass fibre, which is what AmpliTex and PowerRibs allows us to achieve.’

The Gillet Vertigo, a full-natural fibre bodied racecar, competed at Pikes Peak last year, getting to the top in under 11 minutes


EARL'S
PERFORMANCE PRODUCTS
RACE ENGINE PRE-HEATER SYSTEM
NEW SEASON are you ready?
EARL'S
Engine Pre-Heater
FUELAB
DIGITAL FUEL DELIVERY
ADEL WIGGINS
GROUP
STÄUBLI
Holley
Earls Performance
15/16 Silverstone Technology Park
Silverstone, Northants.
NN12 8TL
01327 858 221
sales@earls.co.uk
www.earls.co.uk


Performance Trends
www.performancetrends.com
Work Smarter Go Faster
Visit our website for more info, to download FREE demos, or call...
248-473-9230
Software and electronics for all types of racing and engine building, including:
- Suspension Analysis Software
- Engine Performance Simulation
- Cam Measurement & Analysis
- Manual & Automatic Spring Testers
- Flow Bench Electronics & Software
- Race Car Simulation
- Swirl & Tumble Meters
- Dyno Software, Data Acquisition & Control
- Shock Dynos
Engine Analysis
Cam Testing
Dyno Electronics
Spring Testers
Shock Dyno
Suspension Analysis

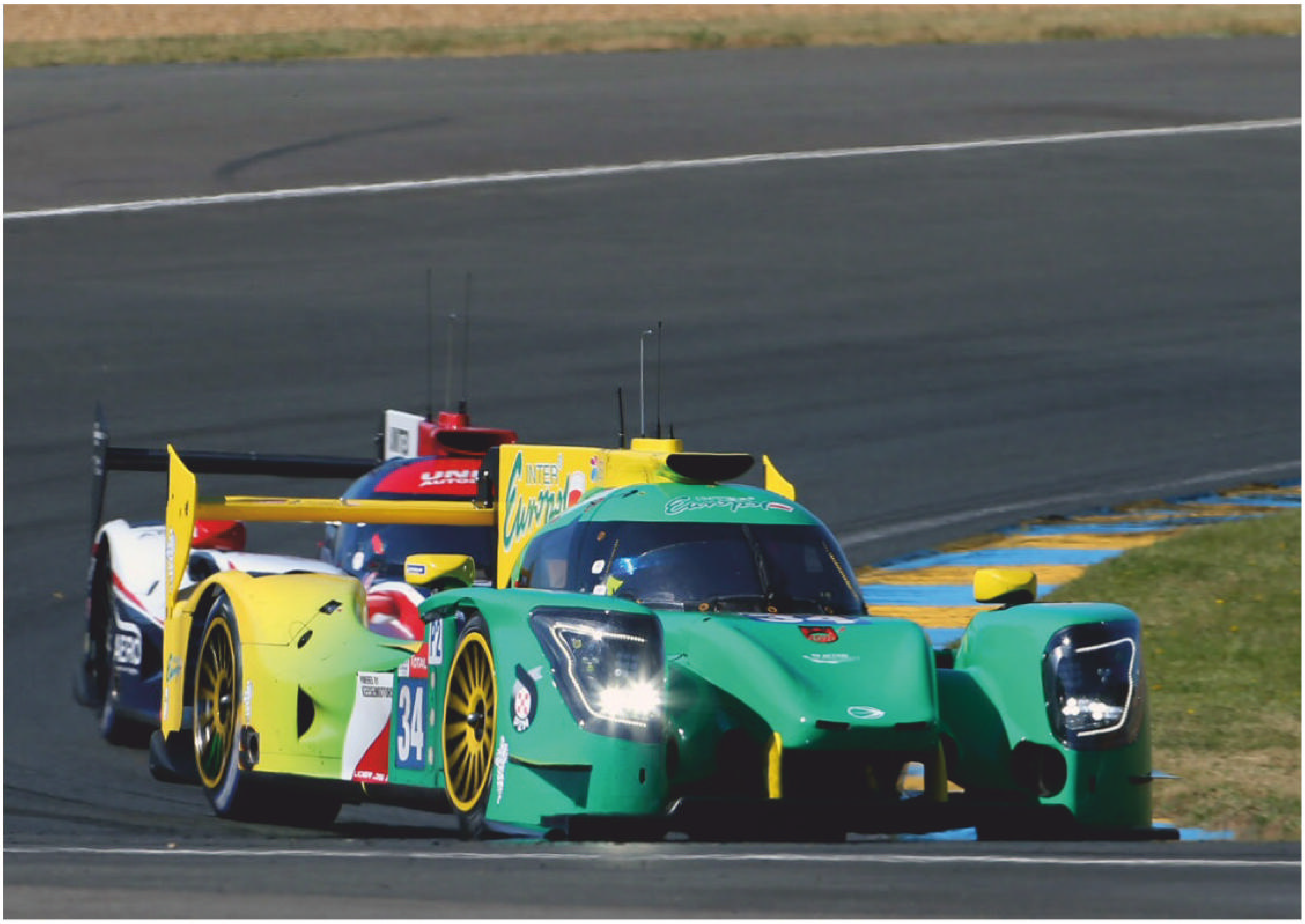

motorsports quality
ROD ENDS, SPHERICAL BEARINGS
and MS spec. UNIVERSAL JOINTS
AURORA®
RODOBAL®
inch
metric
BELDEN®
universal
Seals-it®
contacts in English, Deutsch, Français, Italiano
most extensive stock in Europe, US / EU parts
basic / regular / top product lines,
flexible service, worldwide delivery
support service to OEMs and national distributors
ROD ENDS ACCESSORIES:
side seals, protection boots,
jam-nuts, right-hand and left-hand
grooved bearings staking tools
Getecno Ltd. - ITALY
fax +39 010 835.66.55
e-mail: info@getecno.com


RACING
GST
SEALS
Bespoke design of energy-efficient Oil Seals
for all Engine & Driveline applications.
Minimise power losses & maximise racing advantage
MIA
MOTORSPORT INDUSTRY ASSOCIATION
BUSINESS EXCELLENCE AWARD WINNER 2013
GST Racing Seals
A division of GregSeal Technology UK Ltd
Tel: +44 (0)7756 515 772 • Fax: 02380 224104
info@gstracing.co.uk • www.gstracing.co.uk

# Simulation in action

*Racecar's* chassis sim guru jumped at the chance to prove his systems in the heat of battle at this year's Le Mans 24 hours

By DANNY NOWLAN



Our simulation expert was on hand to help out the team that was running this Ligier LMP2 at Le Mans this year. The car's pace was pretty good but gearbox issues spoiled its race

I was in the position at this year's Le Mans 24 hours where I had the opportunity to help an old friend of mine who was up against it engineering an LMP2 car. What transpired was a great example of just how effective simulation tools can be in helping a race team on a very practical level. And it was also proof of the absolute worth of such simulation.

The car in question was the Inter Europol Competition Ligier LMP2, run by Keese Motorsport. Being new to the class the team was suffering from typical growing pains and they needed a hand, and since there were quite a number of bush fires that needed to be put out I stepped in with ChassisSim, to help point the team in the right direction with its racecar.

The first thing I did was to take the standard base model that had been completed by a colleague of mine and dial it in. Due to time constraints (this was done in two four-hour blocks) I was really forced to focus in on the big-ticket items, and if you ever find yourself in this position this is what you concentrate on: aero; focus on speed and damper correlation at end of straight; then sort the bump and grip scale factors to dial in the cornering speed.

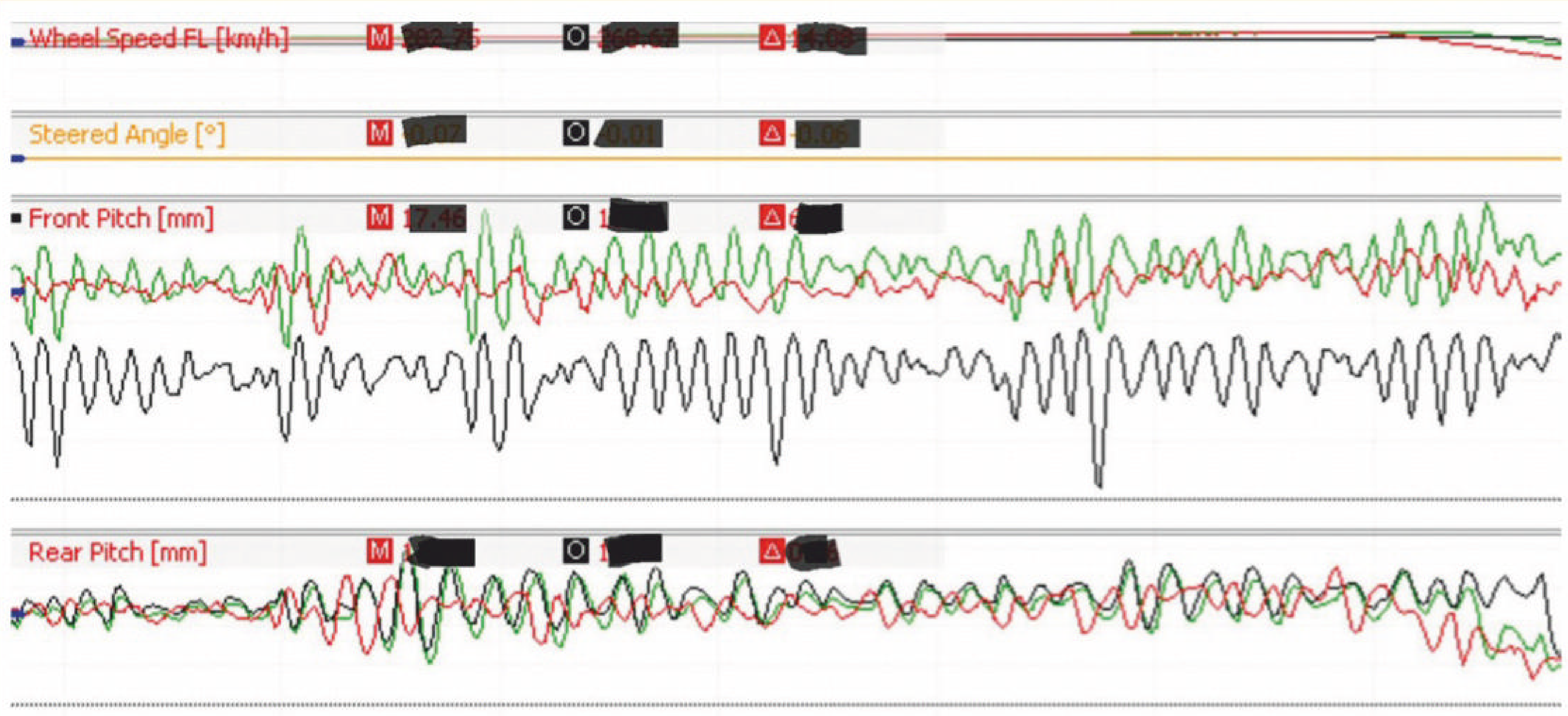
The following run-through of the process employed at Le Mans will not be perfect, but it will get you in the ballpark. The thing is, when you simply don't have much time you have to make do with what you have got.

## Aero model

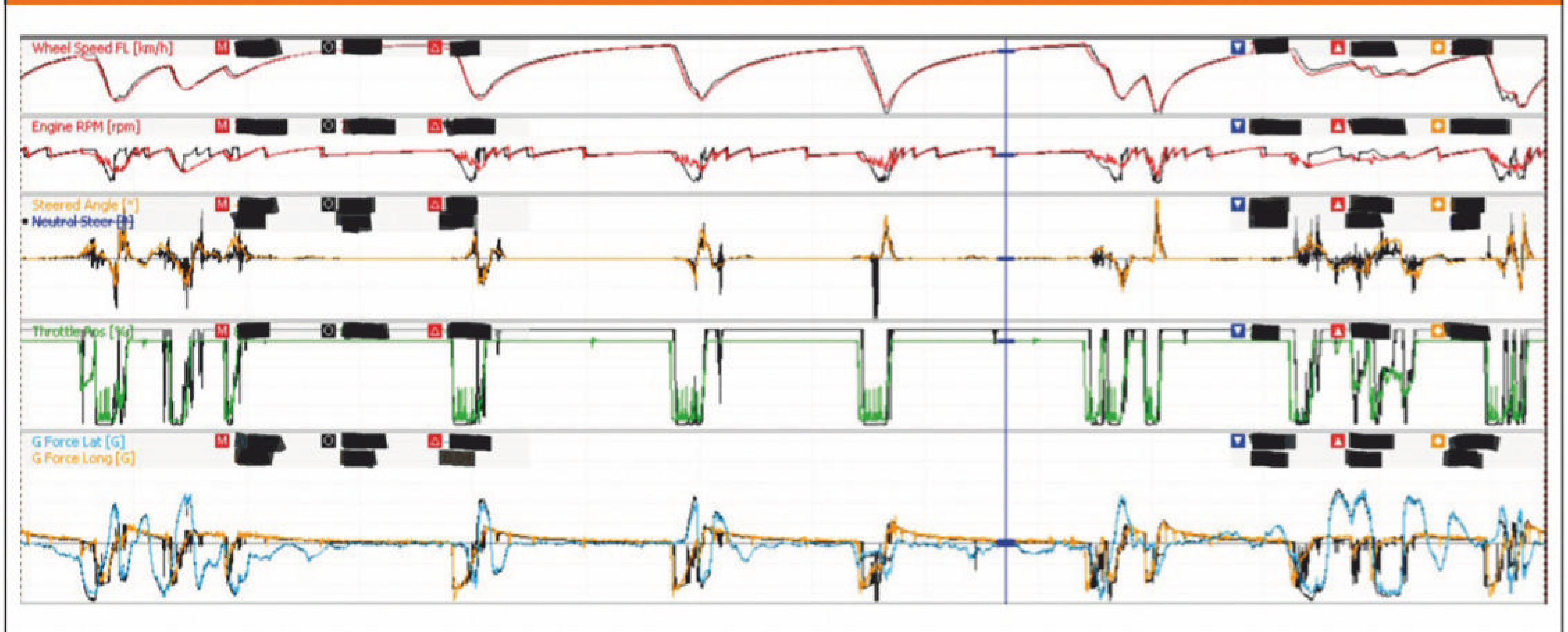
Fortunately, dialling in the aero was very straightforward and the result of the correlation work is shown in **Figure 1**. Here the actual data is coloured, the initial baseline is black and the final aero model is red. The channels shown here are speed, steered angle, front pitch (average of

**To hit these sweet spot targets, the front and the rear third springs really need to become your best friends**

## Figure 1: End of straight aero correlation




## Figure 2: Final baseline correlation




the front left and right dampers) and rear pitch (average of the rear left and right dampers). As always, since this is live data all scalings and numbers are blacked out. In order to get this correlation there were some bump rubber gaps that needed to be corrected. Before and after aero coefficients are shown in **Table 1**.

**Table 1: Global aero coefficients – baseline compared to final model**

| Item | Baseline | Final |
|---|---|---|
| $C_LA$ Max | Bline | -9% |
| $C_DA$ Max | Bline | 0% |
| Aero balance offset | Bline | +4% |

## Delta force

Again, since this is a live racecar I can't give you the absolute numbers, which is why I've given you the deltas instead in **Table 1**. The magnitude of these deltas does not surprise me. For something that has seen a combination of wind tunnel/CFD these offsets are pretty typical. The why of this I discussed in my last article, which focussed on how you should treat your dyno results (see the August issue, V29N8).

The next step was to dial in the cornering speeds. Since ChassisSim is transient lap time simulation your ports of call are the following; altitude and road camber; bump scale factors for the corners; local grip scale factors.

The first and last points are pretty self explanatory. The middle bit reflects that while the ChassisSim bump profiling toolbox is good, it's not perfect. The bump scale factors help you fine-tune what the bumps are doing. Typically 0.6 to 0.7 gets you out of trouble and you focus on that when the corner speed deltas (simulated *vs* real) are greater then 10km/h. The end result of all this is shown in **Figure 2**.

The scales in this chart are speed, RPM, steered angle (at the wheel), throttle and *g* forces. While this isn't perfect, fundamentally it is functional and representative – and when you get to this point you are good to go.

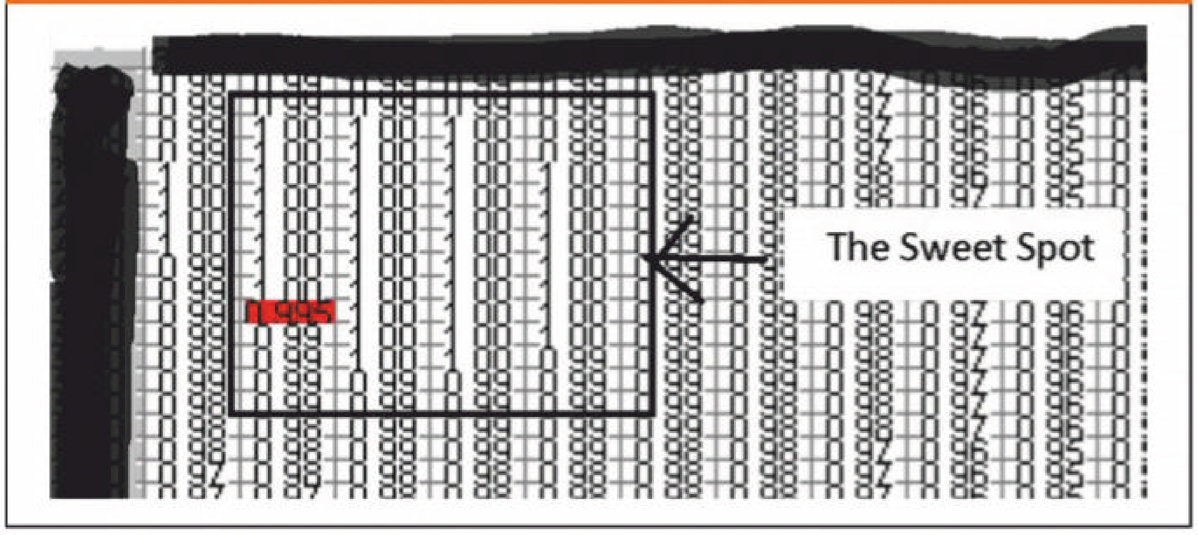
The next step, once the initial correlation had been dialled in, was to make sure that in the high speed corners we were in the aero sweet spot. This is where being able to read your aeromaps and ride height channels become absolutely critical, and your first port of call is to read the aeromap, as shown in **Figure 3**.

For obvious reasons this aeromap has been significantly redacted. The rows are front ride height and the columns are rear ride height. Also, all the values have been normalised. Where you see the max values of $C_LA$, or in this case when they are all 1, will tell you where in the aeromap you need to be from turn-in to mid-corner. These form the ride height targets that you are shooting for at this stage of the corner.

## Sweet spots

To hit these sweet spot targets the front and rear third springs really need to become your best friend. I must confess, I have always been a bit nervous with third springs because from a vehicle dynamics perspective it is very easy to screw this up and the drivers complain terribly when you do. However, for the set-up strategy on this car the third springs were a lifesaver. Once the third springs were dialled in the ride heights where in the sweet spot. **Figure 4** provides a very good illustration of this.

**Figure 3: The sweet spot you need to hit mid-corner**




Here the baseline is coloured the optimum set-up is black. The channels are speed, steering, front and rear pitch and front and rear ride heights. The two channels to watch are the bottom traces, the front and rear ride heights. In particular, what you are concentrating on is making sure that in the mid-corner conditions they are in the sweet spot as seen in **Figure 3**.

In this case the front ride height wasn't too bad. However, the rear third spring for the baseline set-up was too stiff. Once this was addressed it put it right in the ride height envelope and the corner deltas where + 2 to 3km/h. This is a big jump for a simulated change

**Figure 4: Comparison of standard set-up with third springs with ride heights in the sweet spot**

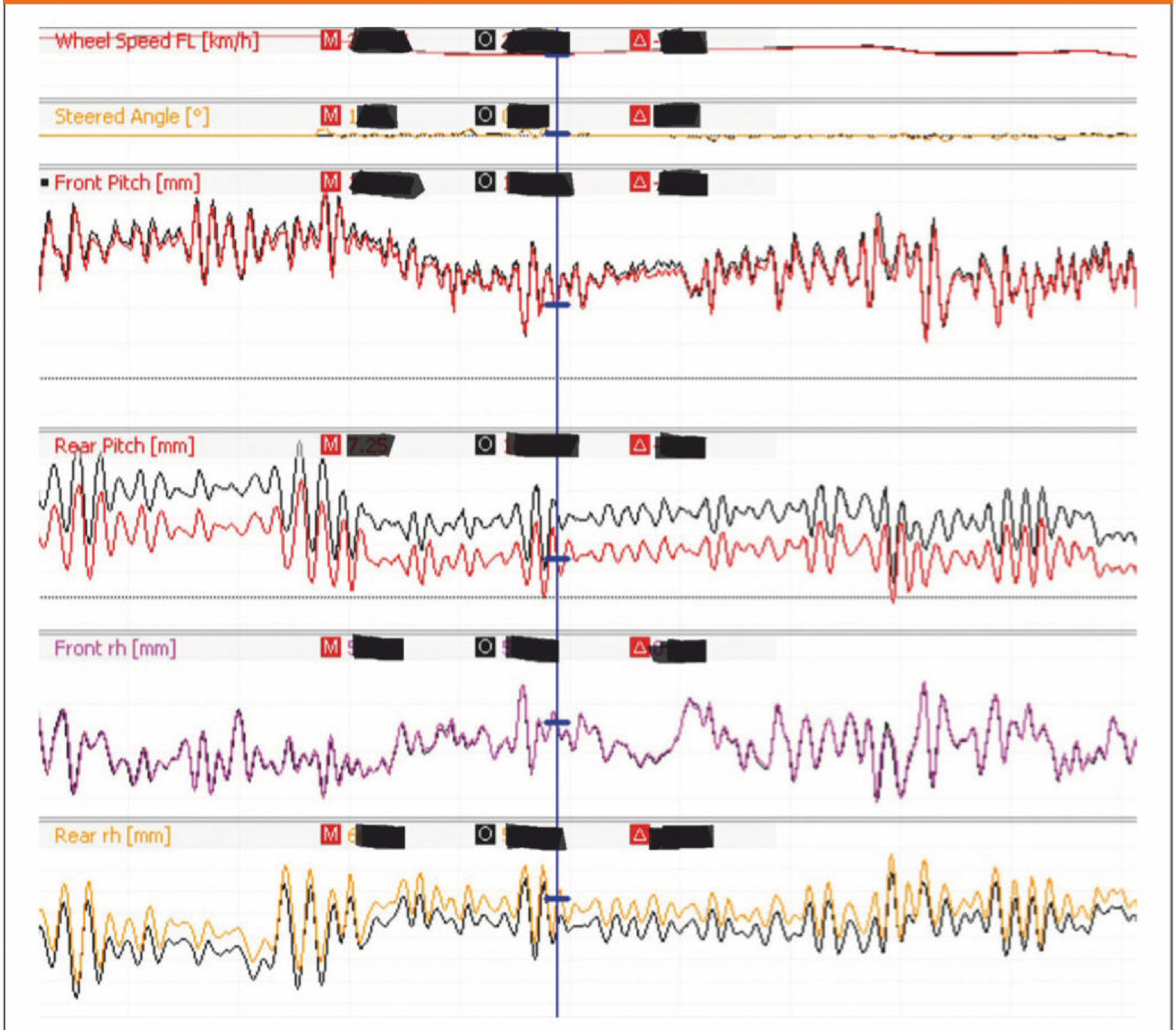
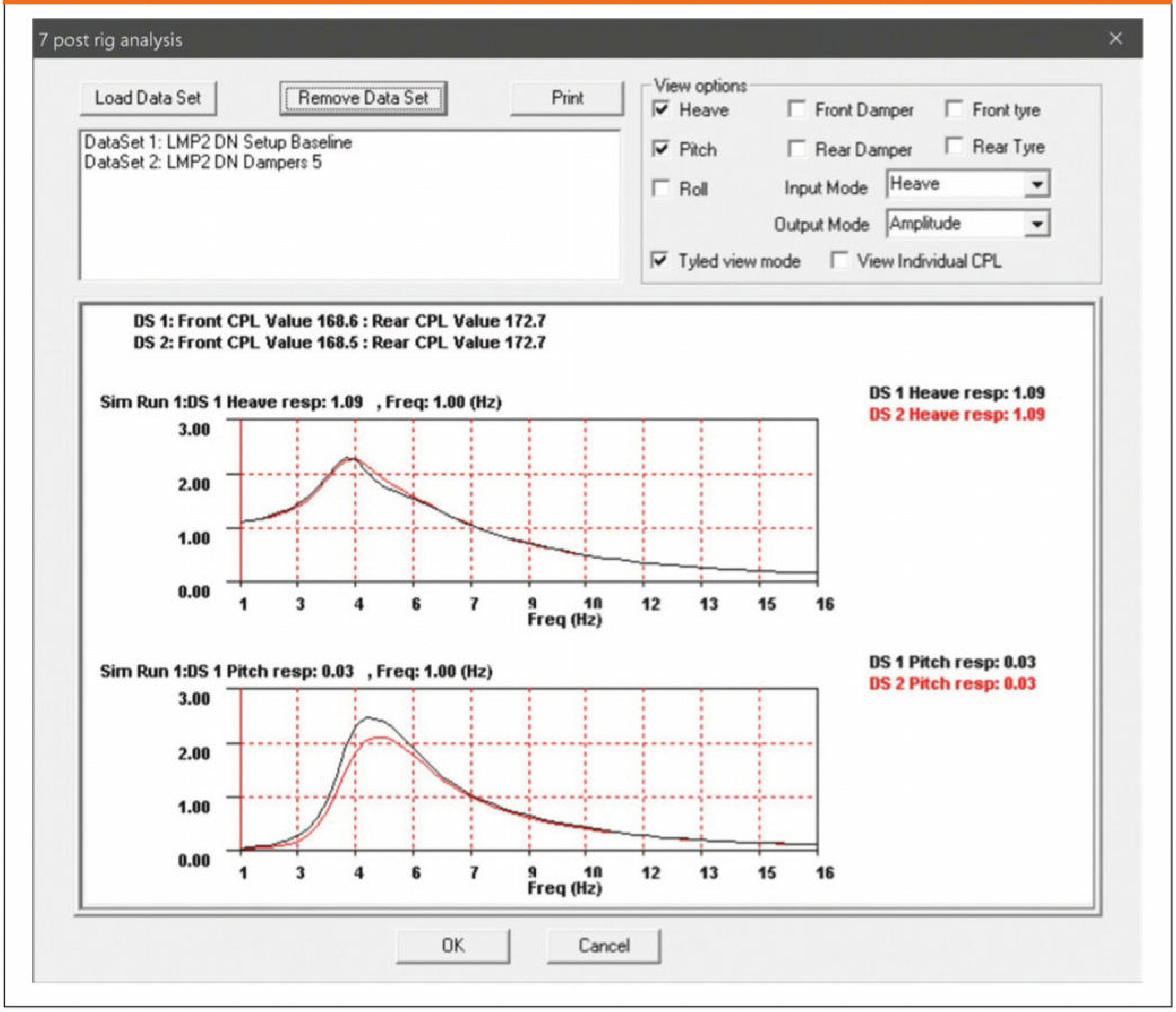


**Figure 5: Standard *vs* suggested damper specs**




# The time requirements for all this were not really excessive, everything that was done here was done in two sessions

and provides a very good example of how you look at the simulated data.

The last thing that was looked at was where to go with the damping. The base spec damping provided on the racecar was reasonable and a quick scan of the damper data didn't show any particular problems. However, I figured I might as well throw some mud at the wall and see what happens. So I used a simple dual rate damper model and then used the shaker rig toolbox to see what direction to go in. The results are shown in **Figure 5**.

Due to confidentiality I'm not at liberty to disclose the direction I went with the damping. What I can tell you is that the baseline is black and the suggested damping is red. The input is a constant velocity heave input and the first trace is the heave response and the second is the cross pitch mode response. The stand-out result is the lower CPL value at the front and the lower cross pitch mode response in heave. If I see something like this, and if I have time, I put that on the racecar. Unfortunately, at this stage of the game at Le Mans I was running out of time.

## Summing up

There were a number of things to note about what transpired at Le Mans. Firstly, the time requirements were not excessive, everything that was done here was done in two sessions. There was a two- to three-hour time session to dial the model in. The set-up sensitivity was completed in four hours, and this was with me running off to see other customers, too.

Secondly, this was a great example of how you should look at a model and the simulated data to get a set-up direction. We didn't do anything fancy here, we just looked at the aeromap and tuned the set-up to get the simulated ride heights where they needed to be throughout the turn-in to mid-corner condition. That was it. I just kept it simple. It's just evaluating the data as you would for the race, but using a slightly different lens.

In summing up I usually give a quick recap of what we did and why we did it. But this month let me take a different tack and tell you about the results. The purpose of all this was to make sure the car qualified midfield, and that was the case. The car had good race pace, which was unfortunately spoilt by gearbox issues in the race. But let me leave you with the words of Roberto Hernandez Garcia, the race engineer for the car. 'ChassisSim was just the final push we needed at Le Mans. We start to go from baby steps to real step in our performance. Many thanks for your help and for your tools.'

Interview – John Clagett

# Muscle memory

**The president of Trans Am reveals the secrets to the US series' long life and the reasons for its recent growth**

**By MIKE BRESLIN**

**'If we gave our competitors a bunch of no-name race tracks our entries would go down'**

Nostalgia might not quite be what it was, as the suitably old joke goes, but in motorsport there's an awful lot of it around, which is part of the reason why historic racing is so popular with spectators and competitors alike. But one question often arises when people start to ponder on the reasons why they're so drawn to the past, and that is; why can't racing be like this now? Well, actually it can. And when it comes to Trans Am, actually it is.

Trans Am is a hugely historic race series in its own right. For around 50 years, with just a couple of dormant seasons in 2007 and 2008, it's brought its own brand of muscle car racing to North America. But arguably right now – despite the lack of the works teams that were once a major part of the series – it is stronger than ever, with around 70 competitors spread across four classes and a calendar that features some of the USA's most iconic race tracks.

## Present and correct

John Clagett, president and CEO of the Trans Am Race Company, which promotes the series, has been involved in Trans Am since 1984, except for a few years working in Champ Car, and so has a good idea as to why it's thriving. 'On the North American scene there's been many series that have come and gone, but Trans Am is essentially the longest standing professional road racing series, and it stays around,' he says. 'That's because it's what America is about, to a certain degree, and that's American muscle. We have a niche where basically we know what we are and we don't go too far away from those roots. It seems to have worked, but you can't just have that, you've got to have a rules package that fits the niche you're going after; a smart rules package that's also an affordable package.'

These days that smart rules package caters for four classes, Trans Am (TA), TA2, GTS and GT. TA is the flagship class, featuring open regulations for spaceframe silhouette racecars packing, and this is the good bit, 850bhp engines. 'They really do sing when they're on a race track,' says Clagett, of the Ford Mustangs and Chevrolet Corvettes that typically populate this class.

TA also offers opportunities for race engineers to use their skills and flourish. 'It's not unlimited, but it is way more free [than other categories],' says Clagett. 'So, if you want to spend money on brakes or shocks or whatever, then you can. And if you want to build your own chassis from the ground up, you can. The only things that are more regulated are things like the bodies; we manage the approval process and have certain people that are suppliers of bodies … The other factors that would be regulated by us, of course, are tyres, RPM levels and things like that. But if you want to bring in your own engine builder, you can.'

Yet while TA is where all the technical excitement is at – and also the spending, the budgets can go 'way up' says Clagett – it's TA2 that attracts the most entries, to the extent that this is usually run as a separate race during the weekend. But this class, which features three typical muscle cars in the shape of the Ford Mustang, Dodge Challenger and Chevrolet Camaro, is much more tightly controlled. 'We regulate almost everything in TA2,' Clagett says. 'There's two primary chassis builders, the engines go through a homologation process and there are only a handful of engine builders that are approved [TA2 powerplants are 530bhp]. There are price caps on a lot of the things like shocks and brakes, and so it keeps things in check.'

All of which makes it a great sell for competitors. 'It does have the deepest fields,' Clagett says. 'In my mind, and the mind of many in motorsport, TA2 is the best bargain on the professional scene that there is. You're buying a car at a little over $100,000 and the maintenance on them is very reasonable and you can do a year with probably $300,000 or less.'

## Choice cuts

One area where costs have been escalating in TA2, though, is with engines, especially the price of rebuilds, and to combat this Trans Am has now developed its own power unit, called the TA2 Choice. 'We took that on as a challenge, to create an engine that would be half price, with rebuilds that would be half of what they are today,' Clagett says. 'We started that project a couple of years ago and now we've introduced the TA2 Choice engine, it is now one of the options for competitors to buy. It's basically creating a sustainable engine future … We're always looking to keep things as affordable as motorsports can be.'

Beyond the two TA categories the GT classes are more familiar, for while they contain the muscle cars that Trans Am is famous for there is also a smattering of European GT machinery from the likes of Porsche and Ferrari, and the inevitable performance balancing that the GT tag brings, too. That said,

The Trans Am TA2 class – pictured at Laguna Seca – is the most vibrant, with big fields competing in standalone races

Clagett believes the spread of venues the series visits is a natural leveller in some respects. 'You would expect a Dodge Viper or Chevrolet Corvette to be a tough car to beat in a place like Road America, but on the flipside a Porsche or other more nimble cars might have a slight advantage at a place like Lime Rock,' he says. 'And as long as we're giving an equal representation of race tracks, having the same amount of tracks that could be advantageous for one or the other, then it kind of makes the BoP slightly less important. We still do BoP, but we're trying to make it where it isn't 100 per cent that.'

## On the right tracks

But for now one of the most important balances in Trans Am is the one between keeping costs down while still racing at the very best of venues. 'I think one of the reasons we grew and became successful again is that we were delivering heritage type race tracks,' Clagett says. 'The Watkins Glens, Daytonas, Sebrings, Road Americas and Indys of the world, and those are not the cheapest race tracks to get deals done with. But that's what we have to have in order for us to be delivering on our promise to our competitors. If we give them a bunch of no-name race tracks our entries would go down, but as long as we can give them the heritage tracks, the iconic tracks, I believe we are doing a proper job of treating our competitors as customers, and then we can keep them.'

Keep them, and no doubt attract others. But perhaps not works teams. 'When Chevy and Ford did it [in the past] then predictably what you had was the top eight cars on the grid were these, and the independents were relegated back out of the top 10, and the numbers of your independents are going to fall off as a direct result of that,' says Clagett. 'So, in today's world, let's just say if Chevrolet and Ford said they wanted to help the series, I would look to build a marketing platform for them, as opposed to a factory works programme. If they wanted to support the series we could support them by going into event markets and doing a substantial amount of cross promotion with car dealerships; that's what I think it should be about.'

And that's the thing about a series with a history, it's not just about retaining the good stuff from the past, it's also about learning from the mistakes of the past.

## RACE MOVES


NASCAR

**Rick Hendrick**, the most successful team owner in NASCAR history, is among those named as inductees into the 2020 Motorsports Hall of Fame of America. Hendrick (pictured) joins former Indy racing steward and safety pioneer **Wally Dallenbach** and motorsport publisher **Floyd Clymer** on the list. Drivers **Red Byron**, **Tiny Lund** and **Jacky Ickx** also feature.

IndyCar has restructured its PR operation with **Mike Zizzo** now its vice president of communications while **Kate Davis** has taken on the new role of director of communications. As part of the reshuffle **Curt Cavin** has moved to the post of senior manager of Digital Content Editorial. Zizzo has been acting as a consultant to IndyCar since February and has 23 years of motorsports PR experience under his belt.

The Sports Prototype Cup, a new championship in the UK this season, has introduced a mechanic of the weekend award. There will also be an overall winner at the end of the season. The award is to recognise the hard work put in by the mechanics during an event and throughout the year.

Tyre engineer **Matthias Bode** is now in charge of Kumho's European Technical Centre (KETC) in Morfelden-Walldorf, Germany. Bode, who comes to Kumho from Dunlop Goodyear, reports directly to **M J Lee**, senior vice president at the company's global R&D centre in Korea.

Also joining Kumho from Dunlop Goodyear (see above) is **Roberto Sangalli**, who has taken up the role of manager, Tyre Engineering, for KETC. Prior to his spell at Dunlop Goodyear Sangalli spent 20 years at Pirelli, where for a time he was responsible for the development of tyres for F1, GP2, GP3, and all GT series products.

**Lee Iacocca**, the US motor industry giant who launched the Ford Mustang and turned around the fortunes of Chrysler, has died at the age of 94. He graduated in engineering from Lehigh University in Bethlehem, Pennsylvania, then joined Ford in 1946, though he soon realised his talents lay in sales and marketing. It was Iacocca's recognition that the automobile market was changing in the US that led to the Mustang in 1964.

Long-time NASCAR television pit reporter and magazine editor **Dick Berggren** is to be the recipient of the 2020 Squier-Hall Award for NASCAR Media Excellence. Berggren becomes the ninth journalist to win the prestigious award, which is named after **Ken Squier** and **Barney Hall**, who were the first recipients. Berggren, who was known for his commitment to grassroots motorsport as much as to the higher levels of US stock car racing, retired in 2012.

UK engineering student **Oliver Milner** has won the Infiniti Engineering Academy European final and from January of next year he will spend six months working at the Renault F1 Team's technical centre in Enstone, UK, plus six months at Infiniti's European Technical Centre in Cranfield, UK. Included in the prize package is accommodation, access to a company car and a competitive salary. Now into its sixth year, 50 per cent of past Academy winners have gone on to secure full time roles at either Infiniti or in Formula 1 following their placements.

**Mathew Nilsson**, the co-team principal of Australian Supercars squad Walkinshaw Andretti United, spent some time in the US with sister operation Andretti Autosport recently, attending the IndyCar race at Road America with the team and then working for a week at its Indianapolis workshop as part of a drive to pool information between the two teams. Andretti took a stake in the Supercars squad, as part of a deal that also included **Zak Brown's** United Autosports, last year.

Erebus Motorsport CEO **Barry Ryan** has bought a share in the Supercars team by way of purchasing a 50 per cent stake in one of its car's Racing Entitlements Contracts (which amount to a franchise to compete in the series). He now joins team owner **Betty Klimenko** as co-owner of the No.99 Holden. Ryan was promoted from general manager to CEO last year.

# Fry leaves McLaren; Lowe Williams exit confirmed

**It's been widely reported that Pat Fry has been placed on gardening leave after deciding to leave the McLaren Formula 1 team.**

Fry rejoined McLaren on a short term contract in September last year after eight years away, with a brief to help run the technical effort as the team awaited the arrival of James Key, who was himself then on gardening leave after parting company with Toro Rosso.

Fry worked alongside Andrea Stella at McLaren and contributed to the much improved 2019 racecar, the MCL34. He has been reporting to Key since the latter joined the team earlier this season. McLaren would not comment on the situation, which is a company policy when it comes to matters concerning personnel.

It's unlikely that Fry could have much input into any team's 2020 chassis, because of the gardening leave he is now on, but he specialises in engineering and development and could be available for this sort of role before the start of 2020 testing.


XPB

Pat Fry's second stint at McLaren has now ended

Fry began his career with Benetton in 1987 and first worked for McLaren in 1993. He was at Ferrari until the end of 2014 before a brief spell at Manor, then came back to McLaren in 2018.

One team that has been linked with Fry is Williams, which is now free to pursue a new technical boss following the official confirmation of Paddy Lowe's departure. Lowe had been on a 'leave of absence' since the beginning of the season, citing 'personal reasons'. This came in the wake of a dismal testing display for the FW42, which has since continued to underperform. The former Mercedes and McLaren technical boss arrived at Williams in 2017.

# F3 mechanic's death was accidental rules inquest

**An inquest jury has concluded that the death of Double R Racing mechanic JJ Wilson at a shakedown crash in February of last year was accidental.**

Wilson was driving one of the team's BRDC British F3 Tatuus chassis when it hit a concrete lighting block at Longcross Studios in Surrey, UK – a popular automotive and media test venue. The 23-year old was pronounced dead at the scene.

Accident analysis revealed that Wilson, who had had extensive karting experience, had reached 137mph just before the crash, which is nearly twice the speed limit at Longcross. He was also not wearing racing overalls, although the court said this in no way contributed to his death. He was wearing an approved racing helmet.

The three-day hearing at Woking Coroner's Court heard that the car's wishbone broke away from the chassis, causing a loss of control, leading to the fatal collision.

Accident investigator David Price, who carried out an in-depth examination of the Tatuus following the crash, said: 'Failure to tighten the bolt to its correct torque would seem the most probable cause.'

In its concluding statement the jury remarked: 'During his final lap, control of the car was lost. The car skidded off the right-hand side of the track, hitting the concrete lighting block. He crashed into trees and the car turned over.

'His colleagues went to assist and righted the car,' the statement continued. 'The paramedics cut the straps and took JJ out of the car. CPR was performed but they were unable to revive him due to his head and neck injuries.'

Wilson, an extremely popular team member at Double R, had worked on the team's F3 European Championship effort before switching to BRDC F3 in 2016, when he tended the title-winning entry driven by Matheus Leist.

## RACE MOVES – continued


NASCAR

**Jim Cassidy**, a veteran NASCAR executive, has joined the board of directors of Parella Motorsports Holdings (PMH), owner of the Sportscar Vintage Racing Association (SVRA) and majority owner of the Trans Am Series. Cassidy is currently president of Cassidy Sports Advisory. His most recent work at NASCAR involved senior vice president roles, chiefly leading its racing operations and its international business development department.

**Georg Seiler** is to retire at the end of August after 41 years at the Hockenheim-Ring circuit in Germany, where since 1991 he has been CEO. **Jorn Teske** and **Jochen Nerpel** will take over the management of the German Grand Prix venue, as joint CEOs, in September. Teske has been head of the marketing department at the track for over 13 years while Nerpel has led Hockenheim's technology and operations division since 2016.

**Nikolai Attard** has joined motorsport, automotive and technology PR agency Influence Associates as a senior manager. He has previously held roles in the media, including working at the Pistonheads website.

Aston Martin Lagonda president and group CEO **Dr Andy Palmer** has received an honorary doctorate from Cranfield University in recognition of his 'drive, determination and constant quest for innovation'.

**Christopher Foster** has joined motorsport and automotive public relations concern Prova. Foster, who takes on the role of chief operating officer, looked after ABB's title sponsorship of Formula E while a director at Influence Associates, while he has also worked at Honda F1, Ferrari and Zytek. He previously held the position of operations director at Market Engineering.

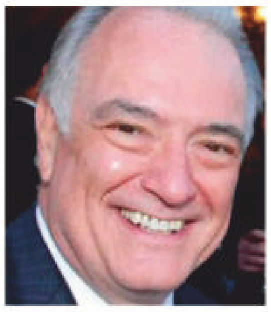
**Kevin Aldrich** is stepping down as business development manager at Spal Automotive UK, which is the sales and warehousing arm of the well-known Italian high performance axial fan and centrifugal blower designer and manufacturer. He is retiring after seven years with the company.

**Brian Wilson**, the crew chief on the No.22 Team Penske NASCAR Xfinity Series car, was kicked out of the Kentucky Speedway round of the series after the Ford he tends was found to be running with an illegal body modification at pre-race inspection. Wilson was suspended from one round of the series, the race at Kentucky, and the team was fined $10,000.

IndyCar and IMSA team owner **Bobby Rahal** has received the Cameron R Argetsinger Award for Outstanding Contributions to Motorsports. Rahal, also a successful driver in the past, was honoured by the International Motor Racing Research Center for his commitment to the sport.

**Chris Gabehart,** crew chief on the No.11 Joe Gibbs Racing Toyota in the NASCAR Cup, was fined $10,000 for an improperly affixed lug nut at the Chicagoland Speedway round of the series. Meanwhile, **Mike Shiplett**, crew chief on the No.00 Stewart-Haas Racing Ford in the Xfinity Series, was fined $5000 for the same infraction, which was also discovered at Chicagoland.

◆ Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then email with your information to **Mike Breslin** at **mike@bresmedia.co.uk**



# Motorsport is good for you

Businesses involved in the sport should not forget their roots, argues the MIA's CEO

Over 15 years ago the MIA first introduced the 'Energy-Efficient Motorsport' initiative to give members an introduction into mainstream automotive R&D, which has been extremely lucrative for many large and small motorsport businesses. But recently I heard that some of these same companies are now considering leaving motorsport to focus purely on automotive engineering and the like, which causes me concern. I believe they should re-evaluate the unique value they gain from being a motorsport supplier.

In July I hosted the MIA's annual motorsport conference on business growth so had the chance to speak with business leaders and hear their plans. Those at the peak of technology transfer from motorsport, such as McLaren Applied Technologies and Williams Advanced Engineering, gave the same response as most others. All agreed that over the next decade we will increasingly see calls for the very capabilities that motorsport-based engineering companies have acquired and are now making available.

Major companies face exceptional challenges as demand for their products changes rapidly as consumers enjoy a wider choice of mobility and transport options than they could have ever imagined. OEMs and Tier One companies will require the skills and capabilities of motorsport to meet these various engineering challenges, to develop and test prototypes in the real world ready for production.

OEMs need this work to be done as cost and time effectively as possible and won't find it easy to keep this in-house. They will look to the motorsport communities for supplies, and no community is better equipped for this work than Motorsport Valley UK.

## Reasons to be cheerful

Recent business news headlines predict gloom; investment falls; cash crunch; inevitable recession in Germany; fall in output; risk aversion and the global economy is uncertain and unpredictable. All positive messages to give confidence to businesses! However, looking at headlines that came out of our motorsport conference and a different picture emerges: Bentley sets a world record; innovations bring victory; fast growth in new global markets; innovators and disruptors grow fastest; Mercedes Formula 1 sets a new record; confidence to increase workforce; Le Mans to race hypercars, and NASCAR new regulations will increase business.

GT Racing has attracted 11 OEMs into GT3 and six into GT4 (Formula 1 has just four). These OEMs want their brands to reach global markets served by GT3 – USA, Europe and Asia. Rule changes in 2022, and with LMP1 from September next year, means there will be some 25 new motorsport programmes in development for GT over the next two years covering engine, chassis, brakes, aero, hybrids, sustainable materials and much more, and most OEM programmes rely on outsourced components and services. And this is just one category.

So clearly motorsport business is indeed good for you; you can celebrate this by approaching the engineering world with total confidence that you can meet its new demands. Our community knows that every second of time, millimetre of space and gram of weight really matters and we always deliver on time. This capability has come from meeting a cocktail of challenges which are motorsport's differentiator and battleground. Meeting rigid time constraints, constant prototyping, changing technical regulations, rapid response delivery and intense competition – there's no business sector like this one, where only winners survive.


**Manufacturers have recognised the value of GT racing in general and GT3 in particular and motorsport companies are perfectly placed to profit from this**

Motorsport Valley also attracts the world's best talent. Professor Greenwood of Warwick University says that just a few years ago he would recommend that his best students should go to major companies, but now he points them towards SMEs and motorsport 'where they will learn fast and rapidly acquire skills fit for the future'. Tony Harper from Jaguar Land Rover and the Faraday Challenge agreed that motorsport is the best place to achieve these aims. Powerful allies indeed.

## The road ahead

The UK Automotive Council regularly produces technology road maps that indicate the likely direction of travel for future technology. Steve Sapsford, with the MIA, overlays changes in motorsport technology to see how best motorsport can stay relevant, improve value for money for R&D and encourage rule makers to connect with the OEM's direction of technology.

This excellent work will be released by the MIA shortly. It shows there will be, for at least 20 years, continuous development of internal combustion engines in low carbon, renewable fuels, hydrogen and many other technologies alongside electric machines, power electronics, battery systems and fuel cell development. There will be developments in integrated hybrids/electric drive units in transmissions and an urgent demand for integrated thermal management solutions. Motorsport will secure work within the connected and autonomous fields where development must accelerate to create safe environments for road users and where autonomy will complement existing race technology, not compete with it. For example, we will see autonomy in pit stops and safety car deployment and connectivity between racers to avoid accidents.

I hope more businesses will recognise that motorsport really is good for you; in fact without it they could become just another 'three-quote engineering supplier' – an awful future. Those with experience and success in motorsport have learnt their business the hard way; they don't let customers down and certainly don't enter quotation battles – what they supply is the very best solution at the right price and always on time.

These unique, invaluable assets can only be learnt and tested through competitive engineering – which is motorsport. I strongly believe those in motorsport have an exciting, positive future and to use the MIA to help you make certain of success, please just contact me at info@the-mia.com

**Our community knows that every second of time, millimetre of space and gram of weight really matters and we always deliver on time**

Racecar engineering
The International Journal of Motorsport Technology

PIT CREW

**Editor**
Andrew Cotton
@RacecarEd

**Deputy editor**
Gemma Hatton
@RacecarEngineer

**Chief sub and news editor**
Mike Breslin

**Art editor**
Barbara Stanley

**Technical consultant**
Peter Wright

**Contributors**
Ron Ayers, Mike Blanchet, Sam Collins (associate editor), Ricardo Divila, Andy Green, Simon McBeath, Danny Nowlan, Mark Ortiz, Leigh O'Gorman, Martin Sharp

**Photography**
Gavin Baker, James Moy

**Deputy managing director**
Steve Ross **Tel** +44 (0) 20 7349 3730
**Email** steve.ross@chelseamagazines.com

**Advertisement Manager**
Lauren Mills **Tel** +44 (0) 20 7349 3796
**Email** lauren.mills@chelseamagazines.com

**Circulation Manager** Daniel Webb
**Tel** +44 (0) 20 7349 3710
**Email** daniel.webb@chelseamagazines.com

**Publisher** Simon Temlett

**Chief Operating Officer** Kevin Petley

**Managing director** Paul Dobson

**Editorial and advertising**
*Racecar Engineering*, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
**Tel** +44 (0) 20 7349 3700
**Fax** +44 (0) 20 7349 3701

**Subscriptions**
**Tel:** +44 (0)1858 438443
**Email:** racecarengineering@subscription.co.uk
**Online:** www.subscription.co.uk/chelsea/help

**Post:** *Racecar Engineering*, Subscriptions Department, Sovereign Park, Lathkill St, Market Harborough, Leicestershire, United Kingdom, LE16 9EF

**Subscription rates**
UK (12 issues) £89
ROW (12 issues) £100
racecar@servicehelpline.co.uk

**Back Issues**
www.chelseamagazines.com/shop

**News distribution**
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
**Tel** +44 (0) 20 7429 4000
**Fax** +44 (0) 20 7429 4001
**Email** info@seymour.co.uk

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

THE CHELSEA MAGAZINE COMPANY LTD
independent publishing company of the year 2015

www.racecar-engineering.com

# Emission impossible

Pollution. It's a dirty word. It's a word that sparks images of harm, the root of all our evil. The reason why war has been waged on diesel cars, and indeed on cars in general. Pollution is damaging our environment, on land, sea and air. Pollution must be stopped, immediately, or our world as we know it will disintegrate. Pollution leads to climate change, leads to death and poverty, as well as natural disasters that rob humans and animals of their habitat. Pollution is the single biggest threat to our existence, and yet we think nothing of putting our 80kg frames into a 1500kg vehicle and travelling short distances. We think it a right, not a privilege, to get into a metal bird and fly thousands of miles for a bit of sunshine. We think nothing of buying cheap clothing and cheap goods from high polluting nationalities, because it suits our wallets. And so, the political war on cars is a bit of a red herring.

My favourite argument is with a friend who has a BMW i3, and says that she is environmentally friendly because she drives her son to school in it every day, all on electric power. This is nonsense. The environmentally friendly way to conduct this business is to walk the less than one mile to school. The i3 serves as a convenience factor, not as a necessity. The number of cars that arrive at the school gates is quite phenomenal. They are not small cars, either, and most are new-ish. Those of us that have older cars are frowned upon because they are pollutants. Worse than a new car, if you take out of the equation the energy needed to create such a car, that is.

The drive towards efficiency is powered by successive governments who react without thinking. Diesel was a god of fuels, until it wasn't anymore. It's now the liquid Satan. Electric is the new god of fuels and mobility, until the full scale of the energy required to build the cars is truly revealed. Even then, it may be that electric is a function of our future mobility needs, but it certainly will not be the largest circle in the Venn diagram of transport.

That, I am afraid, still remains with the IC engine and it will do for the foreseeable future. While racing continually chases down the populist route with no regard for logic, or question, it is nothing more than chasing a shiny bauble. Formula E has its place in racing, that much cannot be argued against. It is motor racing, as there are motors involved in its propulsion. The question is, should it become the major focus for manufacturers, or could their money be better spent elsewhere? Has racing really delivered on its promise to provide a test bench for future technology, or is it a lie?

**Diesel was a god of fuels, until it wasn't anymore. It is now the liquid of Satan**

Hybrid technology in Le Mans prototypes has certainly helped to improve the understanding of batteries and high voltage systems in mobility, and there is no doubt that learning has accelerated rapidly in these areas. But the batteries and deployment systems have absolutely nothing to do with road car application; the exhaust energy recovery system only really works efficiently under full load, for example, so is useless on a motorway.

New regulations under discussion around the world involve hybridisation, and the fear is that if there is not a powerful enough system to see themselves through the next five-year homologation cycle, and motor racing will be left behind. This is a valid argument if you accept the current rules, but these rules are not written in stone and so they can always be changed. The Americans, for example, are having an argument about whether or not to introduce a 100V hybrid system into IMSA, NASCAR and IndyCar. It's nothing more than green paint on a technology map, rather than anything useful, particularly on ovals where regeneration is minimal, but never mind. Bodies are keen to introduce it so that manufacturers can claim, with a minor degree of legitimacy, that they are being environmentally friendly.

The environmental impact of an international motor racing series, for example, is only partially affected by the cars on track. Getting to the circuit, by land, sea or air, for the competitors and spectators, be for electric or hybrid, or non-hybrid cars for that matter, is an issue. There is an obvious solution; accept that racing, and driving for that matter, are not environmentally friendly activities. You will not save the planet by driving anywhere, in anything. So, stop pretending. Accept this, and suddenly everything becomes much simpler. While the working world should be encouraged to travel more efficiently, racing should excite the senses. It should fire the imagination in the same way as a space shuttle launch, so let's go that route.

I can hear the arguments; if manufacturers don't sell 'green' cars, they won't have money to go racing, and racing will die. No, it won't. It will continue, and it will be fun. Will we leave the young behind? No, because they also will go to concerts and drink and smoke themselves into a stupor while deafening themselves listening to music that is louder than it needs to be. Why so loud? Because it lights up the senses, and excites. It is a reason to be there. Racing should be the same.

**ANDREW COTTON** Editor


ARE DRY SUMP SYSTEMS
Everything DrySump!
Over 60 Varieties of Cast Aerospace Alloy CNC Machined Dry Sumps
Over 60 Different Dry Sumps Available!
LS1-6 "Fluidic" Dry Sump Pan
LS1-6, LS7 & LT 1-4
Over 11 Versions - Over 3100 SOLD!
LS1-6 "Ultra Shallow"
LS1-6 GTO/Monaro Dry Sump
LT1 1008-3 Corvette Stingray
SPINTRIC
CENTRIPETAL AIR/OIL SEPARATOR
FOR DRYSUMP SYSTEMS- TOTALLY PASSIVE
"One of the most exciting developments uncovered in research... The new passive Air/Oil Separator.... Providing a doible benefit to overall oil system..."
DavidCooper- Race Engine Technology
Watch on YouTube
You Tube
Type "Spintric"
Spintric Results
6 PATENTS
AIR/OIL FROM SCAV PUMP
EXCESS AIR OUT
OIL RETURN TO TANK
SPINTRIC.COM
SCAVENGE RET. OUT
SCAVENGE RETURN IN
SPINTRIC TECHNOLOGIES
"One of the most impressive innovations at Autosport Engineering... disarmingly clever"
Ian Bamsey- Editor- Race Engine Technology
"PRODUCTS ENGINEERED WITH A PASSION"
WWW.DRYSUMP.COM • 916.652.5282 • WWW.SPINTRIC.COM
European Distributor – Classic World Racing
www.classicworldracing.co.uk +44 (0)1527 521050
CWR