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Going with your gut

Data is fine, but there's nothing like experience to get to the root of a problem

Years ago, as a young engineer trying to reason out some of Colin Chapman's decisions on setup changes at the track, I did not understand how the decisions were made given the information he received and – more importantly – how fast it was being done, after a few terse words about the behaviour of a car in a couple of corners.

No data to look into, just the analog recorder with the voice output of the driver on a full adrenaline supercharge. Sometimes, after thinking about it for a few hours, I could work it out, but the actions seen were despairingly far from my capabilities.

Today, after more than half a century of racing, I understand what was involved. Life is an accumulation of experiences which builds a database of information that can be drawn upon to fit to occasions. A car that is well known will respond in a familiar way, and if you know your driver you can see what he likes and then trim to fit. There is a complex series of causation effects derived from tyre characteristics, vehicle dynamics, power curves and aero envelopes, but this is only teased out of the firehose of information from many different channels, and if it follows a familiar pattern, the sheer correlation will be enough to make decisions. Most decisions end up being binary – like will we change ride height or give it a notch of bar? Or will we give it more front wing or less rear? This, even though the solution is multidependent on several interacting effects with non-linear responses.

The veteran engineer works a lot with gut feeling, or, as the poet WH Auden mentions: 'a riot of subjective visions – feelings in the solar plexus.' They intuitively feel the right answer and only look into data to prove or disprove the feeling used to make a quick decision in the heat of action.

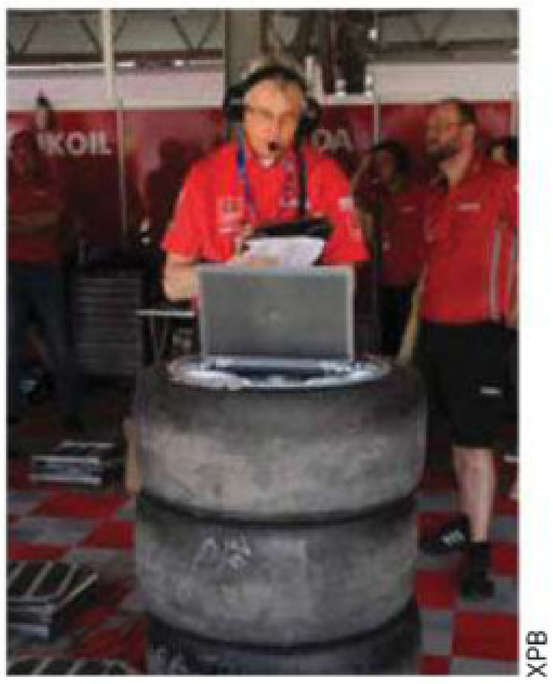
In more structured racing forms, the amount of simulation and pre-programmed test schedules are only running the sessions to a pre-written script where timing, actions and decisions to be taken are all foreordained weeks in advance.

However you prepare, new rules and cars bring new variables and that immutable law of unforeseen consequences, as behoves the Great God Murphy – and sometimes weather can do the same.

Numbers and the quantity of available information far surpasses the ability of people to review and analyse it, giving rise to an automatic system for data analysis. The sheer quantity of things to be viewed can bring about expert systems, with genetic algorithms, self-learning that soon will start having emergent behaviour and giving new insights into what is really going on, at least on the macro, Newtonian part of racing.And don't get me started in quantum mechanics, reality and free will.

I once tried to develop an expert system to generate driver comment from debriefs into a matrix of setup solutions, as chassis dynamics can be analysed from standard braking, turn-in, apex and power on exit car behaviour symptoms. However, trying to programme all of that into a Sinclair computer in machine code ended up being bigger than the poor thing's memory – remember, those were the days where the Apollo 11 guidance system was 11kb of writeable memory.

Today that can be envisaged as a system that would crunch information of the car's basic parameters. But it wouldn't have to do a full six degrees of freedom dynamic vehicle simulation, with all the complexities of having accurate data logging with accurate calibration of the sensors – a rare event in my experience. Instead, it could go into a Bayesian analysis of the input and not have to tie it into a causation correlation Gordian knot. It could use the big data approach, where even fuzzy, imprecise data can give insights and setup changes that will work providing the data set is not a restricted, limited and necessarily precise info one, but instead the data set=all. This is much as Google tracked a flu outbreak by the queries it received, compared to Centers for Disease Control and Prevention (CDC). Google's tracking had only a day's delay, compared with the week or more it took for the CDC to assemble a picture based on reports from doctors. Google was faster because it tracked the outbreak by finding a correlation between what people searched for, and whether they had flu symptoms.



XPB

The more experience you have, the better your instincts to make fast calls

In this type of analysis, the search for causation – informative as it can be in hindsight – can be trumped by correlation, ie it does not search for the why, only for the how. It could ultimately be more effective, because it is not biased by the engineer's relationship with the driver, their communication skills and the interpretation of incoming data through possibly miscalibrated sensors.

The habit of using a fastest lap does not beat the overlay of many laps to see trends. Sectors that repeat are ones without problems for drivers – the ones that vary are the difficult ones and show where car setup problems lie. The calibration of sensors in a team is analogous to the fitting of bodywork, being one of the last items seen to, and paying the cost of being short of time.

Calibrating pushrods by interpolation is the only way to be sure of your aero and chassis loads, but 80 per cent of the pushrod loads I have seen in detail are not correct. The usual check is a simple math channel to see the total weight of the four pushrods while going down the pitlane at 50 or 60kph, with negligible aero loads often giving variations, and once I even saw close to 50 per cent of the car's weight. How can aero loads be calculated correctly if we have this kind of float?

Masses of raw data analysed just for correlation, in a known car, could generate algorithms to give the correct change.

There is often a lack of gut feeling by engineers of what loads a car is seeing, probably because neat printouts with several digits behind the decimal point can generate confidence, notwithstanding the value being a couple of orders of magnitude outside credible range. I have received reports of suspension movement giving values that if derived would mean that wheel is moving at 800 g. Mmmm, really?

One states in full understanding that the search for precise numbers and accurate laws of physics are fundamental to engineering, but there is a non-compliant hormonal driven element in the equation – the fallible human one – so a fresh approach could be interesting.

Maybe new insights will be found. After all, life is Bayesian. We continuously input new information and refine our internal view of the workings of the universe, not necessarily correctly, but certainly useful in navigating this random maze.

Neat data can generate confidence – unless the numbers are wrong

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The new sound of F1

Why the fuss? Quieter, cleaner engines mean engineers are hitting the right note

I propose, albeit slightly reluctantly, to throw my hat into the ring concerning 2014 F1 engine – sorry, power unit – noise. Not having heard a PU so far except via TV broadcast, it is a presumption to some degree on my part to comment, but as F1 is ultimately financed by TV audiences and there has been a largely negative response to the soundtrack accompanying the cameras, it's clear that the lack of exciting noise is a significant issue.

Perhaps this has been exaggerated by two factors, one being the dire warnings of the engine sound over the winter that may have pre-conditioned attitudes, the other the high-pitched scream of the various multi-cylinder engines we've all become used to over the past couple of decades. Before that we had turbo engines in F1 (and just 4 cylinders – not even 6 – in the case of the formidable 1980s BMW units) but while nothing like normally-aspirated motors, they were not as muted as the new PUs. I'm not quite sure why. Perhaps it's because – in qualifying trim at least – they always sounded on the verge of self-destruction! Before that, the widely-used Ford/Cosworth DVF had a V8 bark, but not to the extent of recent 'screamers' – although the 12 cylinders of Ferrari and occasional others always added a nice crescendo.

Adapting to the different volume and pitch is inevitable, and I'm not a believer in creating artificial noise, as has been suggested by some. Let's face it, F1 is artificial enough as it is. The problem must be tackled practically, and steps are being considered to rethink the transmitting of the sound from the racetracks, which I suspect has not changed in essence for a good many years. This will help, as will a general aural accommodation by viewers as time goes by. Hopefully, the primary engine (ICE) rpm will increase closer to the 15,000 permitted by the regulations, whereas it appears that currently 12,000 – less when short-shifting due to the torque – is the norm. Some of this might come from development and further-reduced friction in the ICE, but I think perhaps some tweaking of the fuel flow allowance will be necessary to make that happen. My brother favours a megaphone exhaust...

Although I join those who don't like the TV sound, it fits in with the twin desires of the FIA to reduce noise to comply with ever-encroaching environmental legislation, and to be seen as leading the drive for greater efficiency. It is a fact that noise equates to wasted energy going down the exhaust pipes, so the more efficient the motors, the quieter they will become. I don't doubt that most of the mechanics and pit-crew actually love them – like me, many who've been close to noisy racing engines over a long period of time have eventually suffered hearing difficulties, although the onset of ear defenders/headsets has mitigated the worst effects. Drivers are affected too. German racer Volker Weidler had to unfortunately retire prematurely from the sport in the 1980s shortly after winning Le Mans 24 Hours, due to serious hearing problems. Mind you, he won in the unique Mazda Wankel car, which hurt everyone's ears that year and which most of us on the pitwall prat-perches earnestly prayed would quickly blow up. There can be no doubt that other drivers have been similarly affected, however.

I have not really been a total fan of the 18,000-plus rpm F1 engine note. While never failing to be amazed by the ear-splitting shriek – and the fact that they could all hang together so reliably – there was nonetheless something too controlled and uniform about them. When visiting historic events I am struck by the harsher and more elemental exhaust sound that emanates from early supercharged engines. Along with the scream of the blowers, the exhaust notes somehow convey the almost uncontrolled energy being unleashed – and there is much more variety, as I have mentioned previously. My particular favourite must be the pre and post-war blown straight 8 Grand Prix Alfetta. The urgent, almost primitive and ungoverned sound – simple carburation plus imperfect ignition timing and combustion, all limited by the technology of the time – complete with throttle-off crackle makes my hairs stand on end, cliché or not. And then there's the smell of course – as my *RCE* colleague Ricardo Divila recently reminded us, exotic fuel mixtures and vegetable-based lubricating oils excite the olfactory senses to add greatly to the visual and aural feast.

If technology now was capable of transmitting smells to accompany the TV picture and soundtrack, it would be rather wasted where modern F1 is concerned. You'd be more likely to have the scent of frying hamburgers or boiled bratwurst wafting into your living-room than anything to do with the racecars, given that it's all so clinical.

So we have to face facts – the drone is here to stay. Hopefully, however, so also will be the oversteering and occasional power-on spins largely lost to us since serious downforce, excessive electronic engine control and radial racing tyres stifled what should be one of the arts of race driving. Balancing a car on the limit of adhesion with both steering and throttle – an excess of torque over grip – and scrabbling for traction out of corners still remains a thrill for drivers (surely?) and spectators alike. Let's wish fervently that ongoing refinement and development of power units, software and tyres doesn't take this feature away from us again, as it certainly helps to compensate for the dull exhaust note.

If F1 is going to produce more races of the intensity of the Bahrain Grand Prix just recently seen by hundreds of millions, then perhaps visual stimulation is enough. As for me, however, I'll continue my fascination with F1 and other forms of contemporary motor racing, but will settle for getting my essential sensual kicks from the likes of Goodwood and Shelsley Walsh.



XPB

Hello? Hello? Can you hear me? Ah, I see – you must work in motorsport...

The more efficient the motors, the quieter they become. Mechanics and pit crews must love them

Agent K

Toyota is the only manufacturer to race with a double KERS in its Le Mans prototype, which boasts almost 1000bhp

BY ANDREW COTTON



"The most efficient way to use energy is the fastest. Our system is 6MJ, but our motor power is huge – it is more efficient and more strong than Porsche's"

The battle for supremacy at Le Mans began at the end of March as all the major LMP1 manufacturers announced which hybrid category they would run in. It was in France, at the test for the World Endurance Championship pre-season test at the Paul Ricard circuit, that the final pieces of the jigsaw came together and Toyota announced that it would run in the 6 megajoule (6MJ) category with a double KERS, front and rear.

Immediately, Porsche scaled back its ambition and also entered the 6MJ category in its first year, while Audi made the decision back in November 2012 that it would run in the 2MJ category, and has stuck rigidly to that plan despite apparent flaws.

It was something of a shock to realise that Toyota will not race with the maximum hybrid performance this season, although there are performance advantages to running a larger system and the system could be upgraded next season. Using super-capacitors, a fast charge/recharge characteristic means it is more than capable of meeting the demands needed to run in the 8MJ class, and with front and rear KERS already built and tested in 2012 and refined in 2013, it seemed obvious.

However, the size of the battery and the weight distribution compromise that would need to be reached meant that Toyota dropped to 6MJ to cope with the decreased weight limit imposed on LMP1s this year.

'The minimum weight was decreased from 915 to 870kg, so that impacted a lot,' says team president Yoshiaki Kinoshita. 'We designed our car to the same minimum weight. From 6MJ to 8MJ is a huge benefit because of the fuel allocation, but you cannot do the race with an overweighted car. Last year's hybrid assistance was already 100kg, and this year we added a front motor. With the philosophy behind the regulations, a big hybrid system should have an incentive. It is a bit sad for us.'

For Hisatake Murata, Toyota's hybrid project leader, the decision not to go for the full 8MJ category is not a disaster, and he considers that Audi's system could also pose problems in race conditions this year. 'It is an amateur point of view that 8MJ volume is huge,' he says. 'The 8MJ system is very good, but the 2MJ is also a good system.

'We have already calculated that the most efficient way to use energy is the fastest. Our system is 6MJ, but our motor power is huge. We have a lot of options to use the energy, so that means we can use the energy in the most efficient way. The final conclusion is this year's Le Mans, but I think our system is more efficient, more strong than Porsche's system.

'2MJ is the lightest way, and 8MJ of kinetic is a huge weight. But there are so many factors to consider, from the point of view of assisting the result, a system weight point of view, car weight point of view, from engine system weight point of view, engine thermal efficiency point of view, hybrid system point of view, hybrid assist performance point of view... there are many different systems, and the system design is very complicated. How to use the hybrid system is very complicated. It is a very complicated car, but from an engineer's point of view it is very interesting.'

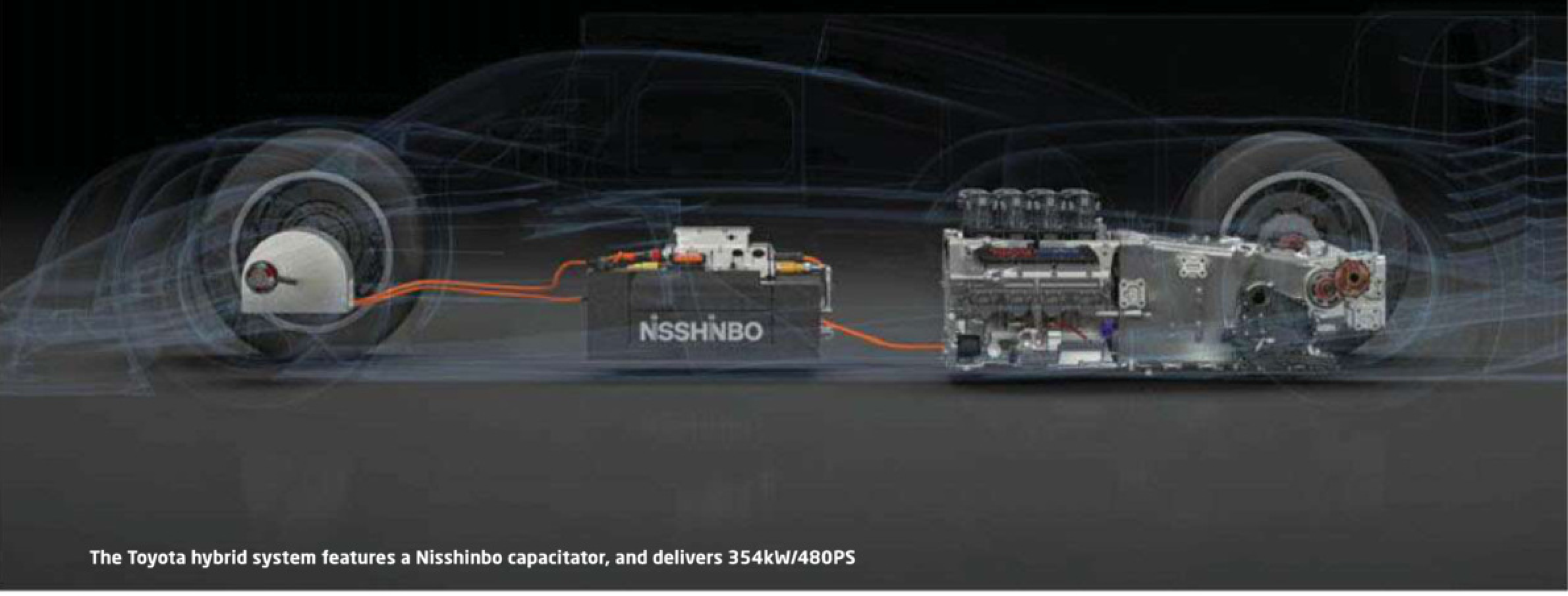
MGU-TALKING

Although the super-capacitors could charge and discharge fast enough, the battery weight and overall system weight prevented Toyota from running in the 8MJ class.

The company did look at alternative plans, and even considered a turbocharged engine, but essentially carried over the normally aspirated engine from 2013. Given that the rumoured budgets between Toyota and Porsche are four-to-one in Porsche's favour, this was a predictable decision.



"Compared to last year, we are burning 25-30% less fuel, so to achieve this we've had to have a big step forward in efficiency"



The Toyota hybrid system features a Nisshinbo capacitator, and delivers 354kW/480PS

TOYOTA'S HYBRID HISTORY

Back in 2006, Toyota first embarked on the development of a racing hybrid system. Production hybrid cars run most efficiently in the city, where the cars stop and go repeatedly, but the fuel efficiency drops during the high speed running. During a race, cars constantly undergo hard braking, which would create a large amount of energy for hybridcars. So, gaining expertise in racing would eventually lead to developing a mass production hybrid system which is highly efficient at any speed range.

In 2006, Toyota participated in the Tokachi 24 Hours using a new hybrid road car, the Lexus GS450h, which featured experimental capacitor technology. That was an early test for this potentially useful energy storage system, which can quickly recover and release energy. During the race, in the northern part of Japan, the team collected various data, focusing on understanding how a hybrid system behaves in race conditions. They tried different driving modes and confirmed a 5-10 per cent improvement on fuel efficiency.



Toyota's racing hybrid programme began in 2006 with the GS450h. Yoshiaki Kinoshita started the project, development was handled by Hisatake Murata

The development team was back in the Tokachi 24 Hours again in 2007. The previous year's car had a system that was based on a mass production hybrid system, but this year's hybrid system was specially made for the event.

The base car was a Supra that was competing in SUPER GT GT500. A Motor Generator Unit (MGU) and a capacitor were installed to assist the Supra's naturally-aspirated V8 4.5-litre engine.

The predominant feature of the car was a four-wheel regenerative system, with additional high power MGU at the rear and in-wheel motors at the front. The extra MGU on the rear was to regenerate the energy efficiently under braking. The Supra HV-R proved a 10 per cent energy efficiency improvement, compared to the car without the hybrid system, during the 3136km 24-hour race in which it achieved overall victory.

The victory confirmed that development of the racing hybrid system was moving in the right direction. But in Le Mans, Audi was winning with a diesel engine. To beat the champion in Le Mans, Toyota had to fill the energy efficiency gap between diesel engine and gasoline engine first. And then it was necessary to reduce the weight of the hybrid system to improve the performance of the car. According to initial calculations, a hybrid system capable of delivering the performance to win Le Mans would weigh 600kg, but to actually have a realistic chance, the system needed to weigh less than 100kg.

THS-R DEVELOPMENT

When Toyota introduced the TS030 HYBRID in WEC, the team had developed a hybrid system called THS-R (Toyota Hybrid System - Racing), which had

'A turbocharged petrol engine is not so efficient,' says Murata. 'We have to separate the diesel engine and petrol engine, and a petrol turbo engine is not so good.

'We don't use an MGU-H because my opinion is that if the engine drives the motor, it means that due to the engine back-pressure from the exhaust, the engine efficiency is sometimes down. We started to analyse such a system, but our conclusion was that the system efficiency was not so good, so we concentrated on MGU-K front and back. Our final conclusion is this year's system. Two years ago we had already completed this year's system, but the regulation did not allow us to run it, so we dropped off the front system. The DI engine needed a starter motor, but if we installed the rear motor, we could drop off the starter motor, and from the car design point of view, the front bulkhead is a very sensitive area for the aero guys.'



The floor of the Toyota TS040 does not offer up too many secrets. The area around the front wheels is more free than in 2013

Toyota announced that the complete system could produce 1000PS – almost 1000bhp – for up to five seconds per release. This is spread between the engine, at 520PS, and the MGUs produce 480PS.

However, the delivery is across all four wheels, which reduces the dependency of a specialist tyre to cope with the necessary forces.

'Compared to last year, we are burning 25-30 per cent less fuel, so to achieve this there is a big step forward in efficiency,' says technical director Pascal Vasselon. 'At the moment we have smaller tyres, but we have no concern of consistency. We are not going to do two stints at Le Mans – Le Mans will be three or four stints. We don't expect issues. We don't expect a big change in terms of consistency.'

Watching the cars deliver power out of slow corners, Porsche appears to deliver its power progressively, while the Toyota waits until it is straight, and then delivers all the power. For drivers such as Anthony Davidson, this is all part of the new driving style – the coasting into the corners, late and deep braking areas, and the fast change from brake to throttle which still favours the left foot braker.

MAPPING IT OUT

First test sessions this year are going to be taken up with calibrating the driver systems which will enable the drivers to save fuel, and – in Toyota's case – the adjustable balance of power delivery from rear to front could also help them to drive the car.

'Power delivery depends on corner condition, weather condition or whatever,' says Murata. 'The driver can choose a map, very similar to the way he can choose the brake balance. Currently we are searching the solution circuit by circuit and by road condition, and we are analysing.'

One of the major problems that comes with KERS is that it is brake specific. In 2013 at Spa, a hybrid failure saw the car pit moments later with overheating rear brakes. The car has run brake-by-wire for two years now to help the drivers to modulate the brakes between recuperation and braking events, but the rear brakes would still overheat massively should the hybrid system fail.

'Our hybrid system, and our motor power is very big, so it means that if our motor stops, the brake disc temperatures increase,' says Murata. 'If we have a motor stop, we cannot continue to run. We have very intelligent failsafe system and motor reliability is very tough. If we have a system failure, it depends on the driver's driving style, but using the same driving style they cannot continue for half a lap. One hard braking they can stop, but two or three hard braking? It's very difficult to continue.'

220kW Denso MGU in between the engine and gearbox. The electric energy regenerated during braking by the MGU was stored in a Nisshinbo super-capacitor installed on the passenger-side of the car. The capacitor was kept at operating temperature by a water-cooling system and controlled by a Denso inverter system mounted on top of the capacitor.

The weight of the hybrid system was less than Toyota had targeted. They were able to reduce the size and weight of the rear MGU without compromising on power, thanks to a reworking of the rotor magnet arrangement. This technology is expected to also downsize mass-production hybrid system without losing power.

At the start of development, Toyota was building a four-wheel regeneration system with an Aisin AW MGU installed at the front. But a regulation change meant that four-wheel regeneration was no longer permitted and the power released in between two braking points was limited to 0.5MJ, down from the original 1MJ. Therefore, Toyota decided to focus on the rear MGU, which delivered the biggest performance gain.

A hybrid system is not all about electrical parts, as the engine is an integral part that can contribute to system downsizing and energy efficiency improvement. For example, of the energy required for driving a lap in the Le Mans 24 Hours, 95 per cent of the 13.629km at Circuit de la Sarthe is powered by the engine, with the MGU responsible for the remaining 5 per cent.

LIGHTER WEIGHT

The normally-aspirated 3.4-litre V8 gasoline engine developed specially for the TS030 Hybrid weighed less than 100kg, like an F1 engine.

WEC prototypes use various materials to complete the installation of a powertrain. To reduce the weight of these items, the TS030 Hybrid adopted a full stress mount structure, which received the input from rear suspension directly. The increased stress means more strain on the parts, but Toyota was able to add 10,000km to the system's durability through careful tests and development.

Regenerative cooperation brake technology is essential to a hybrid system, which efficiently regenerates energy by managing conventional pneumatic braking and regenerative braking, depending on the situations. In situations such as racing, high precision is required from the system. Improving the precision to match 0.01-second gear changes, Toyota was able to achieve both efficiency and drivability.

THS-R for the 2013 TS030 Hybrid was basically the same as the 2012 system – the concept remained the same. The energy regenerated by the hybrid system is transformed into power performance. The concept of the development was to increase the power for a long period without interruption. Compared to the 2012 specification, precision of control – as well as efficiency – was improved to achieve better vehicle dynamics.



The TS040 with one of two aero configurations in testing at Paul Ricard at the start of the season

Setting up the hybrid system for each circuit is not a small task, and the team is going to have to work hard during free practice one at every race to make sure it has the most efficient system possible. Testing alone on track produces one set of fuel consumption figures (although even these change dramatically between the driving styles), but running in traffic, at different temperatures and altitudes, is going to produce even more different results. The computer needs to be programmed specifically at every race.

'We have many different types of actuator, engine, front motor, rear motor, front brake, rear brake – so a five part actuator,' says Murata. 'What is the best way? It is very difficult. We have a lot of simulation and tuning many parameters we calculate through simulation. Five actuators, high middle and low – it means a huge number of buttons. It is very complicated, but if a car's condition is oversteer, we can easily change that to more oversteer or more understeer... we can choose.'

POWER UNIT

The rest of the power unit was also carried over from the 2013 TS030, with the stroke increased slightly to give a capacity of 3.7-litre normally aspirated engine. This was done to reduce the revs, and increase efficiency, although Toyota also toyed with the idea of going further, and producing a four-litre engine.

Ultimately, the Brake Specific Fuel Consumption – the exact amount of fuel in grams to produce horsepower – led them to the smaller of the two solutions. 'We mainly changed the stroke, because of the length of the engine,' confirmed Kinoshita. 'We needed to keep the space for the hybrid system.'

Luckily for Toyota, the systems had already been extensively tested. Back in 2012, when the team was planning a full test season before Peugeot withdrew from racing, Toyota evaluated a front and rear Kinetic Energy Recovery System to see which was best. It was only allowed one at the time, and thanks to more freedom for the aerodynamicists, coupled with the ability to be able to harvest all the energy from the rear only, that was the system that was adopted.

"Intellectually it is nice to do a full carbon gearbox, but in the end the weight saving is not that big"

Now, with a greater amount of energy that can be stored, and with Porsche and Audi running effectively four-wheel drive systems (the regulation limiting four-wheel drive to above 120km/h is now rescinded), Toyota had all the necessary data. 'This year we are forced to have one motor [on the front axle] – we can't have two because the FIA doesn't want torque vectoring,' says technical director Pascal Vasselon. 'It is nothing special. The control system to handle it is more sophisticated, but it is just a good lightweight design. It is very similar to the one that we tested – it is smaller, lighter, and is one integrated unit.'

Toyota elected not to go for a carbon gearbox, having experimented with the technology in Formula 1 in 2009 and found its value to be limited. 'It doesn't make any sense to do a carbon gearbox because you have so much local loading introduction that you need a lot of inserts,' says Vasselon. 'Intellectually it is a nice exercise to do a full carbon gearbox, but in the end the weight saving is not that big. We went through that in F1 in 2009, when 80 per cent of our gearbox casing was carbon. It was not a bad choice at the time because we had a long bell housing. Carbon is very good with well distributed loads, but as soon as you have local introduction points – like pick-up points – then you have to put inserts, and you end up in a

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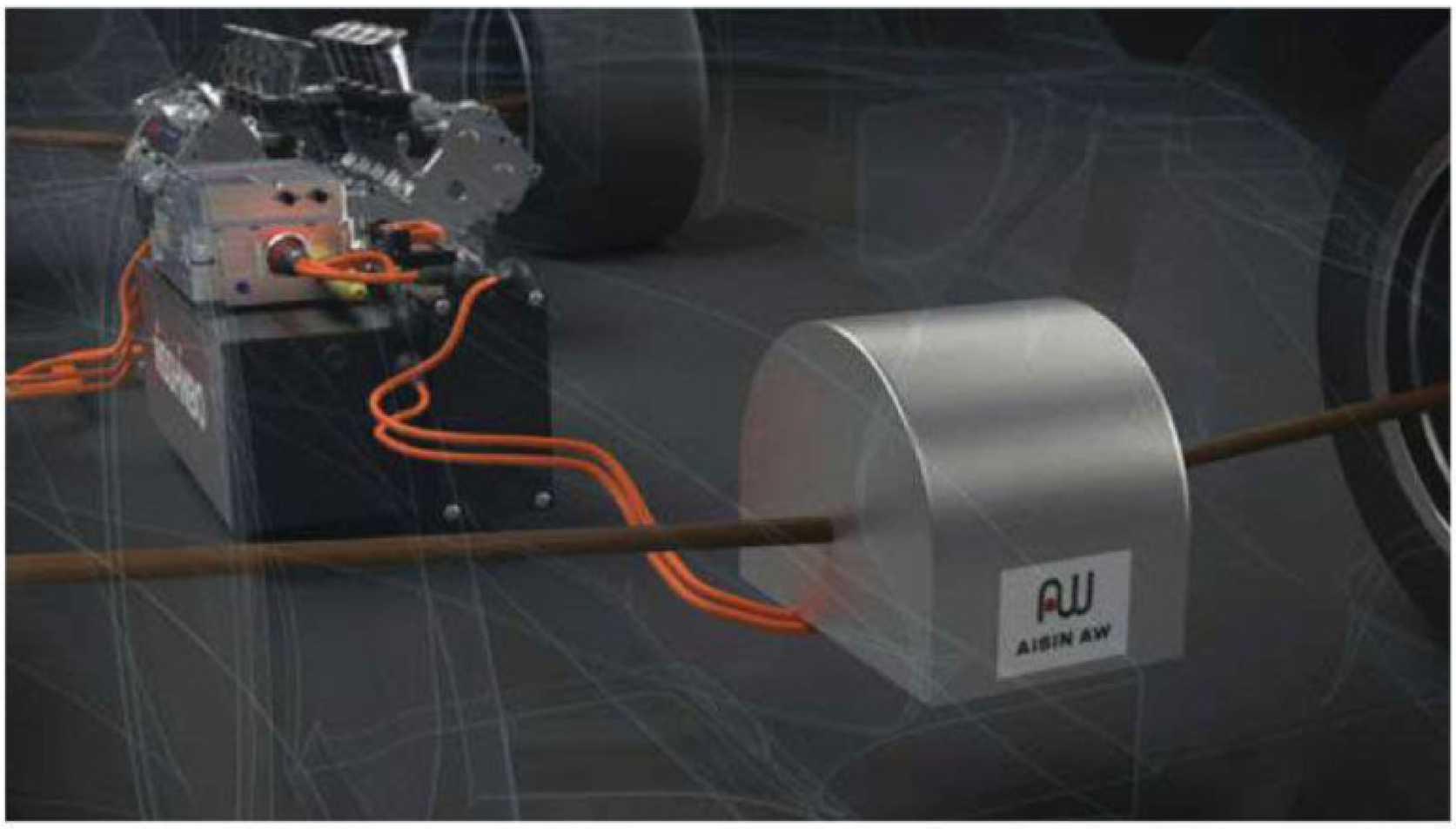
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The front motor has long since been developed - the original plan was to run it during the 2012 season

complex exercise and the weight is not that big. We have some carbon, but only where it makes sense to have carbon.'

IN TESTING

Toyota's test programme has been extensive and has covered more than 25,000km with the two cars before the start of the season, but much of the development work had already been completed in simulation before the car hit the track.

"At the front, if you compare the new regulations around the wheel area it is more open than before"

Using TMG's extensive facilities in Cologne, the car was then extensively wind tunnel tested.

AERO DEVELOPMENT

This year, the cars are narrower and lighter as teams battle to save 30 per cent of fuel compared to 2013, while still maintaining the fastest lap times. Porsche's simulation has shown that the new cars should be capable of producing sub-3m20s laps, although Toyota believes that it will be comfortably in the 3m20s.

The cars are narrower than last year, although much of the width reduction has come from the tyres, leaving the aerodynamic principles much the same as in 2013. 'It is a clean sheet of paper design,' says chief aerodynamicist John Litjens. 'With the new powertrain data that you have, you still have to establish the track efficiency that you need to achieve, so with the simulations we had to start from scratch. The good thing is that the narrowing of the car is taken from the tyre width, so the flow through the monocoque doesn't change that much. The cockpit at the rear stays high for longer but there is not much more than that.'

The big changes come at the front, where the front system requires driveshafts to the wheels, the bulkhead needs to be changed to accommodate the single MGU, and the regulations around the front wheels at the floor have also changed. Where the air attaches to the front of the car, there have been some big areas of development, although Litjens was coy about the detail.

'If you look back to 2012, you would have only one system, and one reason why we went for the rear only system was the aerodynamic decision,' he says. 'Now, we have different rules, we can use more MJ, and you have to adapt the kinematics slightly. If you start at the front, the air starts to flow on the car and is disturbed as little as possible by the driveshafts, and we try to condition the flow.

'There was quite a lot of work from aero to minimise the losses. The air continues further and around the wheel wake. In that time, the floors were quite restricted, so we could do the front diffuser, a Le Mans splitter, and the high downforce splitter which extends into the chassis. Now you have a lot more freedom, so there are changes there. In the front, if you compare the new regulations around the wheel area it is more open than before.'

The introduction of a winglet, similar to that used by Audi on the R15 and which was successfully appealed by Peugeot - leading to the R15 Plus - is back on all three manufacturers. The target for each is to maintain downforce while shedding drag, particularly with the new driving style that requires drivers to coast down the second half of the straights, and into corners.

'It is more to do with efficiency than downforce,' adds Litjens. 'You cannot work on one area of the car because you might make a change and what happens behind it is important. You have to look from front to back - the complete package. You cannot work on one area, because you don't know what happens behind it.'

Toyota will therefore go to Le Mans with an already tested package. From the moment that the car hit the track for the first time - in January 2014 - it was reliable enough to begin meaningful testing immediately. More than 100 laps were completed with the car on day one, and since then the company has tested for more than 18,000km even before the first race at Silverstone. 'You are always in between - this year it was difficult to carry over parts, because the regulations changed, and we had to change the weight,' says Vasselon. 'So carry over was not so much, but then you never throw away what you have done - it is always carry over and white sheet of paper. The engine is a base of last year. The way to do it, Porsche has a 4-cylinder which is the 8-cylinder of the Spyder cut in two. No one will start from something completely new.'

TECH SPEC

Toyota TS040

Category: Le Mans Prototype (LMP1)

Gearbox: transversd with seven gears sequential
Gearbox casing: aluminium

Clutch: ZF-supplied Multidisc differential viscous mechanical locking differential

Suspension: independent front and rear double wishbone, pushrod-system
Springs torsion bars
Anti-roll bars front and rear

Brakes: dual circuit hydraulic braking system, mono-block light-alloy brake calipers front and rear
Discs: ventilated front and rear in carbon

Wheel rims: magnesium forged wheels

Tyres: Michelin radial
Front Tyre: size 31/71-18
Rear Tyre size 31/71-18

Dimensions:
Length: 4650mm
Width: 1900mm
Height: 1050mm

Powertrain: Toyota Hybrid System: racing (THS-R)
Engine: 90-deg V8 normally aspirated engine
Valves: 4
Engine capacity: 3.7 litre
Fuel: petrol
Max power: 382kW/520ps,
Lubricants: Total

Hybrid power: front and rear 354kW/480ps
Capacitor: Nisshinbo
Front hybrid motor: Aisin AW
Rear hybrid motor: Denso
Front Inverter: Aisin AW
Rear Inverter: Denso Overall

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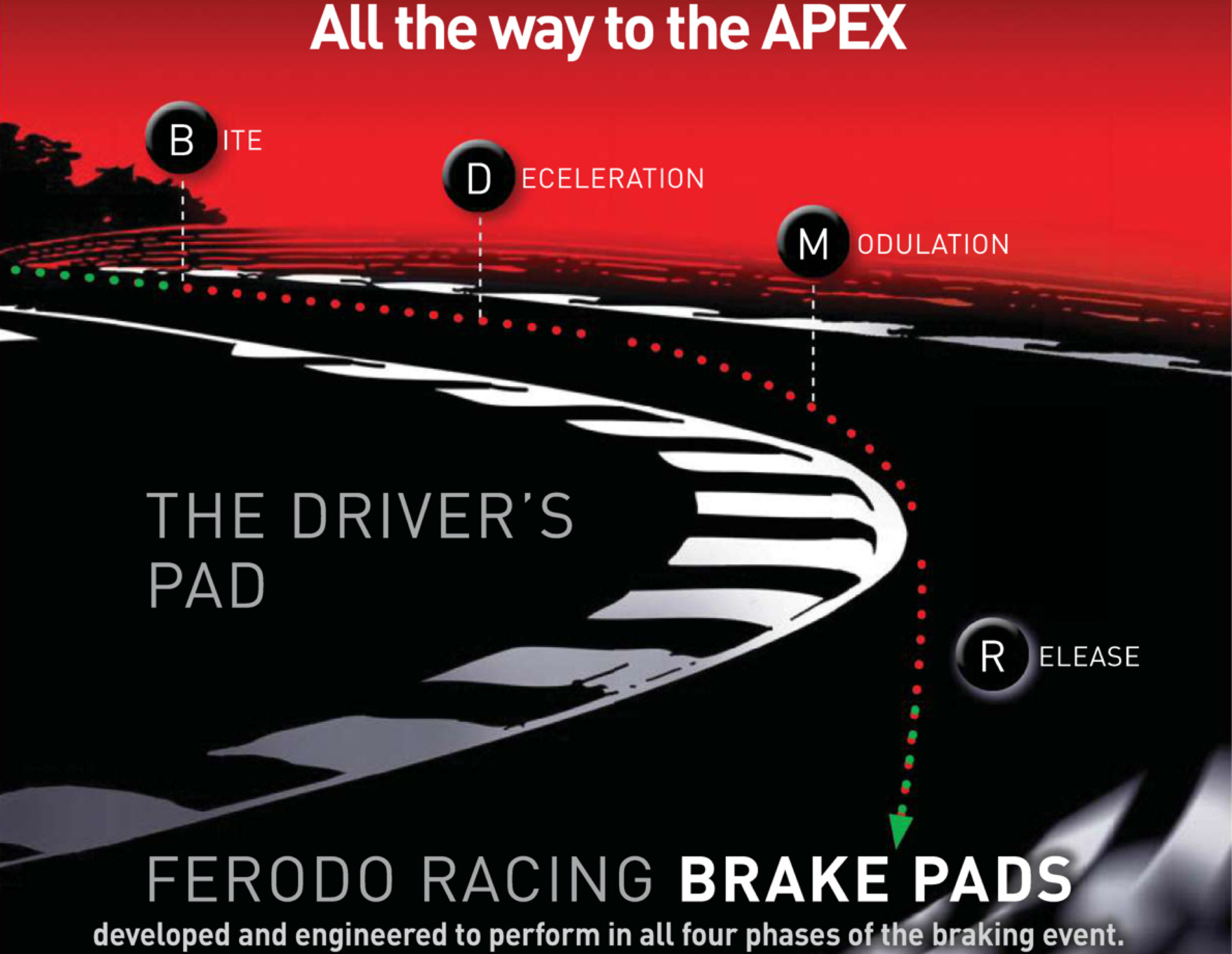
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Surprise package

A GT3 version of the Lexus RC F popped up unannounced at the Geneva Motor Show

BY SAM COLLINS

Toyota has long been linked to a serious GT racing programme. Its German motorsport subsidiary built and tested a Lexus-branded GTE-specification car that never officially saw competition, though a Gazoo Racing entry in the Nürburgring 24 Hours last year looked suspiciously similar. There were also rumours of TMG testing a GT3 variant in Spain, but they are thought to be baseless.

Perhaps it was a case of no smoke without fire, but nonetheless there was some element of shock when a GT3 version of the new Lexus RC F was revealed at the Geneva show in March. And the shock was not just limited to attendees at the annual event in Switzerland. A Toyota insider told *Racecar*: 'When the cars for the show arrived at the place this was rolled out, it was the first we knew about it!'

But it was there and it was given pride of place in the centre of the Toyota stand, even pushing aside the new Aygo which is arguably a more important car to Toyota as a company.

The new car was jointly developed by Lexus International and its subsidiary Techno Craft, and built by the latter in Japan. With a width of 2000mm, the RC F GT3 concept is wider than the standard RC F, at 1270mm it is also lower, and it weighs 1250kg, similar to most GT3 and GTE cars.

A modified version of the RC F's 5.0-litre V8 engine develops some 532bhp. Toyota has been reluctant to reveal too many details on the engine's specifics, something which may be related to the fact that the production RC F uses both the Atkinson cycle and Otto Cycle, actively switching between them according to demand. It seems logical that only the Otto cycle mode would be used in racing but chief engineer Yukihiko Yaguchi would not confirm this. 'What we are using is the base engine from the RC F which has been tuned for racing,' he says. 'The centre of gravity has been lowered by fitting a dry sump, and internal changes have increased output too. We also wanted to use a mainly standard engine for cost and reliability reasons'.

GEARING UP

Toyota claims that the car has yet to be run on track, though the 'show car' at Geneva looked very complete indeed. Yaguchi admits, however, that some areas are still being evaluated. 'The transmission has not yet been finalised, but we will be using something that is commercially available, a six speed sequential unit as you might expect,' he says. 'The suspension in the car is a bespoke double wishbone setup. We have tried to use this project to exploit and discover the full potential of the base chassis.'

The surprise many felt was on the whole little to do with Toyota developing a new racing car, but that it is building it to the GT3 rulebook. The issue is that



"We have tried to use this project to exploit and discover the full potential of the base chassis"





Despite its complete appearance, Toyota claims that the GT3 Lexus RC F has yet to run on track. A modified version of the production car's 5.0-litre V8 develops around 532bhp, with the CoG lowered by fitting a dry sump

developing a new GT3 car – or GTE for that matter – seems to make little sense. In 2012, at the 6 Hours of Fuji, the FIA announced that it would be introducing a new 'global' GT racing rulebook in 2016, which would spell the end of the GT3 and GTE categories. So to develop a car aimed at customers that would only have a one-year life seems illogical, not least as a manufacturer would have to sell upwards of 60 GT3 spec cars to come close to breaking even. The Lexus RC F, then, is clearly a marketing tool.

'With Lexus we really wanted to spread the message and the image of the brand in racing, and launching the RC F was a really good reason to build a new GT3 car,' says Yaguchi. 'It was a very opportune time for us, and we are able to launch both the new road car and the GT3 car at the same time. We were aware that the timing would only give us one year until the regulation change was introduced, but as we had no idea what the changes would entail we were forced to build the car to the only regulations that we knew, and that was GT3.'

The GT3 class is something of an oddity in the history of racing in that it barely has any technical regulations at all. Manufacturers can essentially do as little or as much development as they like on the cars – the Audi R8 LMS has few major changes from the production car, while the BMW Z4 is almost entirely different and features a 4.0-litre V8 engine, something that does not appear in any Z4 production car. But this technical freedom is largely irrelevant as the performance of the cars is tightly governed by Balance of Performance, which means that the pace of each model of car is roughly the same and that the key differentiators are the price of the car and the support offered by the manufacturers.

DOUBLE JEOPARDY

The class was introduced for amateurs to be able to compete in international GT races without the cost and complexity of taking on the works teams in the GTE category, and it has proven to be exceptionally popular with national and international series. But this has irritated some manufacturers such as Porsche, which is forced to build two different racing versions of the same car.

'In GTE, manufacturers only have the possibility to sell 10-15 cars a year, but in GT3 they can sell 30-150,' said Vincent Beaumesnil, the ACO's sport director. 'But the manufacturers also need clear technical regulations in order to develop their car.' The new GT 2016 regulations are designed to address this by maintaining the technical regulation-based formula of GTE, cut costs in GT3 and allow manufacturers to develop one car to race instead of two as is the situation currently.

'We plan to have the rules finalised by June and announce them at Le Mans,' adds Beaumesnil. 'We have the concept of having two classes of cars with the working titles of GT and GT+, the names are not finalised yet. GT will be primarily for amateurs and GT+ – which will have some more technical freedoms – will be for professionals. The idea is that when a manufacturer wants to go GT racing instead of building a GT3 car and a totally different GTE car, he can build a car using a common basis. There will be common parts between the two.'

The Lexus being developed to the GT3 regulations may not fit the bill, but Yaguchi seems to think that this is not a major issue, 'Globally we hope to race the car in all series that run to the GT3 rules, including Super GT,' he says. 'In 2016, like every year, we will introduce an update kit for the car, and when the 2016 regulations come in we will introduce a kit to have the RC F meet those regulations so that it can race at Le Mans.' However, this 'kit' may in fact constitute an all-new car.

But it may be that the new rules will be delayed by a year to 2017, as there is still some uncertainty over some areas of the rules according to some manufacturers. Beaumesnil denies that there is a delay, however. 'We are still on target to announce the rules in June at Le Mans,' he says. 'It takes a long time to write a book of rules, but the aim is that someone will be able to start developing a car from June.'

Even if the rules are introduced on schedule, many series running to GT3 regulations around the world will not adopt them straight away, and will instead allow 'grandfathering' of older cars for a few seasons.

So, the Lexus may be around for more than a single season.

"We are on target to announce the rules at Le Mans. The aim is that someone will be able to start developing a car from June"

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The ugly duckling

Despite controversy surrounding the CT05 nose, and Tony Fernandes threatening to pull out of F1 entirely, there is optimism around Caterham this season

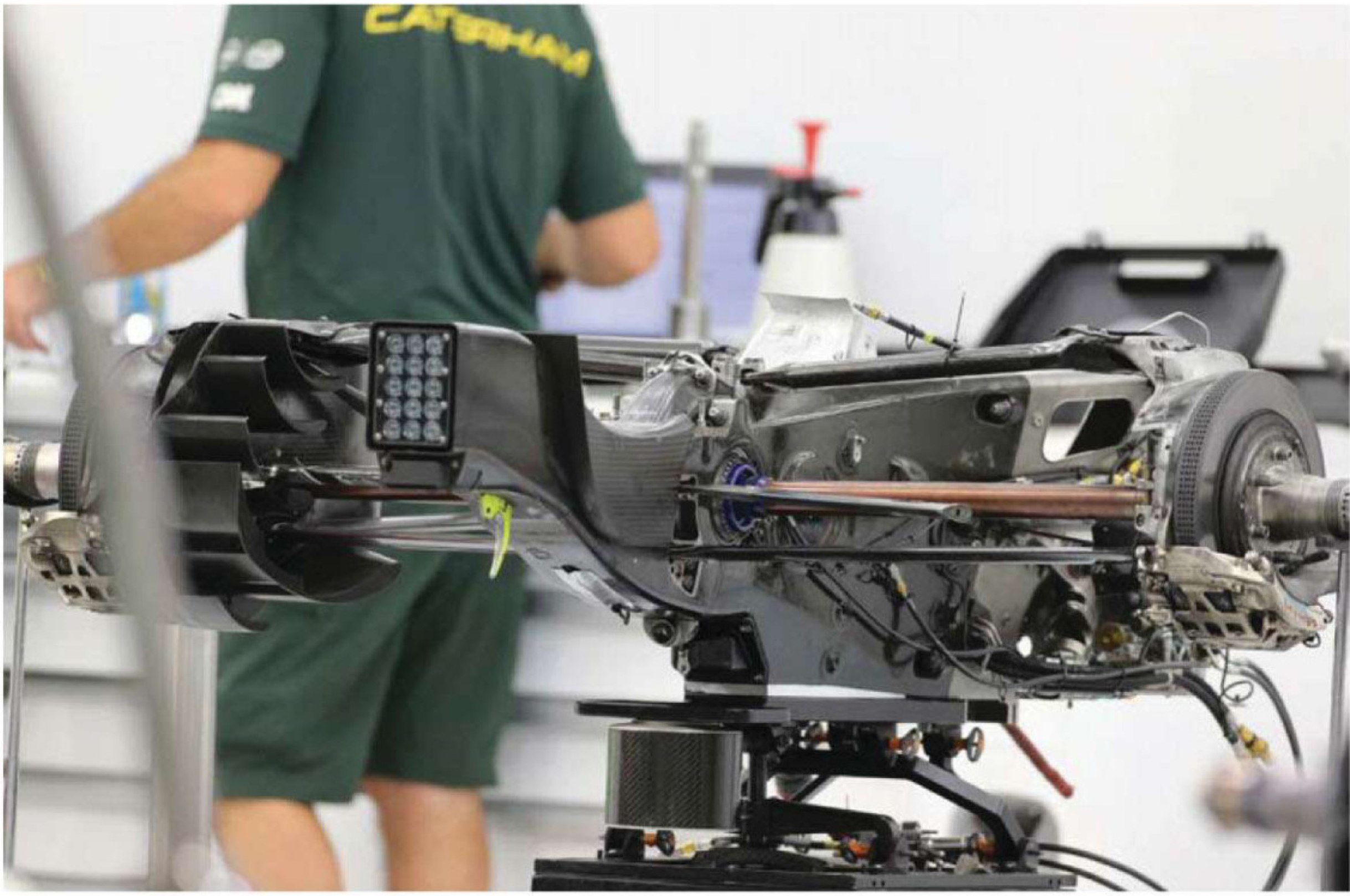
BY SAM COLLINS

Images: JAMES MOY

The Caterham Formula 1 team is happier than you might have expected after the opening races of the season. It has not scored any points and has been dogged by unreliability issues. Just before the team headed off for the first winter test of the year at Jerez, Spain, its owner Tony Fernandes issued an ultimatum: 'If we are at the back, I don't think we're going to carry on. After five years and to get no points, there's a limit to everyone's patience and money. If we are not competing then we have got to seriously examine ourselves as to whether this makes sense.'

Caterham started developing its 2014 design - dubbed the CT05 - in 2012, and largely overlooked the 2013 season to focus on the new rules. As a result, the CT03 of 2013 was a lightly upgraded 2012 spec CT01. The CT05 only just made it to the first test, and when it was first rolled out of the garage it was widely agreed to be one of the ugliest F1 cars of all time!

Fernandes is still supportive of the team, and after achieving the highest mileage at the opening test he micro-blogged: 'More laps than Red Bull, Toro Rosso and Lotus didn't show up. Shows what spirit and right



Caterham buys its transmission casing from Red Bull Technology. The composite design is shared with the Red Bull RB10 along with the internals which are also shared with the Toro Rosso STR9. Using the Red Bull casing means that the inboard suspension layout is essentially identical on the RB10 and CT05

people can do. Not just money.' But then ahead of the first race he tweeted: 'Caterham doesn't look like it has promise. Let's see.'

One of the most striking features of the car's look was its nose design. The main impact structure is forced by regulation to be narrow and low, but teams are still allowed to use a 'vanity panel' to avoid having ugly steps in the bodywork. Caterham has used this to find some aerodynamic gains.

'What you see on the car is not actually our first nose configuration – we looked at something different that is actually on another car,' says Mark Smith, Caterham F1's technical director. 'But we wanted to try to achieve something that did not become a protracted impact test problem for the start of the season. So the impact structure we have is very straightforward. It's kind of a banker, and it's been easy to make it work in terms of the crash test. The reason it looks the way it does is that we wanted to retain some of the benefits of a high nose, like feeding airflow to the rear of the car.'

But the distinctive nose may not last long. Caterham has tested another solution in the wind tunnel – similar to the twin tusk design used on the Lotus E22 – and may introduce it during the European season. 'For quite some time now we have been exploring other solutions in CFD, and we have got something different,' says Smith. 'If it shows that it has some potential then we will probably pursue it, but we have looked at two or three other solutions.'

"We wanted to try to achieve something that did not become a protracted impact test problem"

The space under the car's nose is crucial in aerodynamic terms, and it is a major area of focus for the Caterham F1 engineers based at the Leafield Technical Centre, near Oxford. This focus has seen the adoption of pullrod actuated front suspension, something that only features on one other car in 2014 – the Ferrari. 'We did not just do it for aero reasons – it is something we looked at both mechanically and aerodynamically,' says Smith.

'Because the front of the chassis had to be lower by regulation, we thought it was worth having a look – and then found it was slightly better. The CFD and wind tunnel work we did showed that in aero terms it is not significantly better one way or the other, though it did show that it is marginally favourable, particularly with respect to the way you treat the air around the front brakes.

'Bizarrely enough, we also found that it is slightly better in terms of motion ratio too. Also, we can put more of the inboard components lower in the chassis so there is a small centre of gravity gain too. Overall, however, we did not have a strong feeling one way or the other in terms of which way to go, but when we looked at the subtle benefits it brings we went with it.'

TUNNEL VISIONS

Ever since Caterham arrived in Formula 1 back in 2010 – originally as Lotus Racing – the team has not had access to its own wind tunnel. At one point it considered constructing its own at Hingham in Norfolk, but opted instead to utilise commercially available facilities – initially at Aerolab in Italy, then later one of the wind tunnels belonging to Williams F1. But a small rule change for 2014 forced Smith to

Installation of the RS34 power unit, and some of the substantial cooling required. Caterham has deliberately given itself a larger cooling margin



Front brake setup, with some of the aerodynamic elements visible



Pull rod front allows components to be mounted at the base of the chassis

consider a change, not only to the facility it used, but also the scale of its model.

'One of the main reasons we switched tunnels was the new aero restrictions. We ran 24/7 in the Williams tunnel with a 50 per cent scale model. One of the problems with the new restrictions on wind tunnel testing is that we need to get more return on our time. We had also wanted to go to 60 per cent for a long time, but the additional costs of not only doing a new model, but also developing it, were too high. There are more parts, and the majority of the parts are rapid prototypes, so the cost is really proportional to the volume, making 60 per cent more expensive. When the aero restrictions came in, the number of hours you could run came down, so there was a cost saving there which allowed us to increase the scale.'

That left the team with something of a dilemma. 'We looked around at available wind tunnel options,' says Smith, 'and there were not many available, to be honest. But we knew about TMG, and they are state-of-the-art.'

TESTING TIMES

But switching scale and facility halfway through a car's development is a brave step. The CT05 was initially developed using a 50 per cent model at Williams, but just before the car was launched, Caterham started running a 60 per cent model at TMG in Cologne, Germany.

'We have a reference that we use to correlate between the two models, and the track. It's early days, and we anticipate that there will be some differences, but we get increased resolution from the scale increase. We do have some aero guys who have



The crash at the Australian Grand Prix damaged the CT05's vanity panel, exposing the true shape of its nose structure

used the tunnel at TMG, however, so that should help too.'

The TMG tunnels are widely considered to be the best that are commercially available and give the Caterham engineers some new tools to work with. 'It is very much a bespoke session. Closing the loop with CFD using PIV [particle image velocimetry] is a good step forward for us. We have invested heavily in CFD with both new people and a hardware update that should be running any time now. We have the capacity to do more, but we have to ensure that the quality is there too, and the PIV is absolutely essential in that respect.'

POWER STRUGGLES

Caterham is one of four teams using the Renault RS34 'Energy F1' power unit, and like the others has been hit with a number of issues – not least the fact that is seems to have a larger cooling demand than the two other power units seen so far. This has caused major issues for Red Bull and Toro Rosso, but Caterham did not suffer as badly due to the way that the car was designed. 'My brief was that we should not be in a position where the cooling was marginal at these first four races,' says Smith. 'Obviously there are different demands at different circuits, but we did not want to be cutting holes in the bodywork when we got to Bahrain. We are conservative by intent, and with the data we have in terms of heat rejection from Renault, plus analysis in CFD and wind tunnel in terms of mass flow rate through the ducts, we knew we would be able to cool things and have a little bit of a margin.'

"We are conservative by intent. We knew we would be able to cool things and have a bit of a margin"

In the run-up to the power unit homologation deadline, Renault is thought to have reworked the energy store, turbocharger and a number of other key elements and will bring further updates to the power unit ahead of the European races. But there are still issues with the power unit, as Cedrik Staudohar – the Renault track support engineer embedded with Caterham – admits. 'The chassis-engine package is improving with each session as we understand more about its strengths, and the aim is clearly to keep this upward trend going,' he says.

With issues simply getting the power unit to work properly interrupting the car's early development, some areas appear to be somewhat behind. One of these was brake-by-wire, which has failed on the car on more than one occasion. There were issues with it at the opening test in Jerez, which saw driver Kamui Kobayashi running without any rear brakes at one point. ('It was quite exciting,' he told the Japanese press.) More obvious was a similar failure at the Australian Grand Prix which saw the same driver lose the brakes on the first corner of the first lap, leading to a race-ending collision.

But it's not all been bad news for the Caterham team, and that is why there is some positivity among those wearing green shirts in the paddock. At the second race of the year, Caterham equalled its best race finish under its current name, following a tight duel with one of the rival Marussia cars – 13th position (it scored a 12th place in 2010 as Lotus Racing). This put the team in 10th position in the constructors championship – crucial in terms of prize money.

But as the season progresses and Renault works through its issues, perhaps the Caterham's ugly green duckling will start to look better as the car is developed, not just aesthetically speaking, but also in terms of results. As Enzo Ferrari once put it: 'racing cars are neither beautiful nor ugly. They become beautiful when they win.' and the closer the Caterham CT05 gets to the front of the pack, the better it will look.

TECH SPEC

Caterham CT05

Chassis construction
Carbon fibre, mostly epoxy resin

Front suspension
Twin non-parallel wishbone, pullrod actuated

Rear suspension
Twin non-parallel wishbone, pullrod actuated

Transmission
Red Bull technology

Clutch
AP Racing

Dampers
Caterham, Penske Racing shocks

Wheels
OZ Magnesium alloy

Tyres
Pirelli – fronts: 245/660-13; rears: 325/660-13

Brake system
Brembo carbon/carbon

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
FIA SECU standard electronic control unit

Cooling system
Caterham – aluminium alloy fabrication

Cockpit
Seat belts: Schroth Racing
Driver's seat: Caterham Carbon fibre shell

Engine
Renault Energy F1-2014,
1.6-litre 90 degree 6-cylinder.
Max rpm 15,000, 24 valves.
Cylinder block in aluminium

Dimensions and weight
Front track: 1800mm (max)
Rear track: 1800mm (max)
Wheelbase: More than 3000mm
Length: More than 5000mm
Height: 950mm

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Guilty until proven innocent

Why Red Bull's Australian Grand Prix disqualification appeal failed

BY SAM COLLINS

Red Bull Racing's appeal over its disqualification from the Australian Grand Prix was rejected at a hearing of the FIA's International Court of Appeal in Paris shortly before the Chinese Grand Prix. The Austrian-owned, British-based team had scored a podium finish in the opening grand prix of the year, but was later removed from the results after it was found that Daniel Ricciardo's car had exceeded the maximum fuel flow limit (its other car failed to finish).

The 2014 Formula 1 regulations state that the maximum allowed instantaneous fuel flow limit is 100kg/h and that this must be monitored by a FIA homologated sensor. Currently the only sensor that is homologated is the ultrasonic fuel flow meter made by English company Gill Sensors.

During its development, two practical issues with the Gill product were identified by the FIA. In some cases it would stop providing any signal at all, and in others it would significantly understate the fuel flow rate.

As a result of this, the FIA created a back-up plan for teams to use in the event of a total sensor failure. The system automatically switches to a back-up method using a fuel flow rate estimate generated by the engine's fuel flow model, which is corrected for accuracy by applying the differential recorded between the measurements reported by the sensor before it failed and the flow rate estimates being generated by the model over the same period.

In the event of the sensor understating the flow rate, a second back-up plan was also put into place by the FIA. If the sensor 'offsets', the problem can be resolved by resetting the system. However, this is impossible to do during a race or qualifying.

Two technical directives were issued, detailing the procedure in the event of either of these two situations arising, but the directives did not have the force of regulation.

In Melbourne the Red Bull RB10 in question was fitted with a fuel flow sensor serial No 73, and on its first couple of runs nothing unusual was noted. The sensor reported an average peak flow rate of just under 100kg/hr (98.9 to 99.5) for runs 2 and 3 of the first practice session, but then recorded an increase to just over 100 kg/hr (100.2 to 100.6) for run 4, and then staying at around that level (100.4 to 101.0) for the whole of the second practice. It is worth noting that the Gill sensor has a calibrated accuracy of +/- 0.5 per cent.

This increase in the indicated flow rate was noted by Red Bull – especially as it was not replicated in the engine's fuel flow rate model – and the team felt that it had not made any adjustment to the car that would cause such a change.



So Red Bull decided to change to a back-up fuel flow sensor (serial No 139) and at the same time Renaultsport F1 had discussions with Fabrice Lom, head of powertrain at the FIA. As a result, the engine in the RB10 was turned back to the original settings and the new sensor was used in third practice. However, it failed completely and never gave a flow rate signal at all.

The original sensor (No 73) was refitted to the RB10 and the FIA did not consider the reading in Free Practice 2 to be erroneous. At the start of the race the FIA gave Red Bull a correction factor of 1.015. 'As with all teams we gave them what we can call a "first lap correction factor" in case the sensor did not work from the start,' says Lom. 'For Red Bull this was based on the FP2 reading.'

It seems that Red Bull felt that the indicated flow rate from the sensor was still erroneous. As a result, the team relied on the Renault model. The FIA noted that the indicated fuel flow rate was illegal and instructed the team to change its maps and reduce the flow rate. It complied with this request and asked driver Ricciardo to change the map, which he did, but then found that the car was losing around 0.4 secs a lap.

"As with all teams we give a 'first lap correction factor' in case the sensor didn't work from the start"

After seven laps running the lower 'legal' fuel rate (most of them behind the safety car), the team instructed Ricciardo to turn the flow rate back up again. Red Bull felt that the sensor readings were faulty and that they were entitled to be able to rely on the Renaultsport model. The stewards did not agree and disqualified the car.

The FIA convened its International Court of Appeal in Paris for the first time in 2014 to deal with the situation. Red Bull sent Christian Horner, Adrian Newey, Paul Monaghan (chief engineer), Jeff Clam (R&D project engineer) and David Mart (Renaultsport F1) as well as a legal team. The FIA's legal team was joined by Lom and race director Charlie Whiting.

Mercedes requested to take part in the hearings as an interested third party. The German marque made various written submissions and asked the court to not only uphold the disqualification but also to impose a three-race ban on Red Bull Racing and a further six month disqualification suspended for a year.

McLaren, Lotus and Williams also requested to be interested third parties and attended, but made no written submissions. Additionally, Force India attended the hearing as an observer.

Red Bull argued that, while the fuel flow sensor fitted to the car indicated that it exceeded the fuel flow limit, the sensor itself was unreliable, and the Renaultsport fuel flow model showed that the car did not exceed the 100kg/h limit. The team highlighted the fact that the Australian Grand Prix stewards assumed that the sensor measurements must be conclusive unless the FIA has agreed that they are unreliable and has given its permission to use alternative data. This, however, is only stated in a technical directive and is not enforceable.

The FIA disagreed with this stance and argued that the flow limit must be determined by a homologated sensor fitted into the car's fuel tank. It argued that compliance with the flow limit – like any other clearly defined limit – must be determined by the officially controlled, uniformly



Daniel Ricciardo who finished 2nd at the Australian Grand Prix in his Red Bull RB10, before later being disqualified for exceeding the maximum fuel flow rate. Red Bull denied doing so and blamed a faulty sensor.

applicable method specified by the FIA in the technical directives. Competitors cannot just pick and choose the method which suits them. It continued to explain that it never admitted that estimates produced by the engine's fuel flow model could be used to determine compliance with the limit. The estimates are only back-up solutions to be used under limited circumstances controlled by the FIA, and only if the model estimates are corrected based on the differential between the last valid sensor data and the model estimates for the same period.

Additionally, the FIA denied that some of Red Bull's data in its written submission showed what the team claimed it did, and that the data in fact also showed that that car exceeded the flow limit during the Australian Grand Prix.

Mercedes then added its opinion claiming that the Red Bull evidence was not reliable, as the pre-race measurements differed from the post-race measurements. The difference of 0.14 per cent put forward by Red Bull is only a difference between the levels of inaccuracy. Also, the test provided by Red Bull to demonstrate the accuracy of its method did not replicate race conditions, such as fuel burning or vibrations, and is, therefore, imperfect.



Also, the measurement method used by Red Bull was not based on anything physical – instead it was purely software-based and required the inputting of data that could not be checked by the FIA. The data provided by Red Bull also lacked all the relevant variables – and indeed the four variables included to validate its own method were not even equal.

COURT FINDINGS

The court was then left to mull over the written evidence, which had been submitted in advance as well as the arguments made in Paris. It found that the main issue in the case was whether or not the Red Bull RB10 exceeded the maximum fuel flow limit at the Australian Grand Prix, and that the burden of proof as to a car's legality is borne by the competitor and not by the FIA. In this case it meant that Red Bull was guilty until proven innocent.

The court felt that if Red Bull had complied with the technical directives relating to what to do in the event of a sensor failure then it would have satisfied not only the court but also the stewards as to the car's legality.

'If a competitor decides not to follow the TD, he has to accept the risk that the evidence he intends to bring as an alternative to that foreseen by the TD will not satisfy the Technical Delegate, the Stewards or, should the matter come before it, the International Court of Appeal,' the judgement states.

This all meant that it was down to Red Bull to prove that its method of calculation – using the Renaultsport engine model – was accurate. To do this it presented a series of traces showing that while the No 73 sensor showed an increase in fuel flow rate, the model showed no increase at all.

However, the court noted that some parameters had changed from lap to lap and felt it could not conclude that the flow model did not change notably from run to run – plus not all of the relevant data was available. It also noted that the F1 technical regulations state that 'no mechanical design may rely upon software inspection as a means of ensuring its compliance'.

Evan Short, race team electronics leader at Mercedes, also pointed out that he felt it was impossible to read some of the data due to noise caused by the vibration of the engine.

Ultimately, the court found that Red Bull failed to prove that its fuel flow model estimated the fuel flow (very) accurately and/or more accurately than the flow meter should have done. As a result is could not prove that it did not exceed the maximum permitted flow rate.

So the disqualification was upheld, but despite the request from Mercedes no further penalty was applied, although Red Bull was ordered to pay costs.

A HARSH JUDGEMENT?

When Red Bull was disqualified from the Australian Grand Prix, there were many in the industry who were not surprised. It had been widely reported ahead of the season that there had been a number of issues with the fuel flow meters, including the two raised by the FIA.

The issues were not limited to Red Bull or even to F1 – problems have been experienced in the World Endurance Championship too, with Porsche engineers describing the units as 'not robust', while Toyota added 'we think almost everyone has had problems'.

So it was expected that at some point in 2014 there would be some issues with monitoring the flow rate. This is why the FIA created the back-up plan for the two envisaged failure modes, firstly the total failure (as seen with sensor No 139) and secondly the consistent understating of the flow rate.

But neither of these scenarios seem to match what happened with sensor No 73 in Melbourne. The sensor made a step change in its readings during use in the fourth run of Free Practice 1, and apparently another step change in FP2. If Red Bull complied with the technical directive it would have had to run a fuel map that cost it 0.4 seconds a lap because it was based on data that was already overstating the flow rate. With an unexpected podium finish on the cards, the team opted to run as close to the limit as possible using the most accurate tool it had at its disposal – namely the Renault model.

Because of the 'guilty until proven innocent' approach forced on the court by the wording of the technical regulations, Red Bull was stuck. The available tools could not accurately prove that the flow rate was legal at all times, but by the same token it seems that it was also not possible for the FIA to prove that the flow rate was not legal at any time. That of course is assuming that the flow sensor was inaccurate.

If that is the case then Red Bull was failed by the homologated equipment fitted to its car as well as the lack of a technical directive fully covering the circumstances presented in Melbourne. It was perhaps then harsh of the FIA to uphold the disqualification, but at the same time it could be argued that the court had no other choice as the rules are quite clear: 'no mechanical design may rely upon software inspection as a means of ensuring its compliance.'

But perhaps the penalty could have been reduced to a grid drop at the next race or a fine. Going forward it does seem likely that the use of fuel flow meters in motor racing is not yet a mature process and further problems are to be expected.

Sam Collins

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Champs Elysée?

The World Touring Car Championship welcomed Citroën with open arms, and even brought forward new technical regulations for them

BY ANDREW COTTON

IMAGES: XPB, SHIMPEI SUZUKI

Competitors in the World Touring Car Championship agreed to pull forward the introduction of new technical regulations to accommodate the new Citroën C-Elysée in 2014, but few realise that the reason the French manufacturer arrived in 2014 and not 2015 was due to its employment of driver Sébastien Loeb.

The new technical regulations, which included lowering the ride height of the cars, increasing the size of the wheels to 18 inches, widening the floor, and introducing complex aero packages, were in the minds of WTCC organisers, but it was some risk for Citroën as the final version of the regulations were not finalised until the end of the year, by which time the cars were all designed. An issue with the front bumper, an aesthetic change according to the team for marketing reasons, is the only waiver for the car for the first two races, as it was the last to homologate.

'Loeb had stopped rallying in 2012, and told us that he wanted to follow with us, so it is stupid for us to wait one year more,' says the team's technical director and deputy team manager Xavier Mestelan-Pinon. 'It is important to have Sébastien in Citroën and to try to win with him. If the regulations start in 2015, for us it is one year more. Our thanks go to Honda and Chevrolet, as they are happy for us to do that.'

Having agreed to bring forward the technical regulations, Honda, Lada and RML, the latter of which provides the new Cruze to customer teams, all arrived at the opening race in Marrakech under-prepared for the start of the new season. It didn't help that Citroën has completed six months of testing with its car, and fairly dominated the weekend with a lock-out podium at the first race, and a 1-2 finish in the second.

The rumour mill launched into overdrive, with many taking an estimate at the French budget. Some considered it to be three times what SEAT spent on a five-car team in 2009, while others put a figure on it of between €18-30m. Citroën itself, however, argues that it started from a clean sheet of paper and that it needed the first four months of testing to get up to the speed of the more established teams. And it was not an easy journey to the front of the WTCC grid for a team that has its roots in rallying – in fact, the team used its rally approach to develop the circuit car.

"We did some tests with our DS3 behind a road car to see how the air cooling would work"

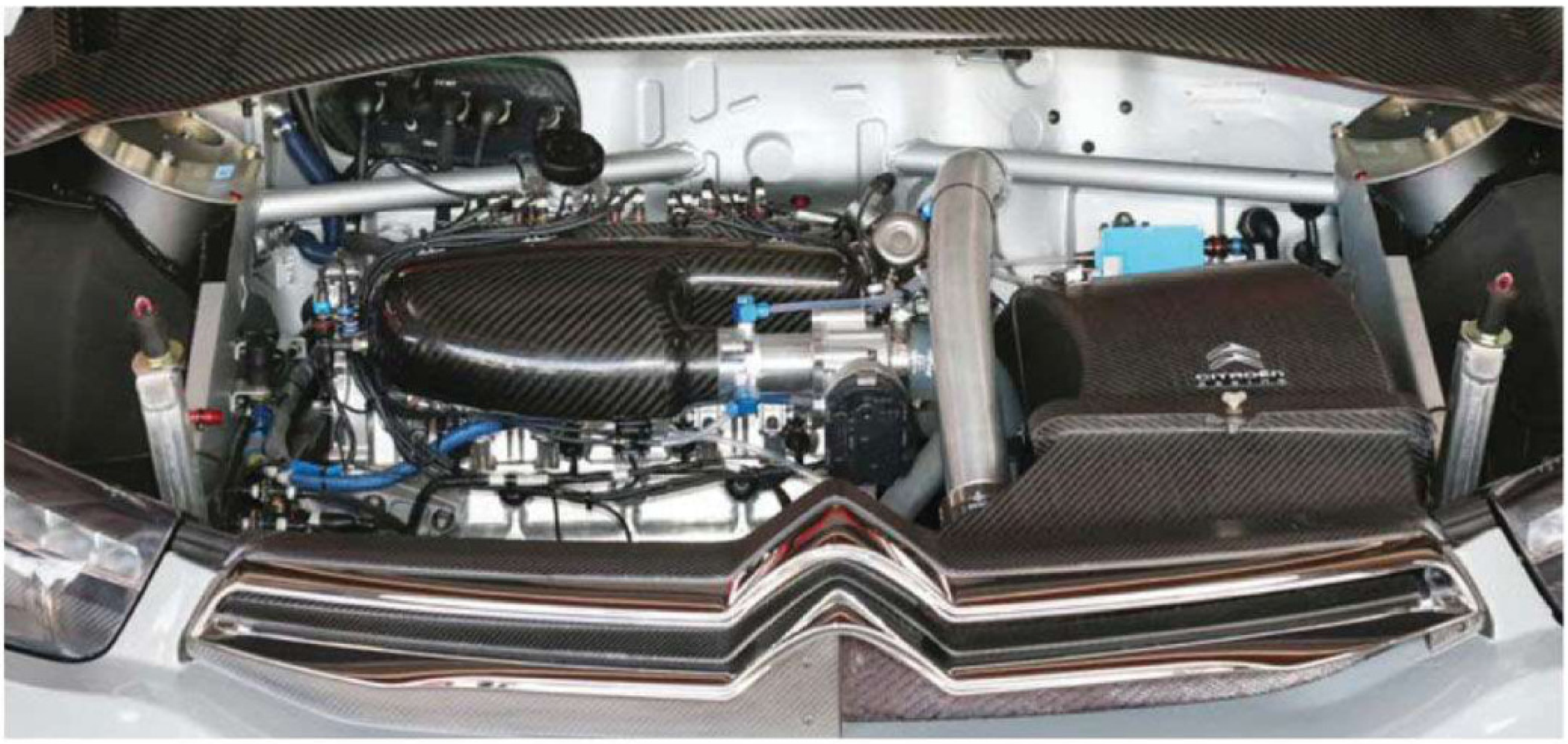
'The first design that we did started with the DS3 World Rally car,' says Mestelan-Pinon. 'We modified some parts of the suspension and gearbox so that it was a front-wheel drive car. We modified the suspension so that we could have the right width of the car, the right wheelbase, which could be similar with the future car. We started to work on the laboratory car, and with the tyres, which were the old ones but they allowed us to start with things like the brakes and how we will cool the engine.'

Engine cooling was a particular concern for the team throughout the development, and in the heat of Marrakech, the drivers noticeably steered clear of running in each other's slipstream. With the new aerodynamics, slipstreaming on such a circuit was worth up to a second per lap but – such was the superiority of the C-Elysée compared to the rest of the grid – the white cars didn't need it.

'We did some tests with our DS3 behind a road car to see how the air cooling would work,' says Mestelan-Pinon. 'It is all brand new for us. After three or four tests, we designed the proper car – the C-Elysées – but even if we did some testing with the DS3, the first C-Elysées was not in a good place. It was very difficult for us to understand what the variation of camber should be, and the stiffness of the roll bar, the centre of gravity – a lot of things. The roll balance, aero balance and everything is new for us. We did a lot of testing.'

Coming from a rally background, the team had a lot to learn, and the design of the suspension was a particular problem. No one knew the forces that would be transferred through the struts running across the kerb, for example, and by the time the cars made their race debut, they were on their third suspension design, having smashed the first two incarnations to pieces.

'All the engineers in the team come from rally, so nobody knows what is good for circuit racing,' says Mestelan-Pinon. 'What should the downforce be? What will be the load when we cross the kerbs, and when we hit the kerbs? What will the force be? How must we design the wishbone? It took a long time –



The C-Elysée features a Citroën Racing 1.6-litre, turbocharged direct injection engine, which was developed from the DS3 World Rally unit



Dampers are supplied by Ohlins, while springs come from Eibach



Front cooling setup, with the front brake setup evident

we changed a lot of things from the first Elysées to the car that we have here. We started from the Xsara kit car, a front-wheel drive car, 2-litre engine, but the same weight. So we started there, but this is now very different.

'We worked on the anti-dive – a lot of parts. You must define what must be the car for the circuit.'

Rivals in the paddock were upset that Citroën committed at the last possible second to the WTCC, but then three weeks later rolled out the new car in testing. It had clearly aggressively pushed ahead with design before the regulations were finalised.

'We have worked with the FIA on the new regulations since the beginning of 2013, but we finalised the regulations at the end of 2013,' says the Frenchman. 'Then the design of our car was finalised. It is very difficult to make new regulations – and especially with regard to all the new aerodynamic parts.'

Privately, however, all the rival teams admitted that they would have played the same game had they had the chance. Since then, Citroën says that it completed a season-worth of mileage before the first race, and Honda looked on with envy as, at the final test, the French team worked on fine details, such as standing starts, while they worked out fundamental issues.

'We tested the car in July, before everybody, but it was too early for us, and everything was new,' said Mestelan-Pinon.

'We had to discover everything. The most important tests were from November in Monza, when we started to understand everything more. We made the biggest advance from November to now. From November, we started to increase the performance. In a few months, when the others can make more tests, they can reach us.'

POWER SUPPLY

The engine development was an area in which the team excelled and – given the ease with which the C-Elysées passed their rivals on the point-and-squirt street track – the engine certainly appears to work well.

'We started with the engine from the DS3 in the World Rally car, but because of the new regulations we could homologate a new engine,' says Mestelan-Pinon. 'So, while we took the opportunity, it was not a full new engine, although we changed a lot of parts. We didn't start from a white paper – we started from an existing engine, but even if we change a small part it is very close to it, a small improvement. This engine will be able to be put into the World Rally car in 2015, because we will homologate a new car for that. We are sharing the development.

'All the aspects of cooling are different because of the average speed. Everything is faster, so you can run a smaller air cooling system. One of the main

"All the aspects of cooling are different because of the average speed. Everything is faster"



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differences is the target for the rev range. On a rally car, sometimes a driver can get surprised at a corner if it is tighter, so he uses low revs. On circuits, the rev range is very narrow and very precise, so you can adapt the map of the engine. It is easier for us.

'On a rally car, one thing that is important is how we manage the turbo. It is harder for someone to go from touring car to rally than the other way round, because it is significantly more difficult to manage the turbo in a rally car.'

TRANSMISSION REVAMP

A new gearbox was designed with partners Sadev, but the team felt that this was one of the easiest parts. 'In the past we designed a gearbox with three active differentials and a paddle shift, but there was nothing to add here,' says Mestelan-Pinon. Chassis design was helped by a light base model, and that also worked for the marketing department, but Mestelan-Pinon didn't want to elaborate too much in this regard.

The team ran the opening races with a waiver for the front bumper. 'Our front bumper is OK with the regulations, but there is a spirit and it is difficult to define spirit in the regulations so they asked us to modify the part. It is only a small part. If I showed you both bumpers, I am sure you would not be able to see the difference. The decision was too late, so for us we were not able to manufacture a new one for this race. So, we will have a new bumper for Hungary. The new regulation is not clear enough. We work with the FIA, but I cannot ask the question after each design. Each time we design a part I cannot ask the FIA if it is OK!

'The change that they asked is only because of the change of the car for marketing. With aero it is the same, but everyone has the same problem. We have a waiver, and are the only manufacturer to have that, but everyone has to design the new part. We were the last manufacturer who had made the homologation inspection, so we didn't have the time to change. If we'd had two weeks more we would have been OK.'

The big question lies around the budget that a manufacturer would need to take on Citroën. One of the strengths of the WTCC in years gone by was the rivalry between BMW, SEAT and Alfa Romeo. Chevrolet joined the fray and went on to dominate as the rivals disappeared, and have yet to be replaced. Lada and Honda believe that they can close the gap to the Citroën, and warn against judging performance against one street race, but it is clear that Citroën has raised the bar to new levels in the WTCC, and that being competitive is no longer a cheap option.

If Honda and Lada, both right at the start of their development programmes, do close the gap, the WTCC will have an interesting year. If not, and no other manufacturer takes on the challenge, Citroën's arrival could signal another crisis for the series.

'When you start a touring car series and try to capture a title, it takes a minimum of three years,' says Mestelan-Pinon. 'But like Peugeot in Le Mans, when someone at the top says stop, it stops.'



Top: rear brakes. Note the anti-roll bar attachment
Above: the front brakes, which feature four-piston calipers



The Elysée's rear wing, which features adjustable elements

TECH SPEC

C-Elysée WTCC

Chassis
Structure: reinforced body with welded, multi-point roll cage
Bodywork: combination of steel and composite fibre

Engine
Type: Citroën Racing – 1.6-litre turbocharged direct injection engine
Bore x stroke: 82×75.5mm
Capacity: 1598cc
Maximum power: 380bhp at 6000rpm
Maximum torque: 400Nm at 4500rpm
Specific output: 237.8bhp/litre
Distribution: double overhead camshaft, four valves per cylinder
Fuel feed: direct injection controlled by Magneti Marelli unit

Clutch
Type: carbon-fibre twin-disc

Transmission
Type: front-wheel drive
Gearbox: Sadev six-speed sequential – manual control
Differentials: mechanical self-locking differential

Brakes
Front: 380mm ventilated discs with four-piston calipers
Rear: 300mm ventilated discs, with two-piston calipers
Distribution: adjustable from the cockpit

Suspension
Type: MacPherson (front and rear)
Shock absorbers: adjustable

Steering
Type: hydraulic power-assisted

Wheels
Dimensions: 10×18-inch wheels – Yokohama tyres (660 x 275)

Dimensions, weight and capacities
Length/width: 4577mm/1950mm
Wheel base: 2700mm
Track: 1750mm (front and rear)
Fuel tank: 50 litres
Weight: 1100kg with driver (regulations)

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Nissan invests in V8 Supercars tilt

CFD investment has placed Nissan's V8 programme on the right track

BY STEFAN BARTHOLOMAEUS

"It's such a complex thing. Unless you have the time and money to invest in a full CFD programme, it's a waste of time doing it"



DARIN MANDY

Of the thousands of parts that came together to produce Nissan Motorsport's Altima V8 Supercar, it was one of the most innocuous that held back its performance. New manufacturers into Australia's V8 Supercars Championship are required to homologate their own 5.0-litre V8 engine and four-door sedan bodyshape to fit a control chassis.

A lack of straight-line speed during the early part of last season naturally threw the spotlight on to Nissan's VK56DE engine, which had to be developed within the category's relatively strict parameters. While the motor undoubtedly started the season a long way behind the pace of the tried-and-tested two-valve Ford and Holden units, higher speed circuits experienced during the middle part of the year soon had the team taking a second look at its aerodynamic package.

The process of homologating three new models for 2013 – the Nissan, the new Mercedes-Benz E63 and updated VF model Holden Commodore – had come and gone with relatively little fanfare. As had been the case in the previous Ford- and Holden-only era, each manufacturer's homologation teams had designed their own kit and then had it open-air tested by the category. The testing took place at a Royal Australian Airforce base in north-eastern Victoria and included coast-downs from 200km/h to measure drag.

After five days of testing, V8 Supercar organisers declared the cars even, the respective manufacturer homologation teams signed-off on the specifications, and the cars headed for the new season. From then on, apart from minor grumbling from the Ford side, which had their rear-wing trimmed despite being slated as the 'baseline' car, the majority of the pre-season talk would be about engines.

AERO ARGUMENTS

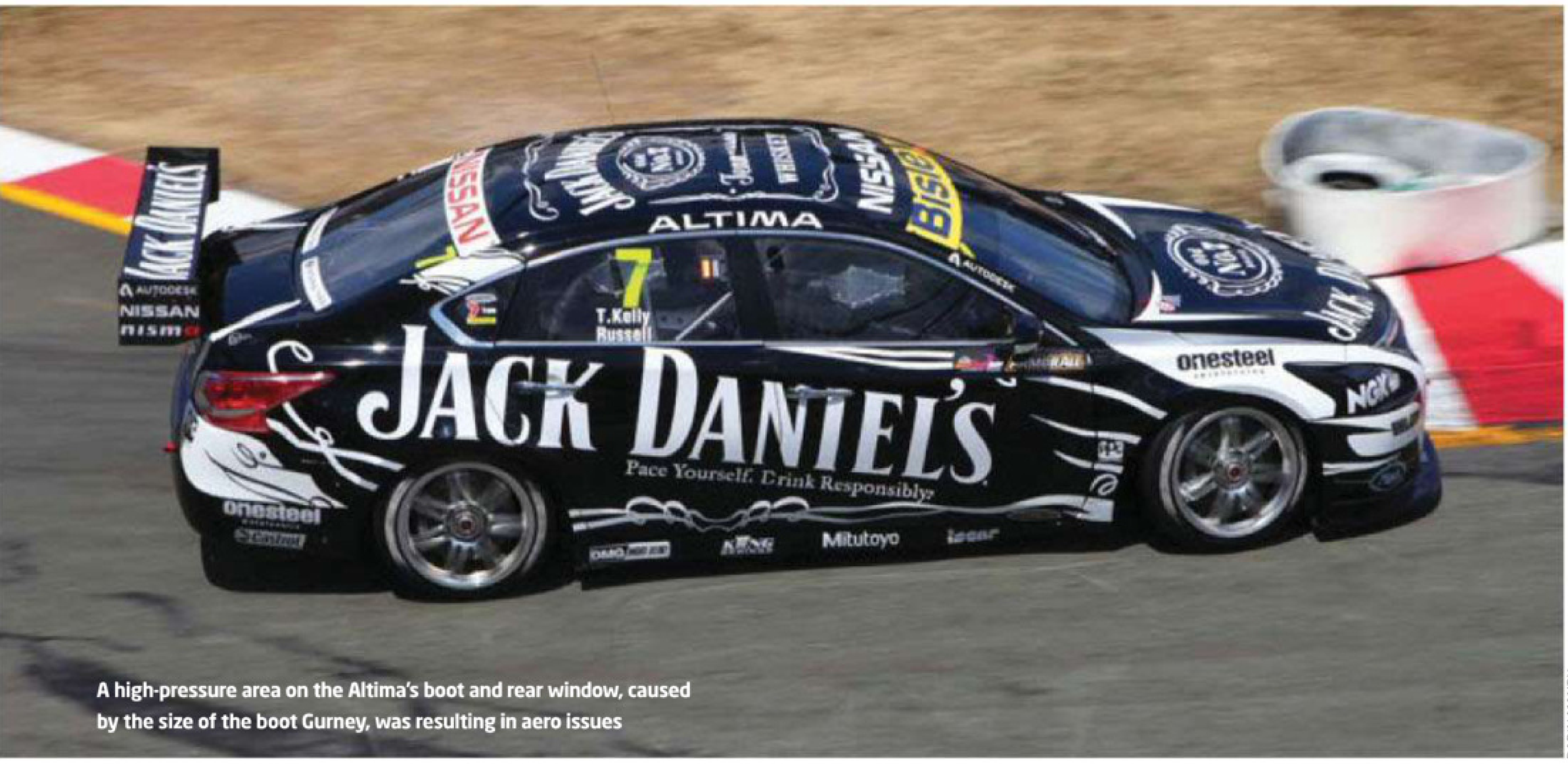
Fast-forward 10 months to October, and a visit to the iconic Bathurst 1000 from Nissan's global motorsport boss Darren Cox triggered an aero parity furore that continues to this day. Aside from creating a firestorm of press by slamming everything from the category's 'archaic' open-air procedures to a perceived Holden influence on V8 Supercars' decision-making, Cox got what he wanted behind closed doors.

Nissan, and any other manufacturer that wished to, could re-homologate its package for 2014, coinciding with the first homologation of that for another new player: Volvo. This was a clear admission from V8 Supercars that its January 2013 testing had missed the mark.

While Nissan had been investigating an aero revision for some months, it was not yet aware of exactly what was wrong with its existing kit. The car had been designed with what team owner, racing director and driver Todd Kelly now describes as 'a few toe-in-the-water exercises with a few different people' on CFD.

'It's such a complex thing, unless everything is 100 per cent spot-on and you've got the time and money to invest in a full CFD programme, it's a waste of time doing it at all,' says Kelly. 'If there's a small error, it can lead you up the wrong path very, very easily. We did limited CFD that gave us a little bit of an idea, but unless you can do a full-scale CFD programme with a reputable company, you can't just go and make parts based on it.

'It wasn't until the second time around [for 2014] that we had the luxury of having a partnership with a



A high-pressure area on the Altima's boot and rear window, caused by the size of the boot Gurney, was resulting in aero issues

DARIN MANDY

company called TotalSim.' The Brackley, UK-based firm played a large role in the development of the Ben Bowlby-led Nissan DeltaWing project for 2012, and was therefore a logical direction in which Cox could point his Australian brethren for help.

Once the TotalSim deal was signed off, the team's engineering department spent a month working with the company to build the CFD model of the Altima from its Autodesk Inventor CAD files.

MODEL MAKING

'You've got to make sure all your surface modelling is up to scratch – your nooks and joins all need to be perfect,' says Kelly of making the CFD model. 'We put a lot of time into the verification of the model. They had the whole car from front cross-member, oil cooler position, suspension arms, brake ducts, engine and sump, exhaust system, diff, gearbox coolers... the whole integrity of the car. It was a lot of work.'

Once the model was built, the team could finally verify its suspicions of what had been causing the real-world speed traces to taper distinctly away from that projected above 200km/h.

'There was a high-pressure area on the boot and rear window, mainly caused by the size of the boot Gurney,' explains Kelly. 'The Gurney needed to be that physical size to energise the underside of the wing to attach the airflow and make the wing efficient. But is also gave a pressure reflection off the boot from the high pressure area, which also detracted from the performance of the underside of the wing. The wing position, as it was, was also not efficient from the A-pillar vorteces flowing on to it.'

With running all taking place at 200km/h or below, the homologation testing had failed to pick up the problem during a number of changes to the boot Gurney and wing positions while trying to match the rear-downforce of the Ford.

"The wing wasn't efficient without the Gurney – it needed it to attach the airflow to the wing"

Prior to the TotalSim deal being reached in November, the Nissan V8 Supercars outfit designed a new rear wing to tackle its own open-air testing. Having been the only team to homologate a centre-mount wing for 2013, this ultimately un-raced version mimicked the end-plate mounts of its rivals.

Undertaken at Melbourne's Avalon Airfield, the testing was done at up to 260km/h. It showed that – with the boot Gurney and rear wing position unchanged – altering the mountings did not have the desired effect. Running the 2013 wing without the boot Gurney at the same test, however, revealed what would soon be proven with the CFD.

'The wing wasn't efficient without the Gurney,' says Kelly. 'It needed it to attach the airflow to the wing, which we knew. Without the Gurney, however, there was a bit of a drag reduction, which backed up the engineering group's thoughts that the wing Gurney position and the interaction between the two was not efficient at those speeds.'

Meanwhile, once the CFD model was finished, the number-crunching could begin back in the UK. 'We gave them six degrees of freedom on the rear wing position. It didn't matter how we held the rear wing, whether it was swan-neck, centre-mount, end-mount – we just took all that away. We gave them an X dimension and a Z dimension for the wing, boot Gurney dimensions, wing Gurney, wing angle and angle of attack. In all those six degrees of freedom in that box, we ran all those up to a couple of thousand iterations.

'They had specific programmes that they could fast-track it all with,' added Kelly. They highlight DOE [Design of Experiments] points that show something, and then they investigate that. That's how we came to our final revised wing position.'

Kelly says that the ability of CFD to run countless iterations through different yaw angles proved highly valuable in this process.

'We got down to the end of it and did everything at a certain yaw angle, and when we straightened the car up with the first boot Gurney design, the wing [even in its new position] actually detached,' he says. 'The parasitic shape of the car dictated the flow at a yaw angle, so we had to do a slight change [reduction] to the boot Gurney to re-attach the wing when it was straight.

'The whole project was probably not as easy as all the other engineers in the pitlane think.'

Although the wing itself is of the same dimensions as previously, revised mounts ensure that it now sits significantly further backwards and up into the airstream compared to its predecessor. The latter is so much so, in fact, that the 2014 Altima has been homologated with the wing further behind the rear-axle centreline than previously permitted in the regulations. The optimised flow path allows a flatter wing profile to create the same downforce with less drag.

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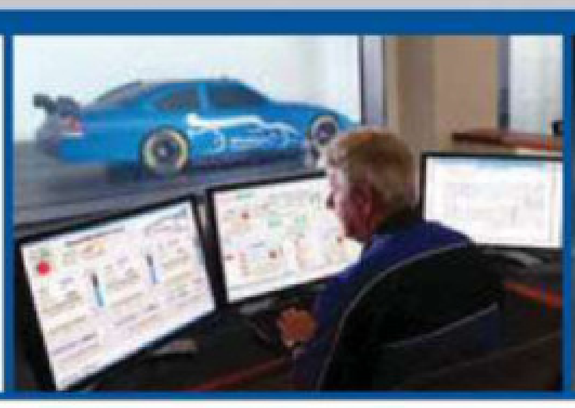
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The mounts remain in the centre of the boot, however, ensuring a significant visual point-of-difference for the Nissan compared to its rivals.

'We carried over the centre-mount purely from a logistics side of things, of ease of manufacturing versus time frame,' says Kelly. 'Yes, the centre-mount isn't the most efficient way, because the wing will have a small amount of detached airflow around the mount. But at yaw the effect was negligible, which is important.'

Revisions elsewhere saw the front bar's upper cheeks pulled back and lower cheeks pulled out, while the side-skirts were also given a subtle tweak.

The team returned to Avalon to validate its new package in early January, before heading to V8 Supercars' 2014 homologation testing later that month. The new season saw the series again utilise an unchanged 200km/h coast-down, open-air testing method.

On this occasion, V8 Supercars' inability to reproduce the 2013 front and rear downforce figures on the baseline Ford raised eyebrows. While all present parties were sworn to secrecy following the test, it is understood that the issue saw the Nissan homologated to an overall downforce figure, rather than the previously targeted individual front (approx 150kg at 200km/h) and rear (approx 220kg) values.

Regardless, Kelly insists that his car has ended up with the same front-to-rear aero balance as it had in 2013. The rearward movement of the centre-of-pressure, thanks to the revised wing position, is said to have been balanced out by the detail work to the front bar.

Having initially aimed for a 9 per cent drag reduction, Kelly says the final result, thought to be around 7 per cent after final sign-off from V8 Supercars, has been 'pleasingly close'.

The team's new package made an impressive debut at the opening round of the 2014 season in Adelaide. Albeit on a circuit with only one high-speed straight, lead driver Rick Kelly finished fifth in Sunday's feature race, despite two drive-through penalties for minor infringements.



Happy with the aero, Nissan are now placing more emphasis on the engine

Michael Caruso then took the team's first pole position two weeks later at the non-championship support races to the Australian F1 Grand Prix at Albert Park, seemingly signalling the arrival of Nissan as a serious force.

'We showed at Albert Park, a place where you're coming on to the straights with a little momentum, that we can now maintain our gap to cars around us right through 220, 230 and 240km/h,' says Kelly. 'We feel that the new aero has been a really good gain. You don't drive up the straight looking in your mirror the whole way. It showed. The speed of the cars was very good there.

'But then we went back to Symmons Plains two weeks later and it was the opposite,' he continued after a meeting that saw all four Nissans end the 200km Sunday race a lap down on the winning Holden.

'You don't have any momentum coming on to the straights. It's all about power down, car handling and engine power until you get to the speed at which the aero becomes a contributor.

'That was a little bit of a wake-up call to us about how much focus still needs to go into our engine program. The aero is fixed and locked in, but there are still a lot of changes that need to happen on the engine front to put the whole package together.

'We'll go to some tracks where you don't necessarily need that punch off the corner. If you come on to the straight with a little bit of speed, we'll be competitive, but anywhere you have to basically come on to a hairpin into a straight, we're going to struggle.'

While significant investment in CFD has seen Nissan Motorsport put its aero worries behind it, the category itself now faces the prospect of needing to follow suit.

The immense speed of the new Volvo S60 – which was also homologated at the troubled January 2014 test – has been the talk of the season to date.

"Our aero programme takes a one-time snapshot at one speed. It doesn't build an aero map"

The collaboration between Garry Rogers Motorsport and Polestar has undoubtedly produced a well-honed aero kit, but whether V8 Supercars' open-air testing process is accurate enough to do the manufacturers' efforts justice is now the biggest question.

The category set-up a seven-man aerodynamic working group in March to assess the situation, subsequently confirming that it will do more open-air running with the Ford and Holden packages to reaffirm its procedures.

TESTING, TESTING

For now at least, V8 Supercars is repelling calls to test all five cars together. It isn't ruling out allowing more re-homologations, however, should the upcoming two-car testing show anomalies in the system.

As for including CFD in its homologation work, Steve Horne – the chairman of V8 Supercars' Commission body that is in charge of the technical and sporting rules – says that it's on the agenda.

'That is something I think I have pushed a little bit,' says the former Tasman Motorsport IndyCar team owner of dovetailing the open-air testing with CFD comparisons.

'Our current aero programme takes a one-time snapshot really at one speed. It doesn't build an aero map, it doesn't check the cars in different angles, or yaw, or anything like that.

'So CFD can potentially be a complementary tool to that and actually can shortcut some of the time that gets spent at an aero test. Will we get to CFD? Probably, but it's not an over-riding magic bullet that is going to change anything, really.

'Nissan did a very good CFD programme and developed where they wanted to be, and when they came to the test were pretty sure what they wanted. It wasn't a case of let's try this and let's try that. That's where CFD is really good.

'But to model the current five cars in CFD is a huge engineering task. It's not an overnight job and it's very expensive.'

So, if there has been one expensive decision in Nissan Motorsport's short history, taking the plunge into a full-scale CFD programme certainly wasn't it.



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The WRX factor

The revitalised world of rallycross has been further bolstered with the arrival of Jacques Villeneuve, racing in WRX for the Scottish Albatec team

YouTube was launched back in 2005 and has become something of a social phenomenon. It has been responsible for riots, court cases and in some areas even revolutions. Motorsport has not been immune to its effects and in fact has been significantly changed by it, not least with series like NASCAR uploading highlights of major events to the site. But one form of motorsport above all others was found to be perfect for the video sharing site: rallycross.

Perhaps this is no surprise. The sport was invented in Great Britain in the late-1960s to provide short, sharp on-track action for a commercial television audience. Mixing traditional asphalt race circuits with purpose-built gravel link roads, the format was hugely popular and became popular across most of Northern Europe.

BY SAM COLLINS

Over the years the popularity waned somewhat, and in-fighting saw the sport fragmented. It remained that way for many years, but in 2010 it made its first appearance in North America. Dubbed SuperRally, it formed part of the X-Games in Los Angeles. The timing was perfect, and the event proved a huge hit online, not least due to the appearance of Ken Block, the first motorsport YouTube star. With tens of millions of views of some of the videos posted from the DC Shoes account, Block is a household name among members of the so-called Millennial demographic.

This was not lost on ESPN, responsible for the X-Games, which went on to create a new championship, dubbed Global RallyCross or GRC (though in 2014 the only non-North American round is in Barbados). It proved to be very popular and has attracted big name teams and drivers, something that was – in turn – noticed by the FIA and marketing agency IMG. The result was the rebrand and expansion of the European Rallycross championship that has created the new World Rallycross (WRX) Championship.

JACQUES-ING UP

The WRX entry list is mightily impressive, with the established European RX fraternity joined by other big names like Ken Block and Tanner Foust from the GRC series, but perhaps the biggest name of all is the singer-songwriter, 1997 F1 World Champion, 1995 Indy 500 winner and 2008 Le Mans runner-up Jacques Villeneuve.

The French-Canadian will be driving a Peugeot 208 Supercar, but while many would expect it to be the new works car from his former team Peugeot Sport (running as Team Peugeot-Hansen), he is instead driving a version of the 208 developed by the Scottish Albatec team.

The development of the car was conducted jointly by the Dumfries-based organisation and its French partners MTechnologies, which developed winning cars for the GRX series. The experienced pairing of Stéphane Orré and Marc Laboulle, which claimed the manufacturer's title in the 2012 FIA European Rallycross Championship, form the technical infrastructure of the Albatec team. 'The programme actually started in December 2012,' says Albatec boss Andy Scott. 'At that time I was looking to build new cars and



The turbocharged engine in the Albatec Peugeot 208 produces 600bhp and 860Nm of torque

TECH SPEC

Albatec Peugeot 208

Class: RX Supercar

Engine: 2000cc I4 turbo by ORECA, producing 600bhp and 860Nm torque

Transmission: Sadev six-speed sequential gearbox and differential

Clutch: Alcon multi-plate

Electronics: Magneti Marelli with FIA-specified data acquisition system

Suspension: MacPherson strut front and rear with Evo dampers and in-house uprights

Brakes: Alcon with Albatec designed pedal box

Wheels: Speedline Corse

Tyres: Avon 225/650/17

Dimensions:
Length: 3950mm
Width: 1880mm
Height: 1400mm
Weight: 1300kg

believed in the transverse engine rather than the longitudinal. And the people with the most experience of building those cars was MTechnology in France. So, after great debate of where to build them, I chose there. It was always my intention to relocate to Dumfries, and that is where Albatec Racing and the Albatec 208s are now based.'

Up until the start of the 2014 season, all cars built as RX Supercars had to start off by being homologated in Group A, but this excluded cars such as the Renault Mégane RS, the Mitsubishi Lancer Evo 9 or 10 and the Subaru WRX STI. The GRC series largely ignored this and allowed cars such as Mitsubishi and Subaru to compete – indeed the latter runs a works team. The FIA has now followed suit and will allow all cars homologated to Group N to compete in the Supercar class.

However, mid-engined cars are outlawed in the Supercar class, with the rules stating that at least 50 per cent of the engine block must be ahead of the centre-line of the front wheels.

The car itself is based on the production Peugeot 208 and not – as many believe – the Peugeot Sport S2000 versions. In fact the French marque has had no involvement in the Albatec car. 'The car is basically a Peugeot 208 body shell which the team modifies, including subframes, roll cage, and various other chassis modifications in order to make it suitable for rallycross,' says Scott.

Under the regulations, cars can be converted from two-wheel drive to four-wheel drive, which Albatec has done via a Sadev transmission. 'I believe that Sadev make the best transversal gearbox suitable for rallycross, capable of handling the torque that we put them through,' says Scott.

HUGE ACCELERATION

One of the most spectacular things the online viewers are attracted to in RX is the huge acceleration of the cars. Most of them are capable of 0-100kph in about 1.9 seconds, much faster than the similar looking cars of the World Rally Championship. This is even more impressive when you consider that traction control is banned.

The reason for this high rate of acceleration is the relatively open technical regulations relating to engine design. Cars in the Supercar class have a maximum capacity of 2058cc for petrol fuelled engines and 2333cc for diesels. Normally aspirated engines can be larger, but no team has taken up the diesel or NA options so far, as all engines must breathe through a single 45mm restrictor mounted on the turbocharger. If an engine is fitted with two parallel compressors each must be restricted to 32mm. Boost pressure cannot be driver adjustable.

"The car is a Peugeot 208 body shell which the team modified to make it suitable for rallycross"

The standard bodywork must be retained, but some modification to the wings is permitted as well as the addition of front and rear aerodynamic devices such as a splitter and rear wing. Overall, the standard body shell must also be retained, but can be strengthened and modified to allow the cars to be converted to four-wheel drive.

The engines themselves must be based on a block produced by the manufacturer of the base model, so a Peugeot-bodied car must use a Peugeot badged engine. But it seems that this does not restrict the use of bespoke motorsport blocks, as long as they were originally produced by the correct manufacturer.

In the case of the Albatec 208, power comes from a PSA-based turbocharged 2-litre inline four developed by ORECA, which produces around 600bhp and – more importantly – 860Nm of torque.

A pair of Albatec 208s will contest the whole World Rallycross championship this season, where they will take on works-backed cars from Peugeot, Volkswagen and Ford as well as a range of privately developed cars.

A full breakdown of the series will be available in a special free digital supplementavailable at www.racecar-engineering.com, and the races will be inevitably available via video sharing sites and www.rallycrossrx.com





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JRM rallies Subaru

The Japanese manufacturer is reinvesting in rallying, and has partnered with UK specialists James Rumsey Motorsport to look after its 2014 campaign

BY GEMMA HATTON



The base car of the Subaru WRX STI, with which JRM feels they have spotted a gap in the market

During Subaru's 19-year presence in the WRC in partnership with Prodrive, the almighty Impreza claimed three World Championships (1995-1997), three Drivers' Championships (1995, 2001, 2003) and a total of 47 rally wins. It was an impressive record that could not be maintained as performance dwindled after 2005 and the economic downturn led to the 2008 withdrawal of the works Impreza. Since then, various Subaru models continued to compete in a variety of championships under privateer teams, but Subaru's dominance of the rally world had well and truly ceased.

However, with Subaru's motorsport arm (Subaru Tecnica International - STI) recently collaborating with the fast-evolving motorsport corporation of James Rumsey Motorsport (JRM), this is set to change - and it is starting with a Subaru WRX STI in Group N.

'We want people to know that there is a serious manufacturer supporting Group N again and that JRM are building, selling and supporting cars,' says Steve Smith, senior sales manager. 'The main parts from this car are the same fit as the 2008 model onwards so there is in excess of 100 cars out there which people may not be using due to the lack of support. Subaru are investing in rallying again with JRM running the programme on their behalf and there are future plans to re-stimulate the market further. JRM are back, Subaru is back and Group N is back as a major category.'

GROUP N

The Group N category is based on 'standard' production models that have had more than 5000 units built and was introduced by the FIA back in 1982 as a cost-effective form or rallying. 'Despite their best efforts, nobody has come up with a cheaper formula then Group N,' says Nigel Riddle, special projects manager at JRM. 'That's it in a nutshell - not everybody wants to jump into a little buzz box that skids about on the front wheels.' Entries are usually 2.0-litre, turbocharged four-wheel drive cars and the regulations only allow the suspension dampers and springs, exhaust systems and engine management systems to be modified. 'Being Group N, 80-90 per cent is road car yet you can still go rallying on the same stages as a WRC car,' adds Smith.

JRM'S CREDENTIALS

'JRM have always been involved in rallying,' says team principal James Rumsey. 'We won the BRC as Mitsubishi UK in 2008, then again as JRM in 2010 in our JRM international Group N specification Evo X. This car has been supplied to many customers across the globe, and continues to be the fastest and most reliable Group N Evo X available.' Add to this their successes with the Nissan GT-R GT3 through their Nismo Partnership, which include the 2011 FIA GT1 Driver Championship, as well as both of last year's Blancpain Pro-Am titles with Nissan GT Academy Team RJN, and the result is an impressive Portfolio.

Although it continues to support its Nissan customers, JRM spotted a gap in the rallying market, as Smith highlights. 'Other base car teams have focused on other areas of rallying,' he says. 'No one has really been driving the Group N market. Our sales pitch is having a car, engineers and stock accessible that is competitive, yet cost-effective - offering the product and having it available is most important to get it back into the market.'

Riddle agrees. 'Now STI are realising that there is still a commercial entity that's got to make its own way inside Subaru. If we can sell some cars and re-ignite interest in Europe and Africa, it's good for them and good for us.'

But given JRM's successful history with Mitsubishi, and strong links with Nissan, why Subaru? 'It is no secret that Mitsubishi has pulled back completely from motorsport over the last few years,' says Rumsey. Indeed, the manufacturer ended production of their Lancer Evo this year. 'To secure our product future in this category, we needed a manufacturer partner with the same drive and focus as us, which we have found in Subaru and STI.' Nissan, on the other hand, are so heavily involved in their GT programmes, rallying was an unlikely option.

"This car races globally and continues to be the fastest, most reliable Group N Evo X available"



The WRX STI is the first of its generation to be built in a sedan configuration in Europe

Another major factor is the value of trust in the Japanese culture. 'Many of our technical and customer support staff are former SWRT members,' says Smith. 'So, even though as a company our relationship is new with Subaru, internally we have the background product knowledge base to develop a competitive Subaru while assisting customers.' With some JRM staff having worked at Prodrive for over 25 years, STI have confidence in the people behind the business.

The final piece of the puzzle lies in the benefit of utilising tried-and-tested components from manufacturers that JRM already have good relationships with. 'We have worked with these manufacturers for a long time,' adds Smith. 'Things such as Ohlins dampers on the GTR, AP Racing/STI brake kit and the PPG gearbox kit that we used successfully on the Mitsibushi – that is the same with the majority of the components on the car really.'

THE CAR

Interestingly, the WRX STI is the first of its generation to be built in a sedan configuration in Europe, as it offers enhanced aerodynamics, traction and balance over the coupe style. The new 2015 model is a sedan so it makes sense as well as reminding fans of the heyday of Subaru and the familiarity of the sedan-style Impreza.

'We start off with the Japanese domestic model road car, complete as a rolling chassis – and then we strip it,' explains Smith. 'The chassis goes off to be painted and you can dip the chassis if you're looking to remove extra sealant around the car to save a few kilos. But because the car is homologated to a certain weight, it is an unnecessary cost. We spray the shell and start to build it up. We fit a lot of the road car components back on as well as rally components such as the racing brake system and sump guard etc. We actually replace the standard ECU with the same MoTec system that we use on the GTR because then we can change the engine maps and so on. Finally, we have a Custom Cages roll cage installed in the car which is done externally.' It takes approximately one week to strip and two weeks to rebuild – a quick process which will be essential when meeting customer demands.

JRM also offer a base car package, so the standard road car can be purchased along with upgrade kits. 'We've already sold two of those over the last week and from the WRX STI launch at the Autosport International Show alone we received 56 prospects – and that's only from key contacts within the UK market.'

With sub assembly, machine shop, fabrication and quality inspection departments, the impressive facilities at JRM will ensure that they meet this heavy demand. 'Any manufactured components we do in-house so we can react quickly to orders and create prototype parts for testing,' says Smith. 'It is definitely an area that we want to grow as a specialist manufacturing plant, because as motorsport companies mature, you need each department to become a business in their own right.'

The Subaru WRX STI will be showcased at Ypres, Barum and Rallye du Valais as part of the FIA European Championship this year to prove the competitiveness of the car, with the aim of supporting customer teams from the second half of 2014.

'James Rumsey's vision is to be the world's biggest private motor company,' says Smith. 'Beneath that is to make the GT3 Nissan market very successful. Subaru is a new market for us, but through JRM's history we have proved ourselves in this sector. We want to expand the engineering side of the business too, which is a large area of growth potential outside of motorsport.'

Will we see JRM expanding into even more markets such as LMP1 in which they competed with their HPD Honda ARX-03a in 2012? 'Potentially, it is something close to our hearts and almost feels like unfinished business,' says Rumsey. 'If the right manufacturer shares our vision and understanding of what it will take to win Le Mans, then we will return.' Another future prospect is the GT-R competing at Le Mans due to the proposed GT regulation changes, 'It would be hard to understand why this couldn't happen from a Nissan perspective – you only have to look at the amazing involvement of Nissan over the last few years in support of this race. With LMP2, DeltaWing, ZEOD and LMP1 in 2015, a GT-R GT+ would make perfect brand sense in my opinion. We will have to wait and see.'

"If the right manufacturer shares our vision and understanding of Le Mans, then we will return"

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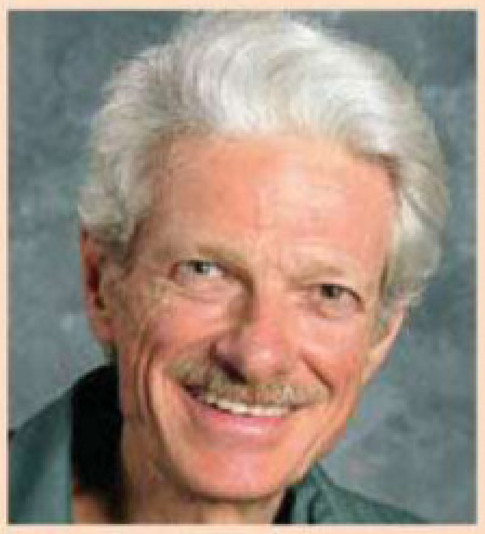
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Double wishbone or MacPherson?

Which system provides better performance in racecars?

QUESTION

Double wishbone suspension systems are said to give better performance than the MacPherson strut type which is universal on most vehicles today. But what are the reasons behind this? Which type – independent of driver use/abuse – tends to have the longest lifespan? How is tyre life affected by these systems? Finally, was the double wishbone system abandoned solely for reduced manufacturing costs?

THE CONSULTANT SAYS

I will assume that the reader is familiar with the basic anatomy of these systems.

Nowadays, it is customary to call a strut and lower wishbone suspension a MacPherson strut when it is used at the front of the car, and a Chapman strut when it is at the rear.

It should be noted, however, that MacPherson originally conceived his design as one that could be used at either end of the car, and Chapman's earliest versions did not have a lower wishbone as such – the halfshaft was fixed-length and a radius arm was added. However, Chapman was the first to actually sell cars with strut rear suspension. Later versions did have lower wishbones, and the system in that form was still called a Chapman strut.

While struts are popular and have been for a long time, it isn't really correct to say that they've become universal. I don't expect to see them on a Miata or a Corvette any time soon. However, they replaced double wishbone – or short and long arm, or SLA – front suspension on Mustangs and Camaros in the 1980s, and more recently on Honda Civics.

Strut suspension is space-efficient if there's room for its height – simple – and gives geometric properties that are inferior to a good double wishbone system, but not awful. It integrates well with unit-construction and spaceframe cars, but not so well with ladder or backbone frames. It applies its loads to the sprung structure at widely separated points, which tends to reduce the magnitude of the loads.

There are various ways to mitigate the system's geometric shortcomings, but these involve compromises to the system's advantages.

CAMBER RECOVERY

The geometric problems are mainly in three areas. The camber recovery in roll is poor. Geometric roll resistance (roll centre height) varies a lot with ride height, and so does camber recovery in roll. Steering geometry generally has more front-view steering axis inclination than we would like.

Camber recovery in roll can be improved by inclining the strut more. However, that makes the steering axis inclination problem worse, and also reduces available space between the strut towers.

The ample space between the struts is the reason that the system is space-efficient. Vertically, it's not so compact – it tends to be tall. That means it packages well in a sedan, minivan or SUV, but not so well in a sportscar or an open-wheeler. It is particularly attractive for cars that either have the engine far forward, or have it in the rear. The tops of the struts can then anchor very nearly directly to the cowl structure. That makes the system good for front-drive or rear-engine layouts, and not as attractive for front-engine/rear-drive cars. In a front-engine/rear-drive layout, we either have to add bulky structure from the firewall forward to the strut towers, or accept poor weight distribution due to the front wheels being too far back.

STRUT LENGTH

The strut has sliding elements, and is subjected to bending loads. This creates friction in the suspension. Making the strut longer helps, or – more specifically – increasing the distance between the piston and the shaft bushing helps. However, that exacerbates the height problem, or reduces available travel. With a single-tube damper, a remote reservoir offers a little help on this, but adds cost and complexity. Consequently, remote reservoirs are seldom – if ever – seen on production road cars. Some designs offset the spring centreline from the strut centreline so that the spring force reduces bending loads on the strut.

The strut suspension has geometry similar to a double wishbone system, with an extremely long upper arm. That makes the front view force line change slope dramatically as the suspension moves, and makes the front view swingarm length increase as the suspension compresses and decrease as the

Camber recovery can be improved by inclining the strut more. However, this can make steering axis inclination problems worse



SHIMPEI SUZUKI

The World Touring Car Championship has switched to wishbone front suspension due to lower ride height this season

suspension extends. This implies that geometric anti-roll – or roll centre height – decreases a lot on the outside wheel as the car rolls, and so does camber recovery. It also implies that both geometric anti-roll and camber recovery in roll greatly decrease when we lower a strut car for racing.

In contrast, with double wishbones the geometric anti-roll varies less with suspension movement and with ride height setting, and the camber recovery in roll generally improves when the car is lowered for racing.

With either system, making the control arms longer improves geometry. However, packaging considerations will impose limitations on this – long arms take up room. One possibility that has occurred to me, but that I have never actually seen tried, would be to substitute a leading or trailing arm (transverse pivot axis) or a semi-leading or semi-trailing arm (diagonal pivot axis) for the lower control arm in a strut suspension. That would provide a longer front view projected lower control arm to go with the very long upper one. There is some loss in structural efficiency of the arm itself, compared to a broad-based wishbone, but it's not prohibitively bad. Lots of cars use such arms without a strut, to carry all the suspension loads.

I think somebody should try a semi-leading arm in place of the lower wishbone, anchored near the intersection of the A-pillar door jamb and the toe board, and at a point near the center of the car and further forward. Anti-dive would diminish as the suspension compresses, but it probably would be no worse than an old Chevelle – or a modern upper-division NASCAR vehicle – in that regard. Load paths would be pretty decent. Steering would need to be re-thought to avoid excessive bump steer, but that's entirely feasible.

Somebody should try a semi-leading arm in place of the lower wishbone, near the intersection of the A-pillar door jamb

It is also possible to use highly diagonal pivot axes for the arms in an SLA system, creating longer front view projected control arms for both upper and lower – again, at some penalty in structural efficiency of the arms.

As for the excessive front-view steering axis inclination usually produced by strut systems, it is possible to make the wheel not steer about the upper strut anchor and the lower ball joint. It is possible to prevent the wheel from steering on the strut, and provide a separate kingpin or equivalent mechanism to define the steering axis instead. One big advantage of this would be to reduce the tendency for the outside wheel's camber to go toward positive with steer. Renault and Nissan have actually implemented this as a performance upgrade on the Clio Cup version of the Clio. The regular Clio has a more conventional strut front end. This has the disadvantage of adding complexity to a design whose simplicity is otherwise one of its main advantages.

As a general rule, double wishbone systems have advantages in terms of tyre wear, because they generally provide better camber control. However, this varies depending on the specifics of the particular system. Some years ago, Buick produced some SLA systems with worse camber properties than the average strut system. Bushing compliance and other compliances also influence this a great deal.

Suspension wear properties are likewise highly dependent on the specifics of the particular design, but we can say that the strut system has fewer wear points and should therefore cost less to keep in decent condition over the life of the car. The strut itself generally ceases to provide acceptable damping before it ceases to provide acceptable wheel location.

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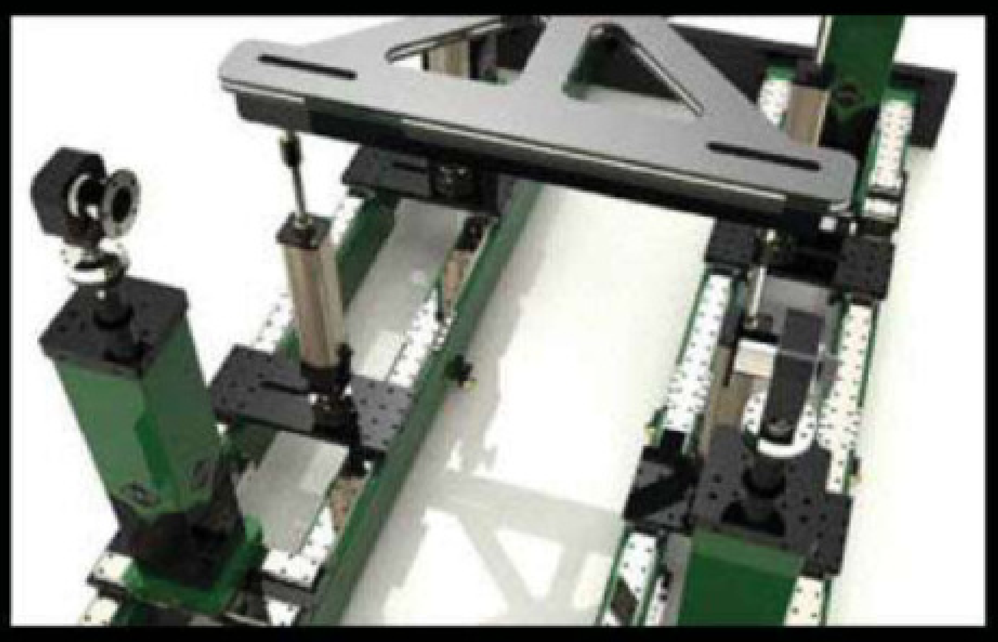
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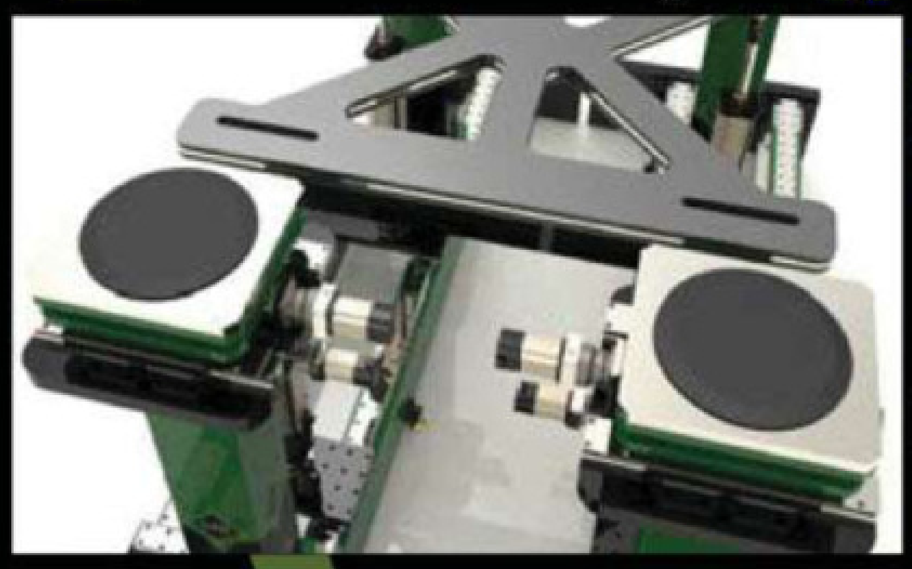


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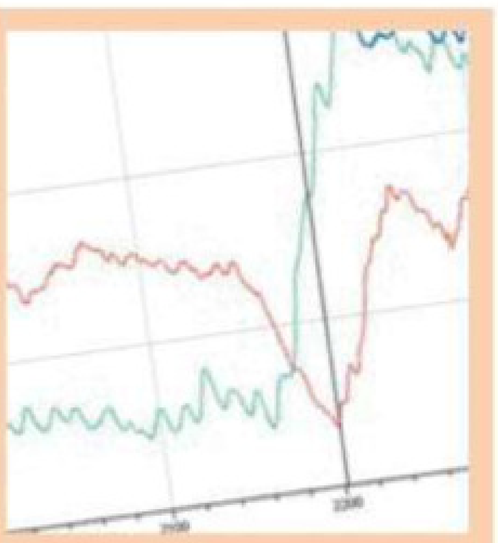
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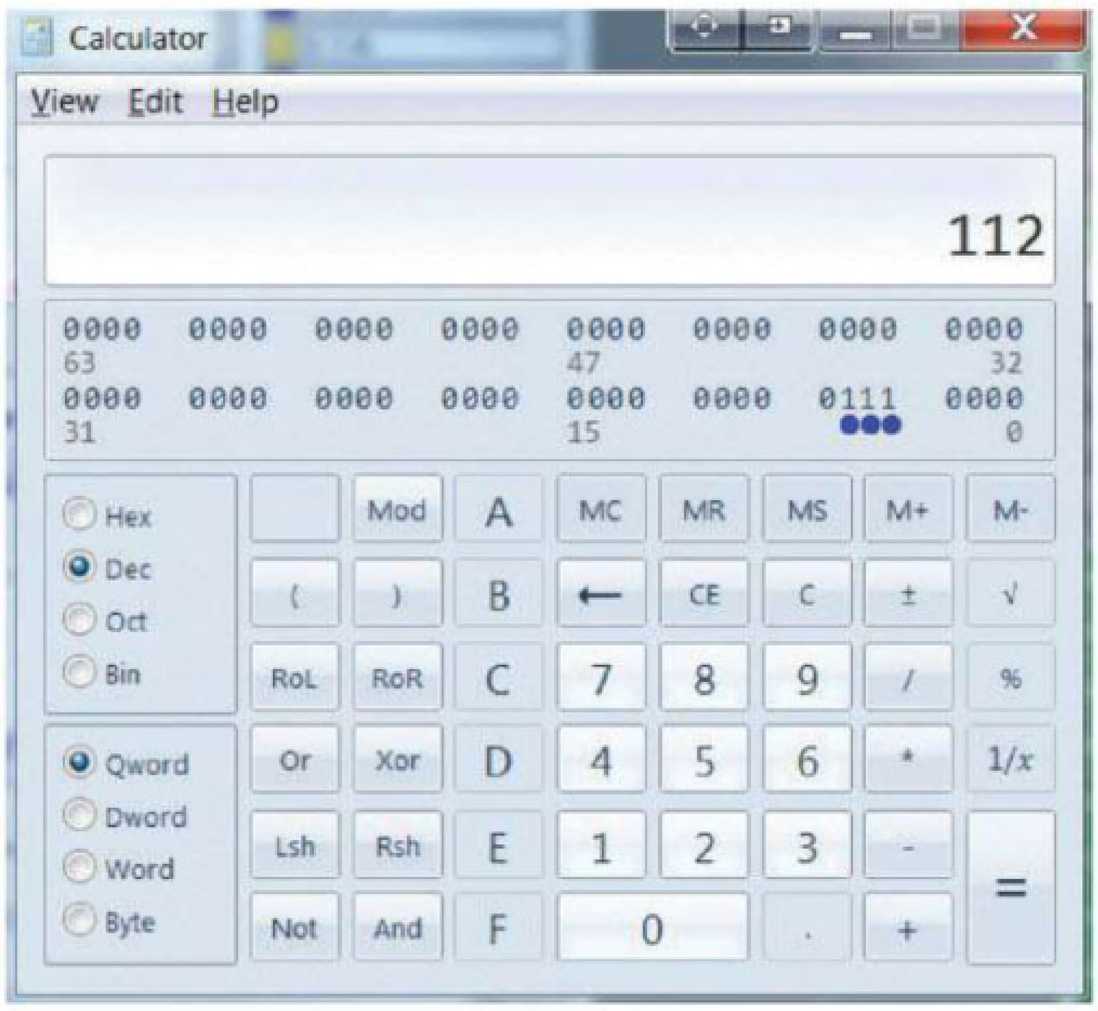
To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Using bit fields and event tags

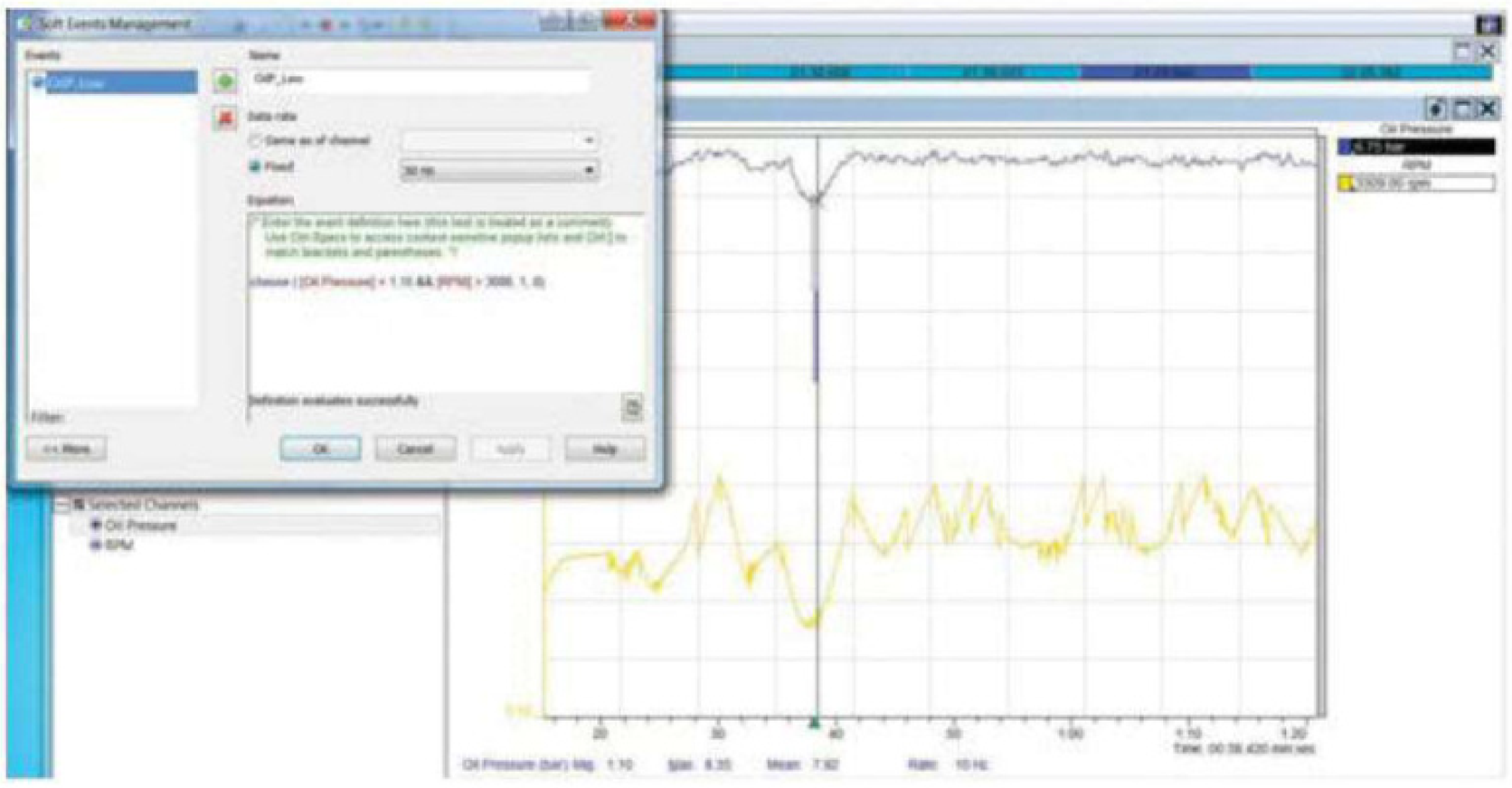
Two tools to help you to make your data clearer and more efficient

With the amount of data available in modern racecars, it has become a necessity to develop ways to make it easier to present and interpret everything. After all, there is only so much you can do with squiggly lines and after a while of staring at them details are easily missed.

MATH 1
choose ([Oil Pressure] < 1.15 && [MS4 nmot] > 3000, 1, 0)



Below: Figure 1 – the Oil Pressure Low event is shown on the graph as a green triangle on the time axis drawing attention to that point immediately. For clarification the oil pressure channel is shown in blue and rpm in yellow



Most data analysis software allows the user to define various controls to display data, but this time around we are going to cover two very valuable tools to make data clearer and more efficient. These are the event tag and bit field control. Individually these two tools are very useful, but if they are used to complement each other they are even more powerful.

The event display works exactly like a math channel, except that it is not displayed as a line but a triangle at the bottom of the time-distance chart in order to highlight a spot in the data. For example a low oil pressure event could be defined as – see **Math 1**.

The qualifiers for this event are oil pressure lower than 1.1 bar and the engine speed over 3000rpm. When both of these conditions are met, the event is shown and clearly draws the attention to a location in the data where the engineer should be looking.

A BIT OF ALRIGHT

Bit fields are a very efficient tool to collect and display a lot of information. They allow the engineer to combine information from many different sources into a single channel. If we look at a bit field channel on a normal graph, it will display decimal values which are difficult to decipher even with a documented bit field.

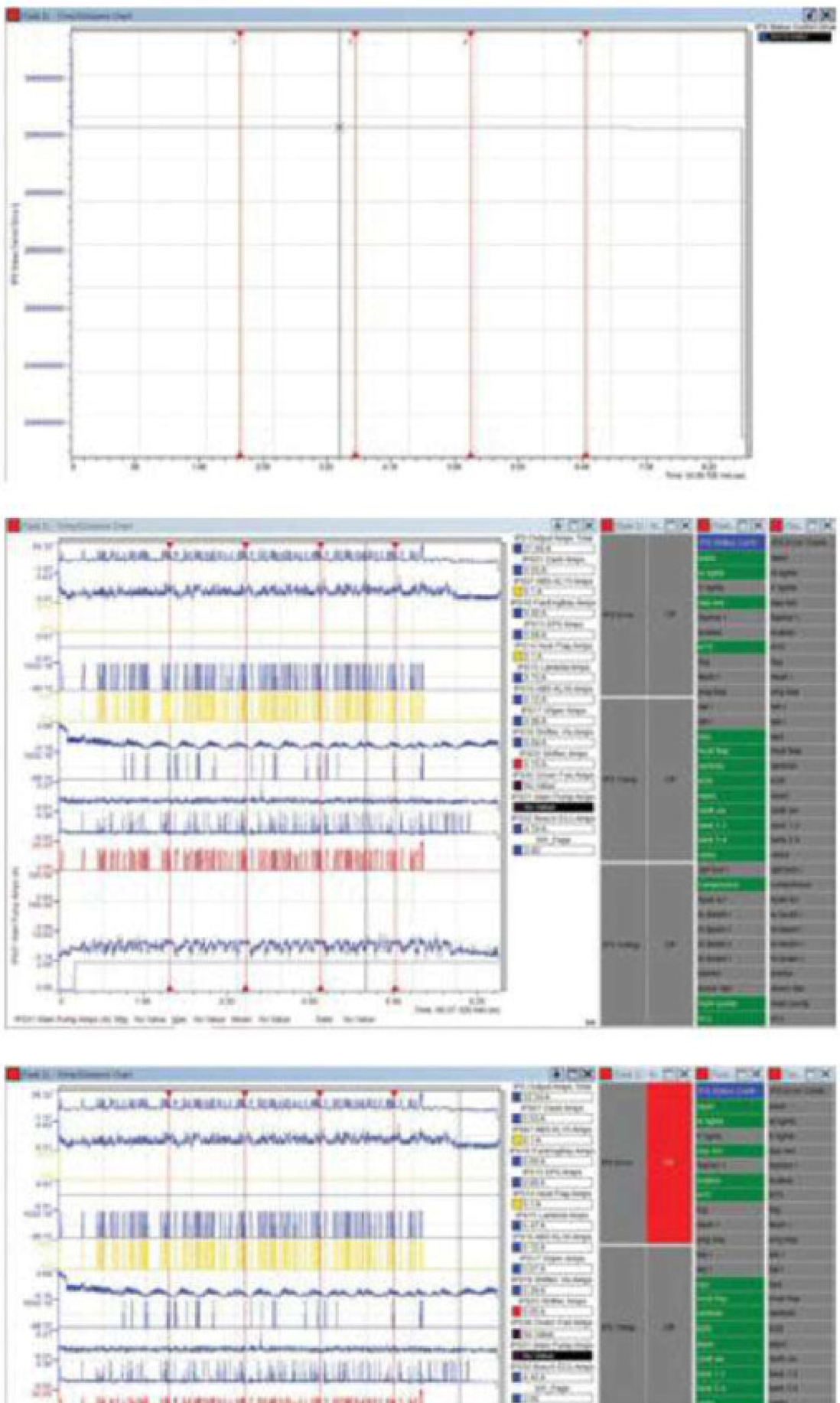
A good way to start understanding bit fields is to use the Programmer function on the calculator found in many computer operating systems. This allows us to set various bits on and seeing what decimal (or hex or bin) value this relates to.

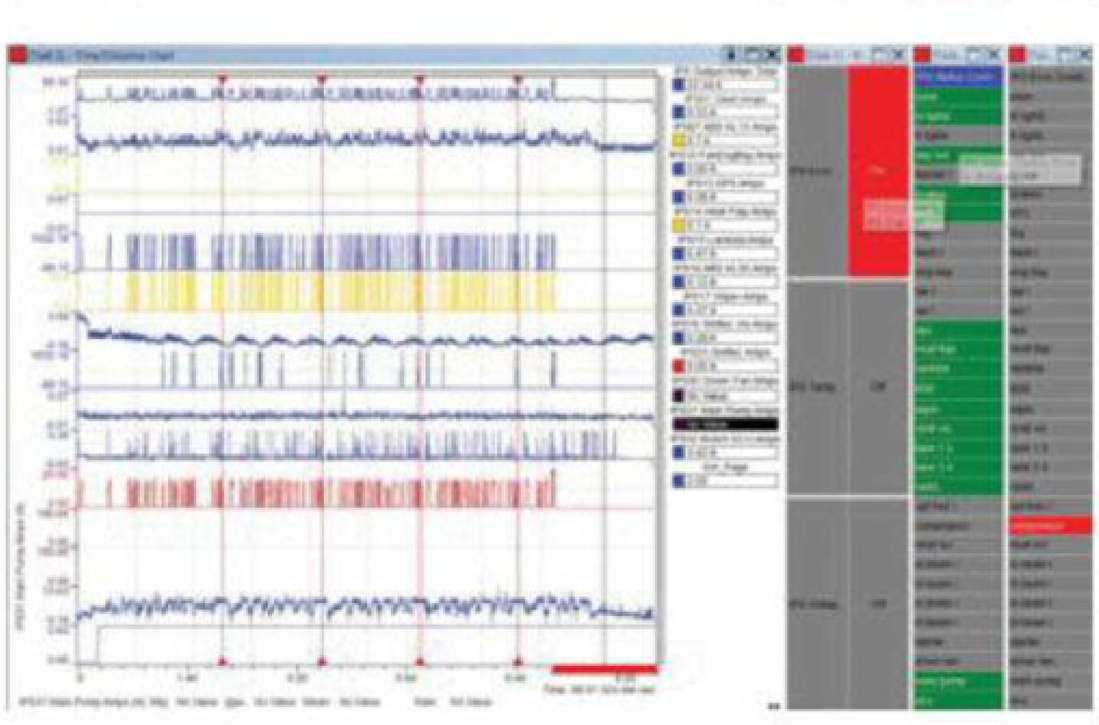
Luckily, it's possible to configure data systems to hide all the numerical complexities



Examples of bit indicator fields

of bit fields and simply show us which channel the bit relates to. Below is an example of a bit field generated by a 32 channel power control box, giving us information about which devices it is turning on at that point in time. However, this channel displayed on a time-distance chart provides little useful information without some pretty serious digging in the bit field definition.





Figures 2-4: data from a 32 channel power control unit with details of amp draw for various channels

This status bit field channel is generated automatically by the power control system and then decoded on the data system to provide the correct information. It is also possible to collect information manually in a math channel and create a status bit field channel. An example of this can be found below – this channel represents a bit field from a CAN steering wheel.

```
[MAP Sw] +
( [Pit speed sw] << 1 ) +
( [Radio Sw] << 2 ) +
( [Light Sw] << 3 ) +
( [Rain Sw] << 4 ) +
( [Launch Sw] << 5 )
```

One downside of the bit field control is that it is normally connected to a time-distance graph and shows the status of the bit field channel only at that time. Therefore it can be useful to combine the event display and the bit field in order to get to some information fast. The event points to the location and the bit field shows exactly what is going on.

Figures 2-4 show how the event and bit field display can be used very effectively to get to a problem spot in the data. In the first image, a quick glance might lead you to believe that everything is running OK. However, scrolling through the data we see an error flag up and that the power module is reporting an error on compressor device in the car. The third image then shows an event based on the IPS Error Alarm channel and shows exactly at what moment the problem starts. Now with hindsight and looking back at the first image we are able to see that towards the end of the outing there might be a problem, but using the event and bit field to their full effect makes the detection much more efficient.

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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

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Closing coverage

The final instalment on the Praga R1 sports prototype coupé

Praga's eye-catching R1 is destined for the new Supercar Challenge Superlights class using normally aspirated and turbocharged versions of its 2-litre Renault engine. With LMP coupé styling and relatively modest-looking aerodynamic appendages, what is its aerodynamic performance like? The team at Praga generously hauled one of their racecars from Slovakia to the UK to spend a half day in the MIRA full-scale wind tunnel for our mutual benefit.

In the previous two issues we have looked in depth at the Praga's baseline aerodynamic numbers and found that it was almost up to the downforce and efficiency levels of the Ligier JS49 CN open sport prototype that we showcased in 2009. We then studied in some detail its ride height sensitivity and the effect of chassis rake.

In this final instalment we will look into several other configuration changes.

REAR WHEEL COVERS

To provide the option of meeting FIA sportscar regulations, covers that masked the upper part of the tyres in rear view were manufactured, but Praga wanted to know what effect these had on the aero numbers. **Table 1** provides the answers, with the differences shown in 'counts' where 1 count = a coefficient change of 0.001.

Table 1: the effect of removing the rear wheel covers

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	0.599	1.312	0.430	0.882	32.8	2.190
Without	0.592	1.250	0.432	0.819	34.6	2.111
Difference	-7	-62	+2	-63	+1.8	-79

Table 2: the effect of removing the front suspension covers

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	0.592	1.250	0.432	0.819	24.6	2.111
Without	0.597	1.322	0.542	0.780	41.0	2.214
Difference	+5	+72	+110	-39	+6.4	+103

Table 3: the effect of rear body Gurneys

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Without	0.605	1.368	0.543	0.824	39.7	2.261
With	0.622	1.410	0.551	0.860	39.1	2.267
Difference	+17	+42	+8	+36	-0.6	+6

So the dominant effect of removing the rear wheel covers was a loss of 63 counts of rear downforce, or roughly 7 per cent, a surprising result that perhaps points to the integral 'dive planes' behind the wheels generating an increment of downforce when the covers are in place. That only seven counts of drag were lost was perhaps not so surprising because we have previously seen small drag differences from opening up rear wheel arches on sportscars.

Another measure to meet FIA sportscar regulations saw front suspension covers being made. Again the car was tested with and without these covers – **Table 2** shows the results.

In contrast to the previous alteration, the car produced better numbers without the front suspension covers, the dominant effect here being a significant increase in front downforce after removing them. In reality this would have been the result of eradicating positive lift generated by the suspension covers, but the net result was the same.

REAR BODY GURNEYS

Gurneys approximately 20mm high were affixed to the rearmost extremity of the upper bodywork between the wheel arches and the wing post and silencer fairing. The results without and with the Gurneys are shown in **Table 3**.

The Gurneys produced 42 counts of total downforce for 17 counts of drag, a ratio of 2.47 to 1, so reasonably efficient. Interestingly, some of that gain was at the front end and not all at the rear as might be



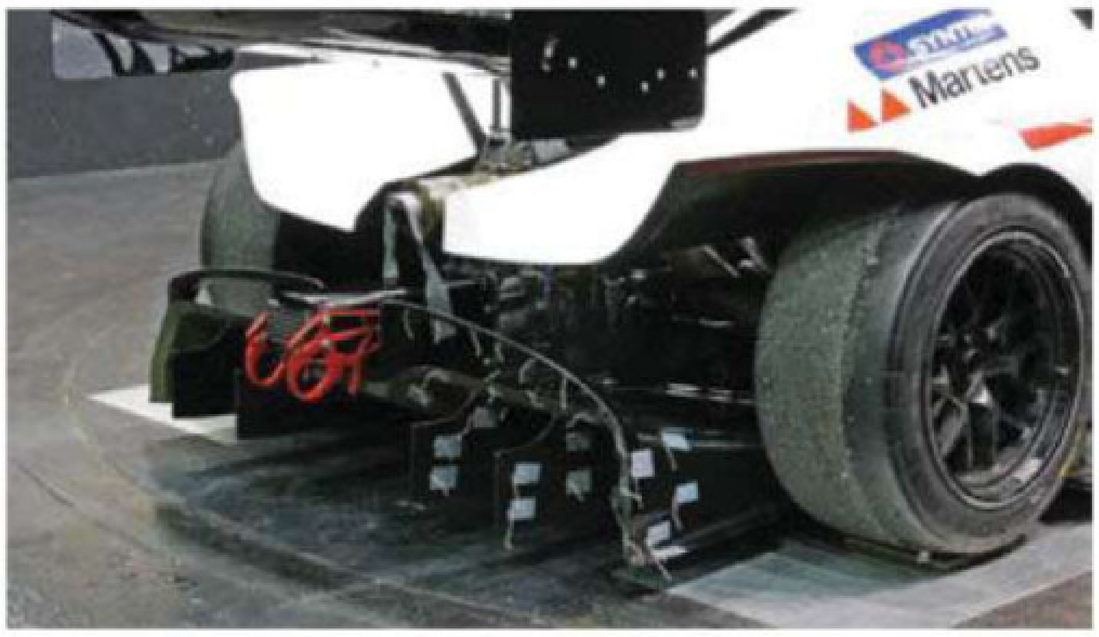
Rear wheel covers (left) produced an unexpected result



Front suspension covers, here being removed by Praga chief designer Juraj Mitro, produced the expected result



At baseline height the rear wing was just above the mirrors' wakes. Lowering the wing may have put it directly into the wakes



Diffuser strakes were evaluated

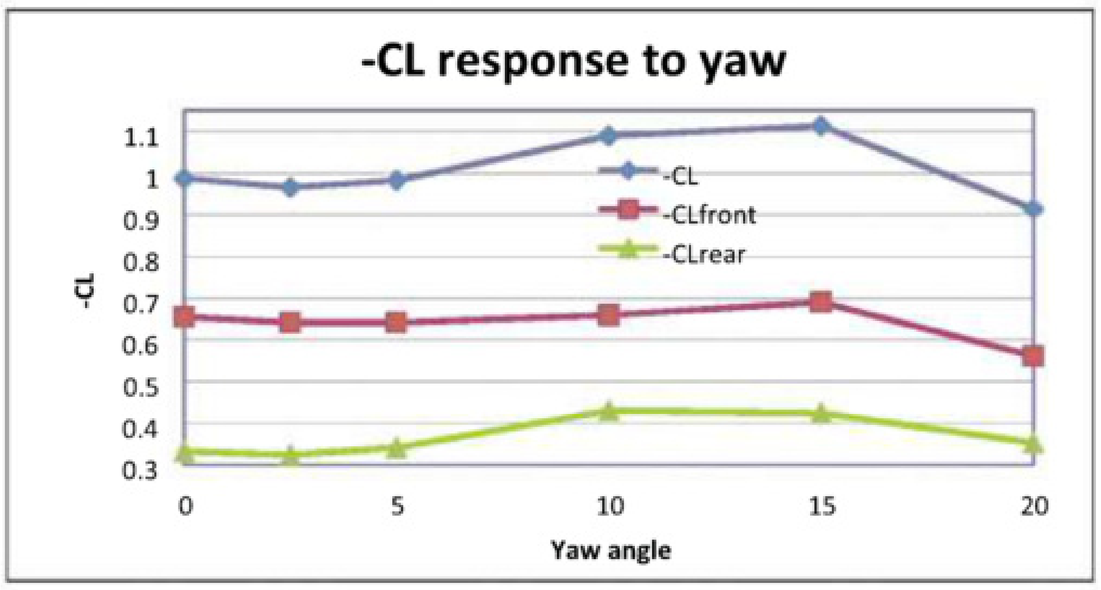


Figure 1: downforce coefficients altered with yaw angle

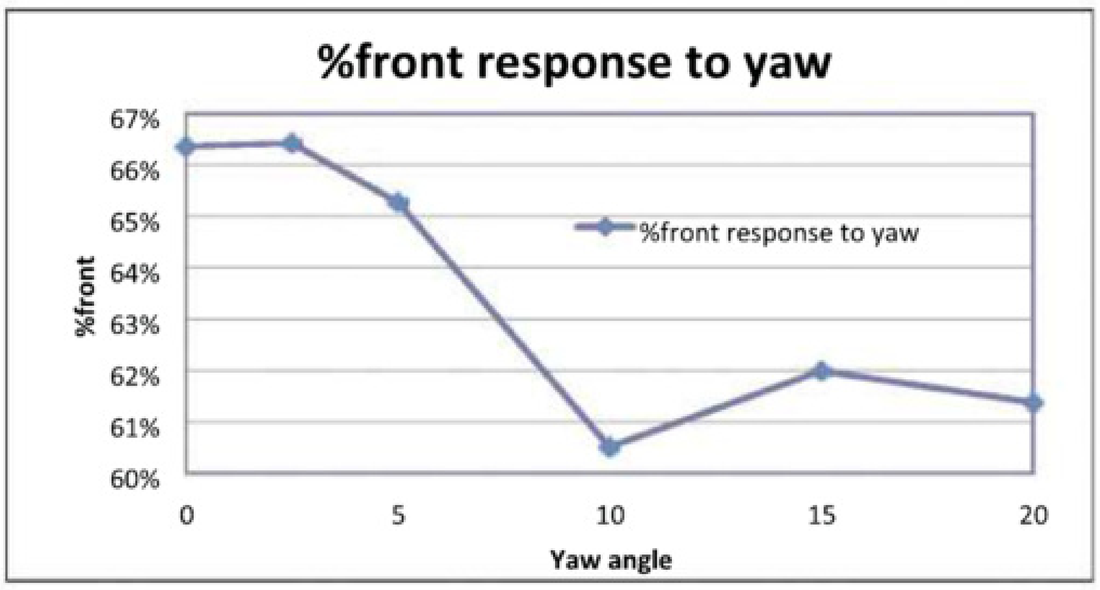


Figure 2: balance also altered with yaw angle

expected, although we saw a similar effect on the Ligier JS49 when fitted with a larger rear body spoiler.

A rear wing position approximately 60mm lower than the baseline position was tried, with the results shown in **Table 4**.

The loss of rear downforce was quite large for such a relatively small wing height change. However, the smoke plume provided a clue because the wakes of the rear view mirrors could be seen to pass quite close beneath the important outer sections of the 1166mm span wing. Lowering the wing would have put its flow field into the mirrors' wakes. A full width wing would mitigate this problem at the same time as providing more efficient rear downforce.

DIFFUSER STRAKES

Just what are diffuser strakes worth? Well, there is an infinite variety of locations and shapes they might adopt, but in **Table 5** are the results of fitting a pair in each side of the R1's diffuser (NB: this was in the low rear wing configuration).

In this configuration, the strakes produced a modest (1.4 per cent) but very efficient downforce gain, mostly at the rear. 20mm high, 150mm long Gurneys were affixed on top of the floor just inboard of the front wheels to see what their effect might be, and **Table 6** reveals all.

These produced a very efficient, modest front downforce increment, probably by reducing lift over the floor where the velocity accelerates (and hence the local pressure reduces) in the convergence between the wheels and the chassis.

YAW RESPONSE

For the final few minutes of a busy session, the car was set at a range of yaw angles so the changes to the numbers could be examined. The rear wing flap had previously been set to minimum, so the balance was well forward. For clarity, the results are presented graphically above.

In **Figure 1** we see the negative lift, or 'downforce coefficients', and in **Figure 2** the aerodynamic balance is plotted as '%front'. Keeping in mind that the rear wing was set to its minimum flap angle and that the responses at the rear may be different when the wing is at a higher downforce setting, the pattern of change at yaw angles up to 5 degrees saw overall downforce change very little, with a mild shift in balance towards the rear as rear downforce started to increase. However, by the time 10 degrees had been reached, rear downforce had noticeably increased, and this produced a marked shift in aerodynamic balance away from the front. This might be perceived as a benign, self-correcting response in that yaw angles between 5 and 10 degrees could represent mild oversteer, and the aerodynamics have changed to give more rear grip, both in relative and absolute terms.

At 15 degrees yaw, rear downforce had levelled off, but interestingly front downforce continued to increase. This saw the balance return towards the front a little. Then at 20 degrees both front and rear downforce had started to decline, presumably because the flow over and under the downforce inducing surfaces was now being disrupted by ends plates and wheels.

Next month we start a new project in the MIRA wind tunnel.

Racecar's thanks to the team from Praga Cars

Table 4: the effects of lowering the rear wing

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Original	0.602	1.341	0.548	0.793	40.9	2.228
60mm lower	0.561	1.238	0.586	0.652	47.3	2.207
Difference	-41	-103	+38	-141	+6.4	-21

Table 5: the effects of the R1's diffuser strakes

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Without	0.556	1.230	0.585	0.644	47.6	2.212
With	0.557	1.247	0.588	0.658	47.2	2.239
Difference	+1	+17	+3	+14	-0.4	+27

Table 6: the effect of front floor Gurneys

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Without	0.556	1.230	0.585	0.644	47.6	2.212
With	0.556	1.252	0.607	0.644	48.6	2.252
Difference	0	+22	+22	0	+1.0	+40



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Empire strikes back

'F1 plus' aero comes to hillclimbing in the form of Empire Racing Cars' latest contender, the Wraith. And the force is particularly strong with this one...

BY SIMON MCBEATH

The honour of naming the latest car from Empire builder Bill Chaplin's Somerset, UK race shop fell to the first customer, Clive Austin, who says he chose the tag because 'it felt stealthy, ephemeral and sinister – a bit like the look of the car'.

'It also continued Bill's tradition of naming his cars after a beer – Force, his original company, and Empire are both ales, and Wraith is also a brand of ale,' Austin added. So, if perchance you thought there was a Star Wars connection going on here, be advised it was more of a familiarity with traditional alcoholic beverages!

And that's about where tradition stops with this latest sylph-like creation. The car carries on the proven mechanical precepts that Chaplin put first into his Force Racing Cars products before he sold that enterprise a few years ago, and which carried over into his '00 series' spaceframe Empire cars, as campaigned successfully by loyal customer Simon Fidoe. But what makes the Wraith stand out is the knowledge and effort that has gone into developing its aero package, together with the integration of the mechanical components into a design that has been very much led by its aerodynamics – and its aerodynamicist.

Sauber F1's head of aerodynamics, Willem Toet, himself the 2005 British Hillclimb Championship runner-up, has had complete control of the aerodynamic design of the Wraith. Here, then, is the background on how the project came into being, and on the creative cooperation (and occasional friendly conflict) that produced this gem.



Newest car, oldest venue. The phase 1 spec Empire Wraith rolled out at a media event at Shelsley Walsh hillclimb, the world's oldest motorsport venue in continuous use, in March 2014

EARLY STAGES

The story begins back in 2005 when Toet approached Chaplin to run his 4-litre Judd V8-propelled Pilbeam MP88 in the British Hillclimb Championship. Chaplin's positive response carried one condition – that one day Toet would have one of Chaplin's cars! With that agreed, the pair began discussions on concepts for what ultimately became the Wraith. At the time Toet was head of aerodynamics at BAR, based at Brackley in the UK's motorsport valley, so combining work with his own motorsport schedule was not too complicated. And the idea was formed that they would create a single-seater that could accommodate a wide range of engine options from 1000cc motorcycle derived units, through the various larger capacity bike engines and up to racing V8s like the torquey 4-litre Judd with which Toet enjoyed so much success.

But central to the project was Toet's desire 'to set new aerodynamic standards in UK



The Wraith's spaceframe predecessor was sampled by 2013 BTCC champion Andrew Jordan at Gurston Down Speed Hillclimb in May 2013



CLIVE AUSTIN

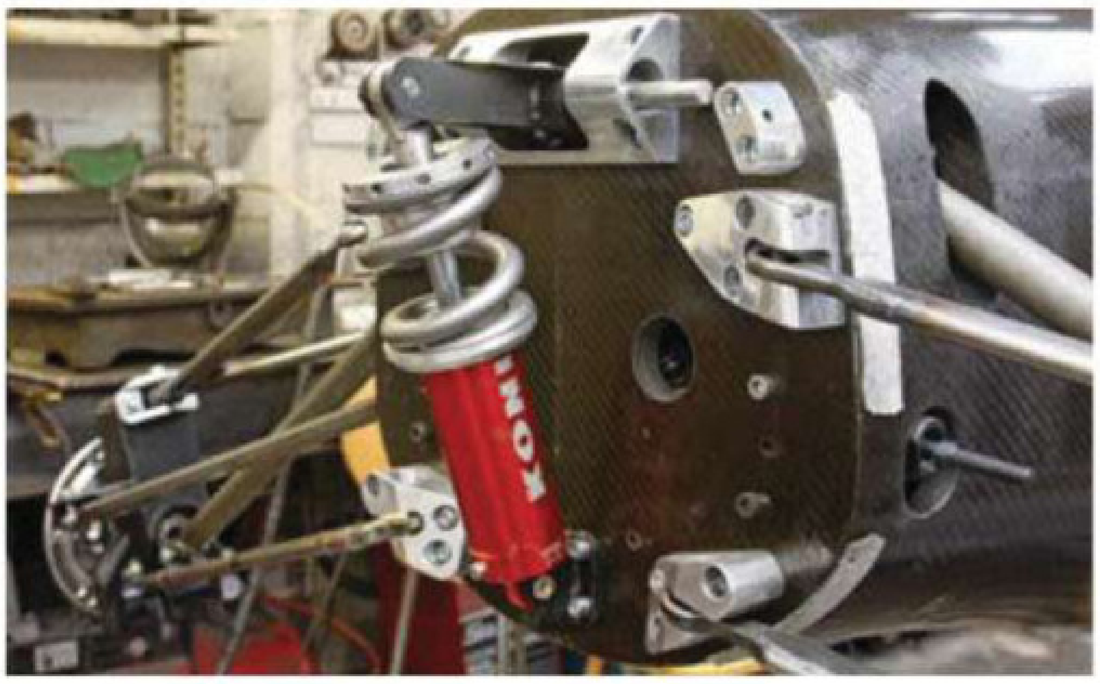
The chassis pattern during the machining process



Hard points being drilled off on chassis number three in October 2013



Safety features include a cockpit side head restraint system



Pushrod actuated monoshock resides on the front bulkhead



F1-esque front suspension, with mounts all tucked out of the airflow



Front wing has a very large plan area; end plates taper in at the rear. Stylish nose, like F1 used to have – and F1-esque front suspension geometry too

hillclimbing', for as he said in *Racecar V12N4* (April 2011): 'I've been hillclimbing for a long time, and have given a lot of people advice during that time. Now I quite fancy the idea of using the knowledge I've acquired over 25-plus years to try and produce a car that, ultimately, is more efficient and, if possible, faster than an F1 car.'

However, a move to BMW Sauber – as it was then known – in Switzerland to head up their aerodynamics department from 2006 not only put the brakes on Toet's own motorsport activities, but also on his role in the project with Chaplin. And it was not until 2010 when Toet returned to the UK for a stint as managing director of the RML Group, where Chaplin was also doing fabrication work, that the pair rekindled the project.

However, far from being dormant during Toet's initial Swiss sojourn, work had continued in the background, with Dave Spiers, then on a work placement from university with Chaplin (before taking up a post himself as a design engineer at BAR and later Toro Rosso) doing CAD work on the project. 'There existed a loose design for the car,' said Chaplin. Also to hand was a digital model of one of Chaplin's earlier creations, and this provided a basis on which to begin some CFD work.

SERIOUS CFD

While at BAR/Honda, Toet worked closely with Dr Rob Lewis, founder of AdvantageCFD under the Reynard Motorsport group umbrella. This then became BAR's CFD department while simultaneously providing a commercial service to the outside world (and providing material to this journal for CFD-based Aerobytes from the March 2004 to May 2006 issues). Honda subsequently assimilated this CFD group entirely into its F1 operation, and Rob Lewis departed to set up TotalSim, now itself a world-renowned independent CFD service provider. It was logical, then, that when Toet returned to the UK, the two former colleagues and friends should tie up again on CFD for the hillclimb project. A programme of work, funded entirely by Toet, began in earnest.

Chaplin picks up the story: 'With Willem back in the UK and both of us working at RML at that time, we had regular discussions and we became much more focused. Willem guided Dave Spiers on the aero design, and my role was to keep things practical, reining in the designers from time to time if they forgot we didn't actually have an F1 budget to build the car!' Chaplin also impressed upon Toet the need to style the car to look good, because the idea was to build and sell them, and as Toet admitted to *Racecar* in 2011. 'I've only ever been interested in performance and often wondered why people like Ross Brawn would be interested in looks. But now for the first time we're interested in style as well.'

So designer/stylist/illustrator John Keogh was engaged to generate a raft of artist's impressions, and Toet then had to indicate what would work and what would not so that Spiers could integrate the best designs into the CAD. In short, 'we kept all the best bits and that's pretty much what we've got now on the 2014 "roll-out" car,' says Chaplin.

The first car (the black one in our photos) had run in a few



High nose and suspension all contribute to the high underbody inlet. Tunnel 'throats' are set well above the base of the chassis



Tidy detailing of inboard suspension mounts have been designed to minimise disruption of airflow to the underbody



There's generous radii on all leading edges, and virtual absence of a 'Coke-bottle' waistline between the rear wheels



Rear suspension follows previous Empire thinking, but the lower links are even higher than previously



Tunnel roofs and sidepod upper surfaces converge at the underbody's trailing edge; the tunnels also merge in top view



The dual-element rear wing will run at a low angle on the 1000cc cars. Note the '3D' end plates

events at various venues during 2013 to prove the mechanical package, but with just the wing kit, as the only body panels that were ready at that point were the engine covers. But even without the benefit of the full aero kit, class podiums and personal best times were set.

A substantial amount of CFD work then went into into what became the first full body kit as seen on the grey car in our photos. And by March 2014, Toet reported that there were already four further update packages.

Toet had moved back to Switzerland in November 2011 to once more head up the aerodynamics department at Sauber F1, and was fitting this spare time project around his F1 priorities. And after many more design iterations up to early 2014 he declared tantalisingly that 'some of the stuff is quite hard to believe. We're making so much progress it is genuinely ridiculous!' As to exactly what will follow the phase 1 aero kit that emerged in March 2014, both Toet and Chaplin were very coy, the latter insisting that it is important for customers to get some seat time during the first part of 2014 before upgrades can be contemplated. Nevertheless, these might be introduced in mid-2014 and late 2014/early 2015.

PHASE 1 AERO

All the Wraith's wing profiles were designed by Toet. The front wing is dual-element with very large chord main element and flap. The main element dips under the nose, maximising the area between the top of the wing and the bottom of the nose, and the main element chord is extended in this region, presumably to compensate for the reduced angle and chord of the flap under the nose. In top view, the wing also features pronounced convergence in the direction of the airflow, the end plates helping to ease the airflow inboard of the front wheels.

The rear wing, mounted well back as is permitted by the rules, is dual-element too, offering a wide range of downforce options.

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Suzuki GSX-R 1000 in the engine bay. Bigger engines will fit too



Close-up of the lightweight front upright and brake assembly

To suit the lower powered 1000cc cars, the main element and flap angles are quite low, but this leaves plenty of scope for higher downforce settings for wet conditions or the slower, twistier tracks and for higher powered cars.

The sidepods are quite wide, and the underbody not only features high inlets, but the throat sections of the twin tunnels are also well above the minimum permitted ground clearance (40mm), suggesting an emphasis on achieving low sensitivity to ride height fluctuations. 'I wanted plenty of air to get under the pods even if the car was scraping along the ground at high speed,' said Toet. 'We may have sacrificed a little efficiency, but we achieved a floor that hangs on aerodynamically even at the lowest ride heights.'

The tunnels fill virtually the whole width between the chassis and the rear wheels, and smoothly blend aft of the final drive and differential unit to form a single wide diffuser exit. The absence of 'Coke bottle' tapering of the upper bodywork between the rear wheels creates a distinctive look. 'I had to find a balance between the efficiency of the underbody and the efficiency of the upper body,' explained Toet. Conventional Coke bottle bodywork would have perhaps looked nicer (more like F1) and would probably have been better for the upper aerodynamics, but it would have sacrificed floor performance which I did not want to compromise.'

MECHANICAL ASPECTS

Inevitably on a racecar where aero takes such a leading role, much of the rest of the car's design has been packaged to suit. The front suspension is the most visually obvious manifestation of this, with the pronounced downward wishbone and steering arm inclinations of an F1 car. This, says Chaplin, is purely aero-driven, to achieve the very high nose for channelling air under the car. Chaplin also stated that

THE WRAITH'S CFD PROGRAMME

Willem Toet is bubbling with enthusiasm for the Wraith project, referring to his role as 'addictive fun! I'm spending far too much money and time on it! However, F1 is still my favourite hobby and my work, and that of course is taking up most of my time.'

Toet outlined the Wraith's CFD programme so far. 'With the model based on the scanned data we had from an earlier car, we initially did three basic studies amounting to 11 full CFD runs. This allowed good progress, but Bill Chaplin said the model featured too many straight lines and looked crude. It had to look good. So in 2010 we contacted John Keogh on the styling, and once we'd explained the technical regulations he then rapidly produced a number of pencil sketch iterations. By late 2010 we had combined the styling with my concepts and the all-important practicalities into a new baseline model, which was published in those 2011 renderings.

'There followed another phase of CFD, some 19 runs, and we had made big gains on efficiency to the extent that it was the best open wheeler -L/D figure I have ever worked with. By March 2014 we had reached run number 140-something! But we keep learning and finding gains.

'We did find it quite ride height-sensitive because of the big front wing, but we've worked on that and also improved the rear wing. We've also got a "solid" cooling system capable of dealing with the 1000cc engine with a single radiator, or the supercharged Hayabusa, utilising additional coolers in the other sidepod.'

As the man in charge of the practicalities, Chaplin needed a line to be drawn so he could get on and build the parts for the 'roll-out spec' and go testing ahead of the 2014 season. 'We have removed some bits to control costs,' says Toet, 'but the efficiency is still very high, just not as good as it could be. The roll-out bodywork is astonishingly simple, with a very simple sidepod, but it works well and is really quite efficient.'

UPGRADES READY

'We are ready with some upgrades if they are needed,' continued Toet. 'There are four more devices, but they will need patterns, moulds and then the parts making and fitting. They add mass, and they will also add complexity in terms of dealing with extra downforce, so springing would need looking at too.'

All the CFD was carried out at TotalSim in Brackley, UK using OpenFOAM open source software, as is being used quite widely now in high end motorsport applications. 'TotalSim have used big meshes on the Wraith project, perhaps not as fine as would be used in F1, but high quality that requires some serious computing power,' says Toet.

In terms of real world fidelity, the simulations featured moving ground and rotating wheels, and although detail inside the wheels was relatively simple, the wheels themselves were quite detailed. Engine inlet and exhaust flows were applied during runs, but 'we didn't play with that at all,' said Toet, adding 'there were no brake ducts either, but we may look at that later.' Brake cooling is rarely, if ever, a necessity in UK hillclimbing, and serves to remind us that Toet's experience of where downforce can be found should not be underestimated.

'There is perhaps the equivalent of a few days F1 CFD development here, but there is also a lifetime of my knowledge behind it,' says Toet. Conscious that some may perceive the programme as something of a sledgehammer to crack a nut, Toet added: 'I want to help Bill, but I don't want to damage the sport. We want to win, but not by a million miles. The hillclimb world is full of very smart people, and they will look at what we have done, perhaps copy it, maybe make mistakes, maybe get it right and catch us, and that's what the sport should be about.'

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Spiers worked on the kinematics and 'it's as good as anything conventional'. It's worth noting that a noticeably stiff front end has been historically favoured on Chaplin's designs, and less suspension movement obviously reduces the range over which tight camber control is required.

Another feature of Chaplin's previous designs has always been good traction, not just from standing starts but also from slow corners, and this is something that has been carried over onto the Wraith, with good start times having already been demonstrated (aided by electronic traction control systems these days too). But while the general principles of the rear suspension are similar to previous cars, the Wraith has achieved this good traction while also having had the outboard geometry dictated by aero priorities once again. This sees a high location for the lower rear wishbone to enable the diffuser to pass, uncluttered, beneath. There will apparently be suspension upgrades to come, contemporaneous with the aerodynamic upgrades.

Also visually obvious is the effort that has been made to tuck as much hardware as possible out of the airflow. The forward front suspension mounts are on the front face of the forward bulkhead, the wishbones passing though notches in the nose structure; the steering arms and pushrods pass through apertures in the chassis, and the rear wishbone legs attach to brackets bolted into recesses in the sides of the chassis.

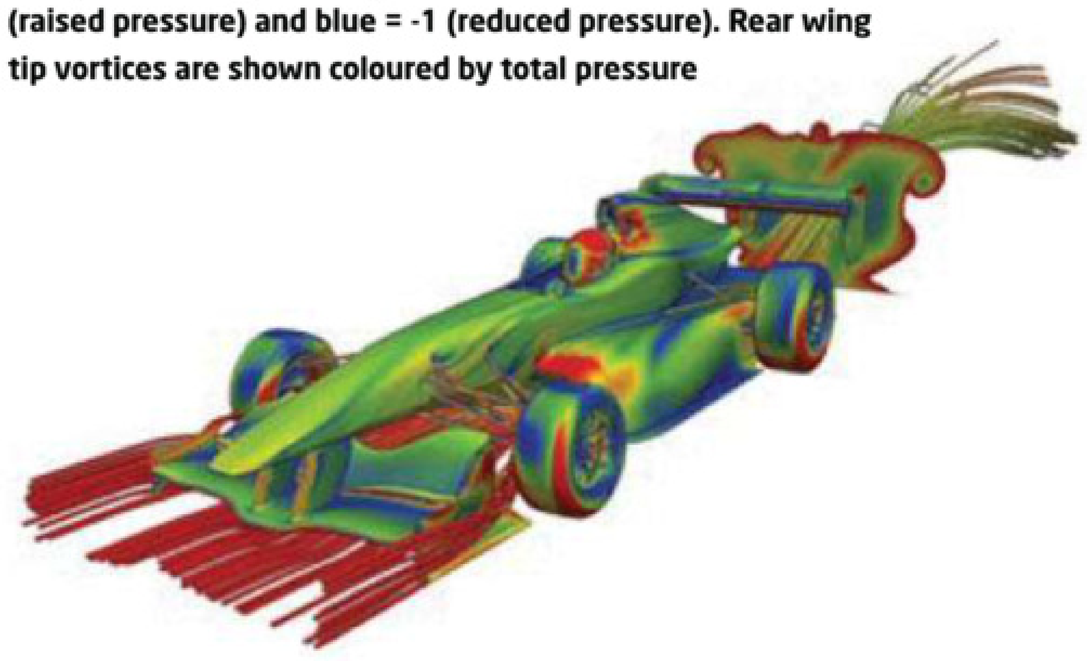
And while the front-mounted monoshock spring/damper unit will no doubt achieve a lower centre of gravity than a chassis top mounted structure, the aerodynamically high forward chassis must have virtually dictated this location, so even this has been affected by aerodynamic priorities.

Elsewhere, the packaging of the bodywork around the mechanical components has been uncompromising. For example, the rear bulkhead is almost ellipsoidal in order to fit tightly within the sleekly tapering rear bodywork. And really the only part of the exterior body where emphasis has been placed on anything other than aerodynamic efficiency is the wide cockpit opening that accommodates the side head restraint system, something Chaplin was very keen to incorporate. 'Even if the car had ended up 10kg heavier as a result, we wanted it to be strong and safe,' he says. 'As it is, it will be less than 300kg with the full body kit and the 1000cc engine.'

The narrow chassis seen without the sidepod kit emphasises the high chassis sides, but drivers measuring up to 6 foot 4 inches (1.93m) and weighing up to 15 stone (210lb or 95kg) had to be accommodated.



CFD plot showing surface pressure coefficients, red = +1 (raised pressure) and blue = -1 (reduced pressure). Rear wing tip vortices are shown coloured by total pressure



TOTALSIM

Surface colours show 'near-wall velocity' where red = freestream and blue = zero. Streamlines are similarly coloured by velocity, and the 'wake slice' is coloured by total pressure



BILL CHAPLIN/TOTALSIM

Shakedown testing, March 2014, streamlines coloured by velocity magnitude

ENGINE OPTIONS

From the project's inception, the intention was that the Wraith would be able to accommodate a wide selection of engines, as previously mentioned. But interestingly Chaplin remarked: 'We ultimately decided against the big V8 idea purely because we didn't think it was the way to go, or what would sell. We thought the days of the big V8 are probably over.' But that still left plenty of options, and the rear bulkhead is nevertheless big enough to take a large capacity V8. 'The sport is obviously trending in the bike engine direction, and we think a supercharged Suzuki Hayabusa unit will be the perfect combination,' he confirmed.

All the new cars have been ordered with 1000cc engines though, and that's because the cost of those, even in a well-tuned state, is well below the larger normally aspirated and the supercharged Suzuki Hayabusas. So we hope to dominate the 1100cc racing car class to start with!'

TECH SPEC

Empire Wraith

Category: UK Hillclimb

Class: racing cars up to 1100cc/1600cc/2000cc

Chassis: carbon composite throughout, autoclave-cured

Engine: Suzuki Hayabusa derivatives, supercharged, turbocharged or normally aspirated. Honda, Yamaha and Kawasaki options also available

Transmission: Suzuki Hayabusa-based gearbox. Chain drive to Empire/Quaife final drive and LSD

Data system: supplied to customer requirements

Suspension: double wishbones, pushrod actuated front mono-shock, double rear spring/dampers with third spring option

Dampers: Koni or Penske

Brakes: Brembo monobloc radially mounted calipers, AP floating 265mm discs

Wheels: Evo Corse F3 magnesium, 8-inch front, 10-inch rear

Tyres: Avon, front 195/530 R13, rear 250/570 R13

Fuel tank: fabricated aluminium, 3 litre capacity

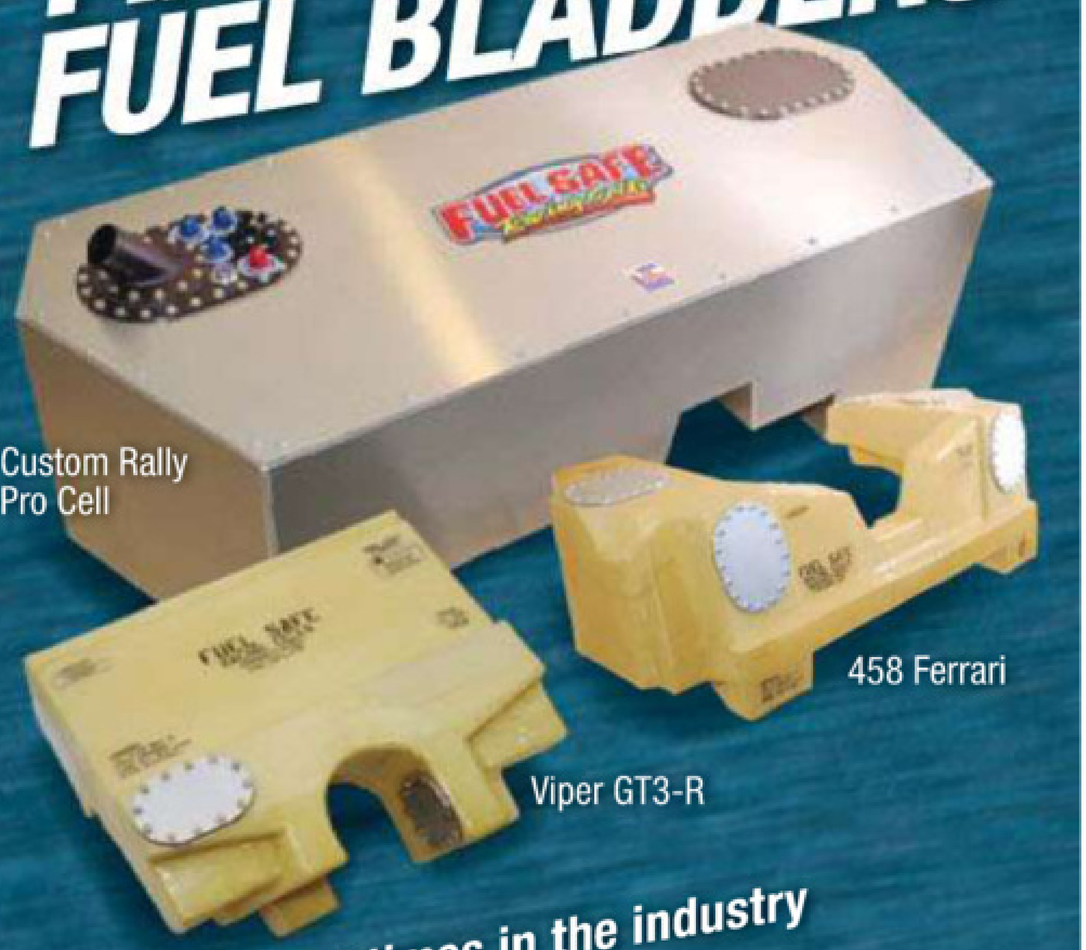
Safety: TRS six-point HANS safety harness. Roll bar to RAC MSA technical regulations, F1-style head restraint system, carbon nose box and crash structure

Dimensions: width 1780mm, height 900mm plus roll hoop. Wheelbase 2300mm
Track front 1580mm, rear 1530mm

Weight: 300kg wet, depending on engine configuration

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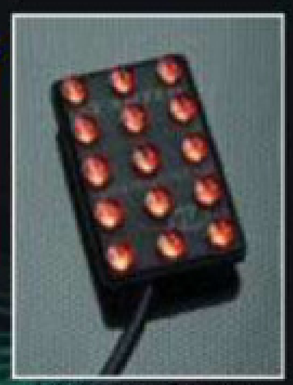
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In safer HANS

Since their widespread arrival in top-line motorsport nearly 13 years ago, HANS devices have helped to prevent injuries and fatalities

BY GEMMA HATTON

HANS – makers of innovative safety devices – has shipped over 800 T-shirts since 2005. That's because these shirts are embroidered with 'HANS saved my neck' and are sent to drivers whose lives were saved by wearing the Head and Neck Support (HANS) device while racing. That's a lot of lives.

There are now around 130,000 HANS devices used every race weekend, and since their mandatory arrival in NASCAR in 2001, F1 in 2003 and all FIA championships in 2007, are said to have prevented thousands of injuries, and hundreds of fatalities. Of course, their acceptance into the sport wasn't exactly immediate. The original 'bulky' designs in the 1990s meant the drivers thought



Thanks to the HANS system, serious head and neck injuries have been avoided in devastating crashes

XPB

GOING GREEN WITH MELECTRONICS

With the first back-to-back race complete, the highly anticipated 2014 F1 season is well under way. Accompanied by a whole array of new technologies, arguably the most important is the ERS – the Energy Recovery System. This system generates energy under braking through the MGU-K (Motor Generator Unit – Kinetic) while utilising the wasted heat from the turbocharger through the MGU-H (Motor Generator Unit – Heat), resulting in an additional 160bhp for 33 seconds per lap.

With the ERS being just one of the complex electronic systems on board, electrical safety has never been so important, which is where Melectronics come in. Since 1999, this niche supplier of electronic equipment has been enjoying substantial growth within the motorsport industry, and is now the official supplier of this year's F1 ERS Status Indicator light, positioned below the roll-hoop camera. 'With the arrival of complex electrical propulsion and ERS, we need to alert marshals as to the status of these systems to ensure safety in the presence of high levels of electrically stored energy,' says managing director Steve Mellish. If the vehicle is safe, the lights will glow green, if not, then they will glow red. 'The unit contains seven high brightness light sources arranged to give 360-degree visibility in a package that would fit in your coffee cup, yet only weighs in at a mere 35g – it was an enjoyable challenge for the team!'

Promoting the benefits of electrical power further is the all new Formula E championship, set to debut this September, presenting another need for Melectronics' expertise. They will be supplying an exterior LED safety light package comprising a high intensity rain light, a safety light and a forward facing light. 'Following the same ethos of maximum safety while being power-, weight- and size-conscious has resulted in these parts being seamlessly integrated into the car without detriment to aerodynamics or aesthetics.'

The entire three-piece package, including electrical fittings, weighs less than 250g – perfect for motorsport applications.

'Both systems have reliability and safety at heart but are also small, low power and lightweight. This has been achieved with our fully bespoke designs tailored to the exact application while building on our existing expertise as a world-leading supplier of LED lighting to the motorsport industry.'



The ERS Safety Light located below the roll hoop safety camera, that all F1 teams are using this year by regulation



The seat fitting process for Arden International's GP2 driver, André Negrão



The HANS Race Seat Kit, with a vacuum casting bag, beads and slow cure resin

they were uncomfortable, and in sportscars, would prevent them from escaping the vehicle during an accident. The 'damned noose' quote from NASCAR's famous Dale Earnhardt Sr who refused to wear it, did not help the campaign either. Regrettably, Dale died in a last lap collision at the 2001 Daytona 500 from a basilar skull fracture – the type of injury the HANS device is developed to prevent. It was after this tragedy that HANS arguably became universally accepted, selling 250 devices per week compared to a total of 250 units throughout the whole of the 1990s.

The theory behind the device is similar to that of an airbag, which cushions the deceleration of the head to prevent abrupt motion, reducing injury. The HANS device uses a raised carbon-fibre collar fitted under two shoulder straps, and is loosely attached to the helmet via three fabric tethers, while the collar is locked in place by

SAFETY THROUGH INTELLIGENT DIAGNOSTICS

During the early development and proving stages of the GEO technology – an 8-post, 16 axis test system – it was common practice to bring professional motorsports teams in for test sessions. The purpose was two-fold. First, this offered early exposure to the system and secondly it allowed us to learn about the range of challenges that teams often experienced. Back at that time, there was a large emphasis on trying to understand what makes a 'good' car good, and what makes a 'bad' – or poor handling car – bad. This is the story of one such scenario that caught everyone by surprise.

One of the teams we had been working with consistently as part of our development had just finalised a complete new front suspension redesign. The team had very good internal resources in testing with hydraulic poster systems and setup rigs, but had not been able to spend much time on the track evaluating the changes they had made in their front end recipe. At first glance, from the prior in-house testing they had done, everything seemed to be very positive. It also began to look like a very favourable change during the early tests on the GEO System.

The engineers from the team were interested in having us create a track lap scenario for their upcoming race on one of the US major event tracks. We built a scenario from some previous data we had on the track, and a similar car to the one they had brought to our test site. After a few minor adjustments, we began to simulate the laps of the track and car on the GEO. We typically do this using lower frequencies so we can better see and capture any potential momentary issue. The team made a couple of minor spring and bump-stop changes during the lap testing. Surprisingly, the car seemed to have much better traits than their previous front end recipe.

We wrapped up the test, sent them on their way, and everyone was happy with the accomplishments of the day. Once I had time to sit down, I evaluated the test data, which I always tried to do when time was not so chaotic and compressed. My goal in doing so was to see what we could do better, more quickly, and with more accuracy. In evaluating this particular data set, I had noticed that there was something very wrong with a small momentary window of data that correlated with the entry point of turn 1 on this particular track. Typically, finding issues or defects comes after years of working on these cars, and is usually fairly easy to see by the engineers, so I often rely on those who are evaluating the data to let me know if they have noticed or detected any possible issue in the current lap completed. In this case, no one had said anything about a potential problem.

LOAD ISSUES

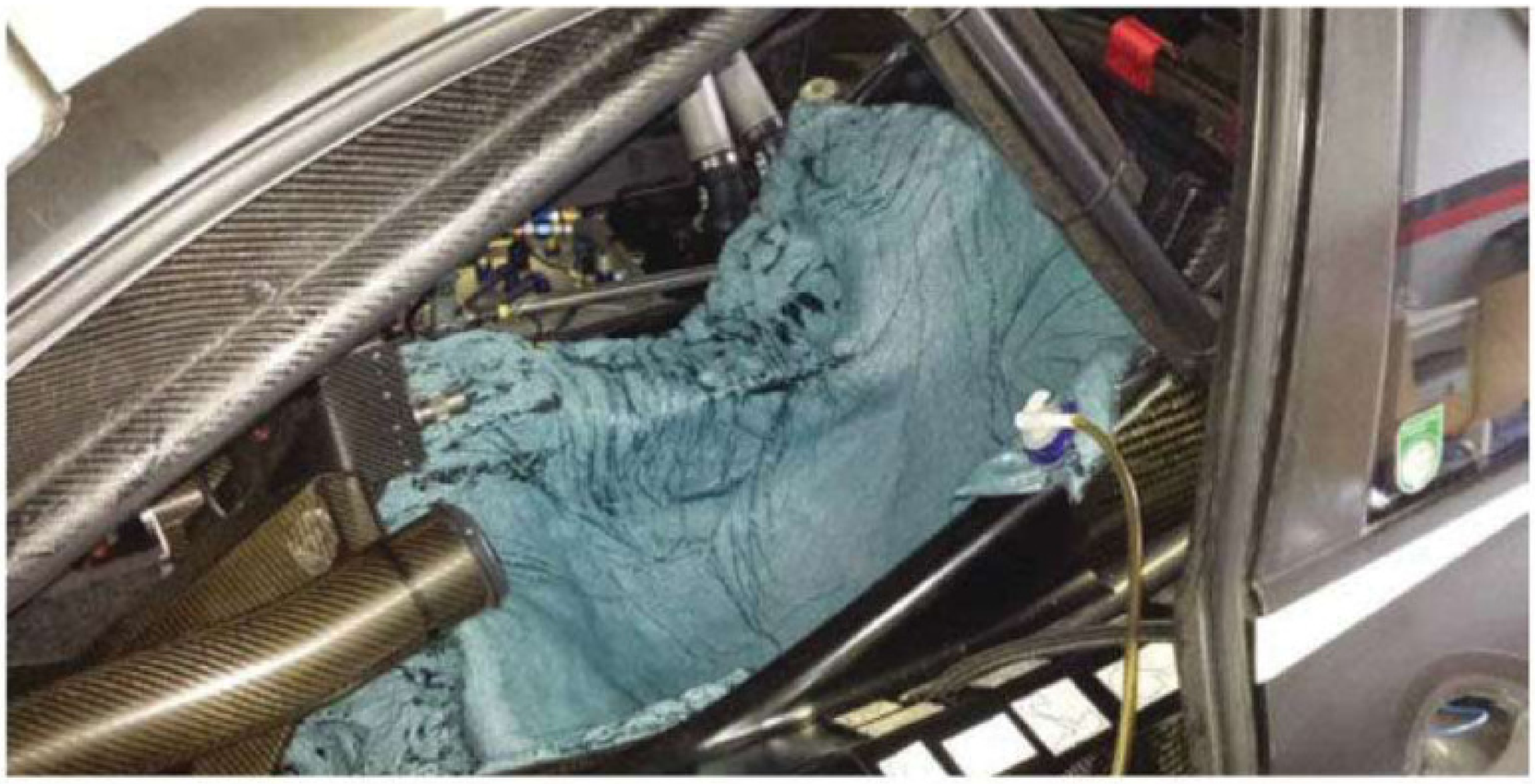
The problem – or at least what I felt was a problem – appeared to cause a substantial loss of load, momentarily, on the right front tyre upon turn 1 entry. It seemed as if the load was reversed from right front to left front. I was puzzled, and before I could bring it to the team's attention, I felt that I needed to dig a little deeper for understanding.

Fortunately, when I looked deeper, I saw that the team had done a very good job in instrumenting many aspects of the car. I looked for any other channel that had a significant change in data in that momentary time period. It was fairly easy to see at this point that the 'sway bar' load cell had a very significant change that corresponded to the same location and time in nearly every lap. At that point in time, a mechanical issue would cause the right front tyre to abruptly unload for a split second – milliseconds in fact. This reduced the front tyre to almost zero downforce. I had never previously witnessed something this abrupt in typical vehicle kinematics and dynamics.

I felt that it was very important to let the team

the safety harness. The aim is to maintain the relative position of the head to the body as the momentum of the crash forces the head forwards, hence the system is secured to the body of the driver, rather than the seat. This ensures that not only does the amount of energy absorbed by the neck and skull reduce, but the helmet loading is transferred from the base of the skull to the forehead, which is far better suited to dealing with force.

Ironically, the additional weight of the helmet actually increases the momentum of the head and therefore the strains on the neck during a crash. During a 40g head-on collision it was found that a helmeted head weighing approximately 6.8kg accelerated forward at 107g. This resulted in shear, where two opposing forces act perpendicular to the neck, and tension, where pulling forces act along the neck axis. Both leading to loads that exceeded the threshold of injury – increasing the risk of death. However, with the HANS device, neck tension reduced by 81 per cent, neck shear reduced by 72 per cent and the head experienced a more tolerable 62g.



How the HANS vacuum bag fits in with the rest of the seat during the curing process

'In those early years between 1986-1991 we got almost no one to wear it,' says multiple IMSA champion Jim Downing who developed the HANS device with his brother-in-law Bob Hubbard, a world expert in spinal biomechanics. 'We had a few early adopters like Paul Newman, but he had a neck problem – that's primarily where a lot of our early market came from.' Downing highlights how times have changed: 'I've been racing for 49 years, 25 of which professionally, and I can't go to a track without people coming up and giving me at least an anecdotal story that says HANS saved their lives. Now, I know that they probably exaggerate, but HANS has prevented a lot of injuries.'

As crucial as the HANS device is, to ensure ultimate driver safety it has to work effectively in conjunction with the harness, belts and seat. 'The HANS Seat Kit system ensures that the driver is accurately positioned inside the cockpit for safety, comfort and performance,' explains Chris

know, and see if we could get the car back in to evaluate this phenomenon. After speaking with the engineer responsible for the car, I felt a little like I was being told 'thank you very much, but we know what we are doing'. Even so, I thought I should probably let a second person know, just in case. I did speak with the crew chief, and he indicated that the car was already on the hauler, and headed for the race. He also stated that they had also run the car on their kinematics rig, as well as their 7-poster, and saw nothing that I was describing.

My concern was dismissed, and I was told that I probably had a problem with our equipment. This seemed to be a common response I would hear every time something new was discovered using the GEO System. Knowing I had done everything I could, I now had to rely on the team experts to do what was best. I felt at the time that all involved believed that if there was any substance to what I had found, it was insignificant enough that the driver would just drive through that little moment in time. I hoped they were right, for the driver's sake.

I tried to watch as many of the events as I could to keep abreast of the challenges teams experienced on a weekly basis. That weekend, I had enough time to catch the qualifying runs. I watched until the car and driver I had concerns about made his attempt for a qualifying position. The driver came on the track and brought the car up to speed as he crossed the start/finish line for his first qualifying lap.

As the driver entered turn 1, he was at full speed, and turned the car hard down to the bottom. At that exact time he turned down, the car did one abrupt wiggle, and shot right up into the outer wall. No one was expecting the horror of what happened next. The car had so much speed and inertia that it bounced off the wall, tumbling, rolling and cartwheeling all the way through turn 2. The car was reduced to rubble in seconds, and just welded structure remained. I don't think one person who witnessed the crash felt anyone would walk away from that twisted mass of tubing. But a miracle happened that day when the driver crawled from the mass that once was a complete racecar. The driver stumbled away with a haunted look on his face, unaware of what had just happened.

LUCKY ESCAPE

I was relieved the driver walked away with no permanent injuries. The car was destroyed beyond any possible point of determining what really went wrong, which was attributed to either a sudden loss in traction, or to a catastrophic mechanical failure.

There was and still is no doubt in my mind what happened, and I never heard another word spoken from the team about what I had warned them about. Since that day, I have personally seen the importance of diagnostics prior to hitting the track at 200mph. I learned that just because something doesn't make sense, hasn't been detected elsewhere, or is a tiny blip in time, doesn't mean that it should be ignored. The results can be catastrophic and deadly. I have discovered other such scenarios on the GEO System since the one that first concerned me about safety.

I caution people in testing that such scenarios can go undetected in 7-post high frequency testing. It was not designed for these types of diagnostics.

Likewise, basic kinematics rigs can also completely miss this phenomenon. Discovery of this type of phenomena takes placing all of the wheels in the correct combination at the correct time under motion and force, at the correct frequency. I have experienced the same resistance over the past few years in some instances, and the only power of persuasion I have is to retell the story of what can happen in the blink of an eye. Testing is not just about squeezing out optimum performance data any more.

Chris Meurett,
Powerstream Industries



Nic Hamilton's seat is a perfect example of how the HANS seat technology can be integrated with Cobra seats

"We continue to increase our energy absorption without affecting weight and driver useability"

Norton, director at HANS Seat. 'Once cured, the HANS Seat is a deformable structure around the driver with a given thickness offering energy absorption and anti-vibration qualities.' The kit uses a vacuum casting bag with a unique bead and slow cure resin mix. 'We have moved on from traditional, old-fashioned, polystyrene beads and epoxy resins to our unique bead and resins mix similar to a crash helmet liner. These materials have been tested at an FIA-approved test lab. Along with our technical partners, Cobra Motorsport we work on driver ergonomics, driver safety and driver anti-fatigue systems all important to ensure drivers are as safe as possible. We also work closely with teams such as Arden Motorsport and Drayson Racing to make sure our HANS Seat works in different environments and conditions.'

The company also utilise their skills in developing other products, such as padding systems for the HANS device and cockpit, headrests and a SIM Seat which is a vacuum-only simulator insert, ideal for multiple drivers. 'The future for HANS Seat is to develop the system even further to ensure that all drivers at both professional and amateur levels have access to our technology. We are expanding our activities into Moto GP, powerboats, aircraft and many other applications where driver safety and comfort are paramount. We continue to research new materials to increase our energy absorption without an effect on weight and operator usability.'

Some argue that motorsport is now becoming 'too safe' and there is no sense of danger any more. But with more championships, more full grids and more competitive drivers, has the overall number of crashes actually changed over the last 30 years?

The only difference now is that the driver walks away.

ISOLATED BATTERIES

As on-board electronics and hybridisation continue to increase in motorsport, the use of batteries is becoming more and more important. From a safety point of view, battery isolators have to be implemented and are required by the FIA to not only disconnect the battery from all electrical circuits, but also stop the engine.

'It may appear to be a simple device from the outside, but inside there are highly sophisticated electronics,' says Neil Armstrong, managing director of Cartek. 'Many customers cannot believe that a device smaller than a credit card can handle the cranking current of a V10 Dodge Viper – but they do.' This automotive electronic specialist invented their solid state battery isolator over 10 years ago and have been evolving it ever since. 'They are the only fully electronic devices to perform both functions in one small unit.'

The device contains two isolation circuits. The first breaks the connection between the negative side of the vehicles battery from the chassis earth, while simultaneously disconnecting the positive electrical power from the engine ECU and/or ignition system. Microprocessors control the circuits and include other safety systems such as over-temperature, over-current monitoring and also ensure that there's no false triggering for instant activation of the kill switch.

As the design is solid state, there are no moving parts and all of the power switching is fully electronic. This is a vast improvement on the old mechanical master switch designs, and even modern systems with electro-mechanical solenoids, because sparking used to occur resulting in erosion on the mechanical to electrical contacts due to the shocks, vibration and high electrical current found in a racecar.

'The devices are fully "potted" in a hard setting resin, which makes them completely resistant to shock, vibration, water and dirt,' adds Armstrong. 'Our systems are also designed to be fitted close to the battery which keeps cabling short, saving further weight and reducing the risk of electrical fires in an accident. Our system also lends itself to having more than one external "kill" button which many drivers, teams and car builders are beginning to appreciate by installing a switch on either side of their cars. This means that, no matter how a car ends up after an accident, a marshal should always have quick and easy access to kill the engine and disconnect the battery.'

NEW SOLUTION

The newest type of battery isolator is Cartek's XS, which is 30 per cent smaller, and 40 per cent lighter. 'The XS still disconnects the battery in the same way, but the engine kill function is different,' says Armstrong. 'With many race and rally cars now being fitted with professional motorsport ECUs or Power Distribution Modules [PDMs], this then allows the XS unit to simply output an "engine stop" signal to these devices rather than disconnecting electrical power. We have therefore been able to reduce the size and weight of this unit by removing the positive power switching "engine kill" circuitry and replace it with a low current signal output which is compatible with most ECUs and PDMs.'

Cartek are now expanding into a wider range of motorsport electronics, including power distribution modules and wireless steering wheel controls, with the latest being the power control panels. 'These are driver switch panels that are very much bespoke and are designed to individual customers requirements and utilise much of the power switching technology.

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Working the problem without a computer

Want to be an engineer? Then you need to master these essential basics...



BY DANNY NOWLAN

About a year a go I wrote an article about hand calculations, and followed it up with another article on mathematical reasoning. Both of these pieces were motivated by what I'm still seeing – to my considerable alarm – among graduate and recently graduated engineers. That is, a lamentable lack of basic skills and the inability to work out a problem without opening a computer.

So here, once again, I will go over what I consider to be the most important hand calculations that you need to master to classify vehicle performance. We are going to cover aerodynamics, weight transfer, damping and quantifying tyre performance. We will be dealing with older material along the way, and for this I make zero apologies. As far as I am concerned these are must-have skills and if you ever worked for me and it turned out that you couldn't do this, I would fire you on the spot.

Before we begin, let me outline again why I consider hand calculations to be such an important skill. The ability to work out something using a calculator a pen and a piece of paper is an essential skill for any engineer. When I did my undergraduate engineering training in the early 1990s, computer aided engineering was just at the peripheries. Yes it is true – I remember Matlab with an MS-DOS interface and I had to use a library to get information as opposed to Googling it. However, this forced us to use our heads to work out a problem and the

These are must-have skills and if you ever worked for me and couldn't do this, I would fire you on the spot

EQUATION 1

$$\Delta L_x = \frac{a_x \cdot m_t \cdot h}{wb}$$

$$\Delta L_y = \frac{a_y \cdot m_t \cdot h}{tm}$$

where:

dL_x = longitudinal load transfer to longitudinal acceleration (N)
dl_y = lateral load transfer to longitudinal acceleration (N)
a_x = longitudinal acceleration in m/s^2
a_y = lateral acceleration in m/s^2
h = centre of gravity height (m)
wb = wheelbase of the car (m)
tm = mean track of the car (m)

EQUATION 2

$$\Delta L_x = \frac{a_x \cdot m_t \cdot h}{wb} = \frac{1*9.8 \cdot 500 \cdot 0.3}{2.7} = 544.4N = 55.6kgf$$

$$\Delta L_y = \frac{a_y \cdot m_t \cdot h}{tm} = \frac{1*9.8 \cdot 500 \cdot 0.3}{1.5} = 980N = 100kgf$$

EQUATION 3 $rcm = rcf + wdr*(rcr - rcf);$

EQUATION 4 $hsm = h - rcm;$

EQUATION 5 $rsf = (krbf + kfa)*ktf/(kfa + krbf + ktf);$

EQUATION 6 $rsr = (kfb + krbr)*ktr/(kfb + krbr + ktr);$

EQUATION 7 $prm = rsf/(rsr + rsf);$

EQUATION 8 $prr = (wdf*rcf + prm*hsm)/h;$

where:

rcm mean roll centre (measured in metres)
rcf front roll centre height (measured in metres)
rcr rear roll centre height (measured in metres)
wdr weight distribution at the rear of the car
wdf weight distribution at the front of the car
h centre of gravity height of the car (measured in metres)
rsf wheel spring rate in roll for the front (Newtons/metre)
rsr wheel spring rate in roll for the rear (Newtons/metre)
ktf front tyre spring rate (Newtons/metre)
ktr rear tyre spring rate (Newtons/metre)
kfb spring rate of the rear coil, acting at the wheel (Newtons/metre)
krbr rear roll bar rate (Newtons/metre)
prm lateral load transfer due through the sprung mass
prr lateral load transfer distribution at the front
tm mean track of the vehicle

EQUATION 9A $$WR = MR^2 \cdot k$$

EQUATION 9B

$$rcm = rcf + wdr \cdot (rcr - rcf) = 0.1 + 0.5*(0.25 - 0.1) = 0.175m$$

$$hsm = h - rcm = 0.5 - 0.175 = 0.325m$$

$$rsf = \frac{(krbf + kfa) \cdot ktf}{kfa + krbf + ktf} = \frac{(50 + 50) \cdot 305}{50 + 50 + 305} = 75.3N/mm$$

$$rsf = \frac{(krbr + kfb) \cdot ktr}{kfb + krbr + ktr} = \frac{(50 + 10) \cdot 305}{50 + 10 + 305} = 50.13N/mm$$

$$prm = \frac{rsf}{rsf + rsr} = \frac{75.3}{75.3 + 50.13} = 0.6$$

$$prr = \frac{wdf * rcf + prm * hsm}{h} = \frac{0.5*0.1 + 0.6*0.325}{0.5} = 0.49$$

Table 1: stockcar parameters

Quantity	Value
cg height	0.5m
Front weight distribution (wdf)	0.5
Front roll centre height	0.1m
Rear roll centre height	0.25m
Mean track	1.7m
Front wheel rate	50 N/mm
Front bar rate	50 N/mm
Rear wheel rate	50 N/mm
Rear bar rate	10 N/mm
Front and rear tyre spring rate	305 N/mm

Table 2: sample values for an aero hand calculation

Item	Quantity
Front motion ratio	0.9
Rear motion ratio	0.8
FL damper/FR damper	10mm/10mm
RL damper/RR damper	15mm/15mm
Front spring	140.1 N/mm (800 lbf/in)
Rear spring	140.1 N/mm (800 lbf/in)
Torque at RPM	200 Nm
Rolling tyre radius	0.28m
a_x	0g
Vx	220km/h
Gear ratio value	3
m_t	500kg
h	0.3m
wb	2.6m

ability to use hand calculation sharpens up your instincts as to what the numbers should look like. This is why it is such an important skill and unfortunately it is being lost.

Let's begin this discussion by looking at weight transfer. The ability to calculate weight transfer for a given lateral and longitudinal acceleration is a key skill and it is presented in **Equation 1**.

So let's crunch some numbers. Let's say we have an F3 car that weighs 500kg, it has a wheel base of 2.7m and a mean track of 1.5m, a centre of gravity height of 0.3m and it is subject to an acceleration of 1g both laterally and longitudinally. Crunching the numbers we see **Equation 2**.

What this tells us is that for a 1g acceleration, the loads longitudinally on the front and rear axles have shifted a delta of 55.6kg and side to side they have changed by 100kg.

Let's now look at the close cousin of weight transfer – calculating lateral load transfer distribution. This is a very important racecar metric, and the procedure to calculate it is shown in **Equations 3-8**.

Classifying the effects of aero is an essential skill. If you can't get your head around it, this probably isn't the profession for you

If I'd been really cruel I could have combined this in one equation. However, the reason I've broken it down into its constituent parts is so you can see how the numbers evolve and you can create an Excel spreadsheet based on this. Also, all the spring rates you use here have to be in wheel

rates as opposed to rates at the damper. The conversion is shown in **Equation 9A**.

Here WR is the wheel rate, MR is the motion ratio expressed on damper/wheel ratio and k is the spring rate at the damper.

Let's walk through an example. Some sample parameters are presented in **Table 1** for a road course stockcar. For brevity, all numbers will be quoted as wheel rates.

Crunching the numbers we see **Equation 9B**.

What this tells us is that 49 per cent of the load transfer of this car occurs across the front axle of this car. This is the mathematical backbone of the so-called magic number.

The next thing we are going to discuss is calculating damping ratios. If you are serious about understanding what your dampers are up to, this is an absolutely essential skill. We have discussed this at length in a number of my articles, but in essence damping ratios are the mathematical language of quantifying damping. This is described in **Equation 10** and **11**.

So, for our example here let's assume a quarter car mass of 125kg, a spring rate of 800lbf/in or 140 N/mm and a damping rate at the damper of 17900 N/m/s. Let's assume the motion ratio is 0.75. Crunching the numbers we see **Equation 12.** Do not underestimate the power of what we are discussing here.

Moving on to hand calculating aero, I realise I have repeated this example on a number of different occasions, and to be honest I don't care! I am still shell-shocked at the number of engineers who can not do this and I'm going to keep repeating this example until people get it right. Quite frankly, classifying the effects of aero is one of the chief jobs of a race/data and assistant engineer. If you can't get your head around this stuff, then you may need to

EQUATION 10

$$\omega_0 = \sqrt{\frac{K_B}{m_B}}$$

EQUATION 11

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B}$$

Here the terms of the equation are:

K_b = wheel rate of the spring (N/m)
C_b = wheel damping rate of the spring (N/m/s)
m_b = mass of the quarter car
ω_0 = natural frequency (rad/s)
ζ = damping ratio

EQUATION 12

$$K_B = MR^2 \cdot SR = 0.75 * 0.75 * 140 * 1000 = 78750$$

$$C_B = MR^2 \cdot C_{DAMP} == 0.75 * 0.75 * 17900 = 10070$$

$$\omega_0 = \sqrt{\frac{K_B}{m_b}} = \sqrt{\frac{78750}{125}} = 25.1 rad/s$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_b} = \frac{10070}{2 * 25.1 * 125} = 1.6$$

EQUATION 13

$$C_L A = \frac{\sum_{i=1}^{4} F_{s_i}}{\frac{1}{2} \cdot \rho \cdot V^2}$$

$$C_D A = \frac{T(rpm) \cdot gr / r_t - m_t a_x}{\frac{1}{2} \cdot \rho \cdot V^2}$$

$$awf = \frac{\sum_{i=1}^{2} F_{s_i} + \frac{m_t a_x h}{wb}}{\sum_{i=1}^{4} F_{s_i}}$$

EQUATION 14

$$FtDownforce = MR_f \cdot k_f \cdot (FL_Damp + FR_Damp)$$
$$= 0.9 * 140.1 * (10 + 10)$$
$$= 2521.8N$$

$$RrDownforce = MR_r \cdot k_r \cdot (RL_Damp + RR_Damp)$$
$$= 0.8 * 140.1 * (15 + 15)$$
$$= 3362.4N$$

$$C_L A = \frac{FtDownforce + RrDownforce}{0.5 * 1.225 * (220/3.6)^2}$$
$$= 2.57$$

$$AeroBal = 100 \cdot \left(\frac{FtDownforce + \frac{mt \cdot g \cdot a_x \cdot h}{wb}}{FtDownforce + RrDownforce} \right)$$

$$= 100 \cdot \left(\frac{2521.8 + \frac{500 \cdot 9.8 \cdot 0 \cdot 0.3}{2.6}}{2521.8 + 3362.4} \right)$$
$$= 42.9\%$$

$$C_D A = \frac{gr * T / r_t - m_t \cdot g \cdot a_x}{0.5 * 1.225 * (220/3.6)^2}$$
$$= \frac{3 * 200 / 0.28 - 550 \cdot 9.8 \cdot 0}{0.5 * 1.225 * (220/3.6)^2}$$
$$= 0.937$$

EQUATION 15

$$L_1 = \frac{wdf \cdot m_t \cdot g}{2} + \frac{awf \cdot C_L \cdot A \cdot \frac{1}{2} \cdot \rho \cdot V^2}{2} + \frac{prr \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_2 = \frac{wdf \cdot m_t \cdot g}{2} + \frac{awf \cdot C_L \cdot A \cdot \frac{1}{2} \cdot \rho \cdot V^2}{2} - \frac{prr \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_3 = \frac{wdr \cdot m_t \cdot g}{2} + \frac{awr \cdot C_L \cdot A \cdot \frac{1}{2} \cdot \rho \cdot V^2}{2} + \frac{(1 - prr) \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_3 = \frac{wdr \cdot m_t \cdot g}{2} + \frac{awr \cdot C_L \cdot A \cdot \frac{1}{2} \cdot \rho \cdot V^2}{2} + \frac{(1 - prr) \cdot m_t \cdot a_y \cdot h}{tm}$$

Here we have:

L_1 - L_4 = tyre loads on tyres 1 to 4 respectively (N)
wdf = weight distribution at the front
wdr = weight distribution at the rear = 1 -wdf
m_t = total car mass
awf = front aero distribution
awr = rear aero distribution = 1- awf
CLA = downforce coefficient times area
h = centre of gravity height (m)
t_m = mean track of the car (m)
ay = lateral acceleration (m/s^2)
prr = lateral load transfer on the front

Table 3	
Item	**Value**
Total mass (mt)	1330kg
CLA	2.4
Front weight distribution (wdf)	0.43 (43% on front axle)
Max ay	2.4g
Aero distribution at the front (awf)	0.43 (43% on front axle)
Max speed at max ay	220km/h
Roll distribution at front	0.5
Mean track (tm)	1.65m
Centre of gravity height	0.335m
Air density (p)	1.225kg/m3

Table 4: max tyre loads	
Tyre Load	**Value**
Front	8590 N
Rear	10052 N

Table 5	
k_a	**Value**
Front	2.72
Rear	2.56

Table 5	
k_b	**Value**
Front	5.82 x 10-5
Rear	4.97 x 10-5

EQUATION 16

$$F_{\max} = k_a \cdot (1 - k_b \cdot L)L$$

$$k_b = \frac{1}{2 \cdot L_{MAX}}$$

EQUATION 17

$$wdf \cdot m_t \cdot a_y \cdot g = k_a((1 - k_b \cdot L_{out})L_{out} + (1 - k_b \cdot L_{in})L_{in})$$

$$L_{OUT} = \frac{wdf}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) + \frac{prr \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

$$L_{IN} = \frac{wdf}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) - \frac{prr \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

EQUATION 18

$$(1 - wdf) \cdot m_t \cdot a_y \cdot g = k_a((1 - k_b \cdot L_{out})L_{out} + (1 - k_b \cdot L_{in})L_{in})$$

$$L_{OUT} = \frac{(1 - wdf)}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) + \frac{(1 - prr) \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

$$L_{IN} = \frac{(1 - wdf)}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) - \frac{(1 - prr) \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

consider whether this is the right profession for you. These are essential, fundamental skills.

The language of aerodynamics is CLA, CDA and aero balance. Mathematically this is expressed in **Equation 13**.

Here, ax is the inline acceleration, T(rpm) is the engine torque in Nm, gr is the gear ratio (in terms of torque multiplication from engine to gearbox) and rt is the rolling radius of the tyre and FSi are the individual spring forces that are in N.

Let's illustrate via example. The best place to take your numbers for hand calculating the downforce is at the end of the longest straight with minimal lateral acceleration. Also zero the dampers on the ground. It will make your life a lot easier. So for this example we will take the numbers as illustrated in **Table 2**.

Here, all motion ratios are Damper on wheel, and the gear ratio is Engine/Wheel velocity. For simplicity, I've omitted bump rubbers. Crunching the numbers we arrive at **Equation 14**.

It's really as simple as that.

Next, a quick primer on performing hand calculation for all four tyre loads of the racecar. This is actually really exciting because it brings together everything we have discussed about load transfer, calculating lateral load transfer and aerodynamics. This is presented in **Equation 14**.

This is an invaluable addition to any setup sheet, because what it does at a moment's notice when you make a setup change is instantly provide what the tyre loads are going to be for a given lateral acceleration and speed. This isn't simulation, but it gives you a good visualisation about what is going on with the car.

However, where this really comes to the fore is being able to 'guesstimate' tyre models. I presented this a number of years ago but given that we are talking about hand calculations it would be a very good idea to review this. To put some numbers to this, let's consider a case study of a FIA GT2 sportscar. The particulars for this particular car are shown in **Table 3**.

Using **Equation 15** we can get a very good idea of what the maximum tyre load should be. Putting the numbers into **Equation 15** and crunching them we arrive at **Table 4**.

I invite the reader to use **Equation 15** to derive those numbers. To get us going for the traction circle radius I'm going to assume a function of load only. The function we are going to fit is that shown **Equation 16**.

Where L is the load of the tyre in N and Fmax represents the traction circle ellipse in N. This curve is a simple parabolic fit to ensure we get max tyre force at the specified peak load and ka represents the initial coefficient of friction with no load applied to the tyre. Going on from our values in **Table 5**, the k_b values for our tyre model are shown.

Now we have this we can estimate the k_a values. By using **Equation 15** and applying a force equilibrium for the front axle, it can be seen in **Equation 17**. Similarly for the rear we see **Equation 18**.

Doing the arithmetic and solving for k_a, you arrive at **Table 6**.

I leave it to you, the reader, to prove these numbers for yourselves using hand calcs.

The key benefit of hand calculations is that being able to perform them will make everything you do on the computer that much easier

However, here are the conditions:

- **You *can't* use a computer**
- **You *can* use a calculator**
- **Use pen and paper and work your way through Equations 15-18**

In summing up, many characteristics of the racecar can be characterised using hand calculations. The examples and equations I have presented in this article are what I consider to be the fundamental skill base of classifying vehicle dynamics. We have discussed load transfer, lateral load transfer, damping ratios, aero calculations, and the calculation of individual tyre loads and using them to estimate a simple tyre model.

While this may not cover everything, if you can hand calc these, you are well on your way to being a very accomplished race and data engineer. The key reason for this is that the ability to do hand calculations will make everything you do on the computer that much easier. It is also the ultimate lie detector because you will be able to tell when the computer is sending you the wrong way.

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Audi's big gamble

The German marque opted early to go for the lowest WEC hybrid category possible for a manufacturer. But will it regret that decision?

BY ANDREW COTTON

Images: XPB

Audi entered the 2014 World Endurance Championship season with something of a handicap, having abandoned for now its MGU-H on the grounds of overall weight, and weight distribution, and opted to contest the 2MJ category back in November 2012. Now, the team believes that it could have achieved the 4MJ category and would have made the decision to enter this class had the option been there, but finds that it has to cede two seconds to the opposition at Le Mans, if all things are equal.

At the FIA World Endurance Championship pre-season test, Toyota launched its TS040 and announced that it would contest the 6MJ category at Le Mans. The reason was that the battery would be too heavy should it go for 8MJ. Almost immediately, Porsche announced that it was still targeting 8MJ, but the next day also opted for 6MJ, which helped with cooling.

Audi's decision looked ill-conceived, although it did argue that by going with a simpler system – one that it has run for the last two years – it may steal the march in reliability terms over its rivals. The engine size was announced as a 4-litre diesel, meaning lower revs and higher torque than last year's 3.7-litre engine.

The decision to abandon the MGU-H had no bearing on the category in which Audi is to run this season. The energy from this system was never going to be stored – it was only to be used to combat turbo lag. To have abandoned it is a big disadvantage for the marque.

DECISIONS, DECISIONS

'First of all, we take such a decision based on simulation,' said Thomas Laudenbach, head of Audi Sport's hybrid division. 'If you see that the difference is small, you go for a car that is not that complex because you have to bear in mind that testing time is limited. The difficult thing is that if you decide a concept at an early stage, and the figures change until they are really fixed, it sometimes puts you in trouble.'

Dropping the MGU-H would have meant the development of a new turbo, but Laudenbach – formerly head of drivetrain at Porsche – says that was not the case. 'It wasn't in the thinking to develop two turbos,' he said. 'When you adopt new technology, if you can afford it you look for a back-up. That is a common procedure. If you have the compressor and turbine and the MGU on one side or in the middle it doesn't matter – from the gas exchange side it is not that different. It is a different part, but you don't have to do two completely separate turbochargers.'

The decision to go for the 2MJ class appears to be a a strange one, considering



Porsche (left) has a 2-litre V4 with battery storage hybrid; Audi (centre) has a 4-litre diesel with flywheel storage; Toyota (right) has a 3.7-litre gasoline engine with supercapacitor storage

that at Le Mans, under the old regulations, the Audi was theoretically able to generate 3.5MJ (seven times 0.5MJ), delivered over 120km/h. However, Audi struggled to harvest a full amount of energy from its two motors at the front axle, and never managed to achieve this target.

'It was an early decision to go for 2MJ, but it was made before I got there,' says Laudenbach. 'That decision was made based on the fact that we had said this was quickest. We have a disadvantage in weight [running a diesel] so we couldn't have got to 8MJ, but 4MJ in 870kg should have been possible. It is not that easy. If you don't have weight to play with, then there might be a decision that from a pure hybrid side you would have gone to four, but you are losing the advantage of weight distribution.'

TAKING THE WHEEL

'You could do a 4MJ system with the flywheel, and I would assume that the decision was taken purely from the weight aspect, and that is important for us because we have a diesel engine which is heavier than a gasoline engine,' adds Laudenbach. 'Weight is the major aspect. From a weight point of view, the flywheel is still the way to go.'

So, what can Audi expect from the regulations? If all the cars are equally developed, it would expect to lose two seconds per lap at Le Mans. However, the Porsche is new and is not expected to be a part of the fight for the win, although on testing form it won't embarrass itself. Toyota is the bigger threat, but the Japanese manufacturer completed more than 25,000km of testing pre-season. So, how will Audi fare against the TS040?

'The disadvantages are clearly that if you have the energy in the electric power, that is additional,' says Laudenbach. 'So if you have, for example, a 400KW engine and a 200KW front axle, you put down the 200KW as soon as you get traction from the tyres – you boost as much as you can. That is the most efficient way to gain lap time. If you were to get the same energy from the ICE, you would only release it over the whole straight. It would be the same energy but would lead to a slower lap time, so that is a disadvantage.

'Even at 6MJ, they have a higher boost figure, which will make it extremely difficult for us to overtake or follow out of the corner. The lap time should be the same, but it could be difficult to overtake. We don't have the room to play based on the concept. We don't know the power figures, but the energy is there. They will be able to boost more out of the corner, and this will be a disadvantage. The figure in the end we don't know, because it is new for everybody.

'At the stage where we started, the 2MJ was the way to go. It was the quickest solution, but things have changed. Everyone has worked on energy strategies, which have a big effect on lap time. When we began, no one was working on the strategies because that was development. So I am not 100 per cent sure that the decision would be the same with the knowledge that we have today.'

It is not only the allowance of energy per lap, but the way that you use it, and how close to the wind you are prepared to sail. The amount of energy allowed is defined by the hybrid restrictions, as well as the Brake Specific Fuel Consumption. Roughly put, this refers to the amount of horsepower produced by a gram of fuel. Exceed your stated limit by more than two per cent and you could face exclusion from the race.

'If you exceed your megajoule per lap you get a penalty, so everyone will be extremely careful. On the other hand, if you leave 1 per cent unused, that is lost speed, and that will be the challenge,' says Laudenbach. 'Are you in a position every lap to use what they give to you, or do you have to be on the safe side? Are you really in a position to use everything that they give to you? From a control side of view, this is so challenging. If you take a professional driver in a racecar, even without traffic, the fuel consumption varies. Drivers, weather and track conditions all play a part, and this is really challenging. Everyone is asking about the system. If we simulate something, we simulate with a perfect lap, but what people underestimate is that you have your car, but are you in a position to use it in the best possible way? This has changed. The job of the driver is going to change.'

"Even at 6MJ, Toyota has a higher boost figure, which will make it very difficult for us to overtake or follow out of the corner"

Fuel consumption between drivers can vary wildly, simply due to the way that they drive. However, what is also going to be important this year is traffic management. Low corner speed means harder acceleration, and more energy consumed. So, drivers will have to corner fast, and – particularly in slow corners – rely on mechanical grip. Watching out for slower cars will also have a large effect on fuel consumption, overtaking them in the right place, for example without losing too much time.

This is racing, but not as we know it. Audi's decision could be a liability, but there are so many unknowns in this new era of racing that they could, after all, have made a smart move.



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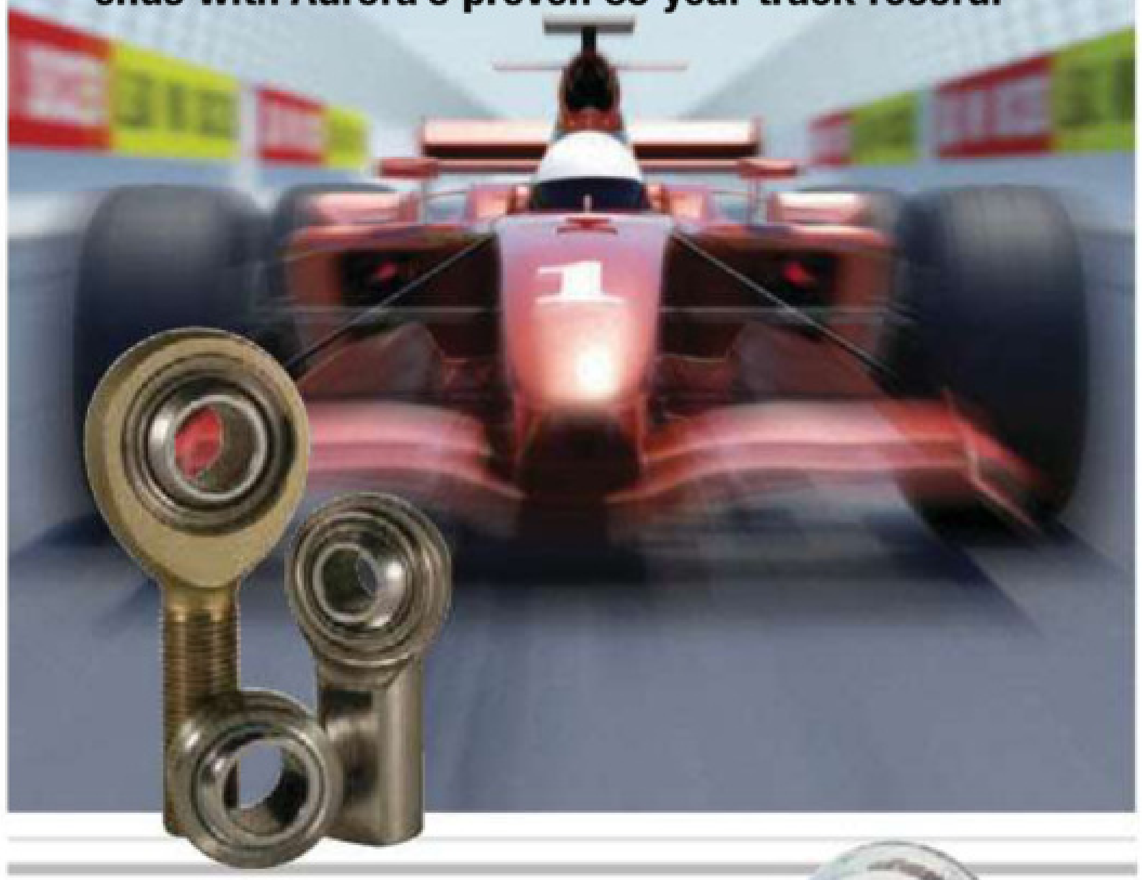
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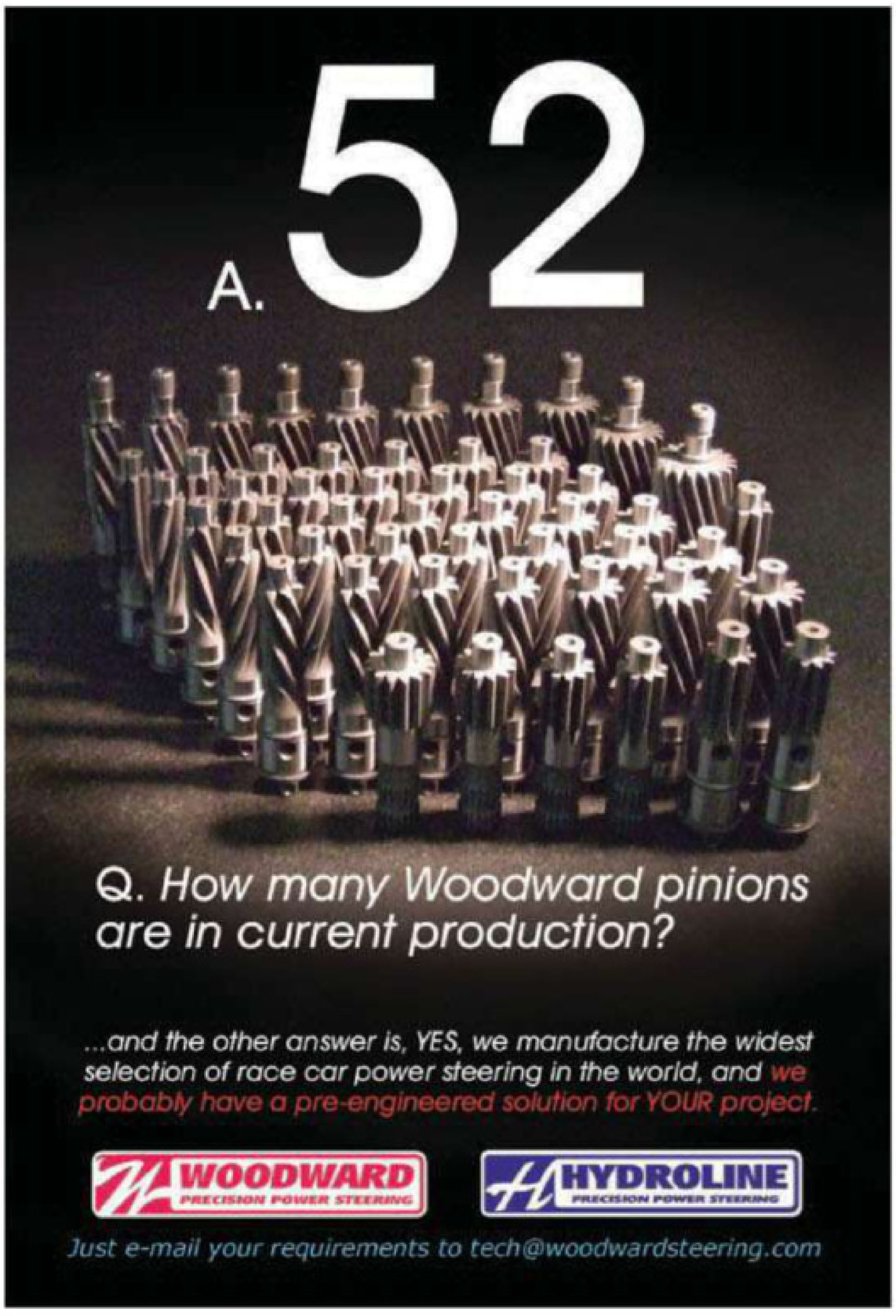
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Haas entry confirmed for Formula 1 2015 as second team waits in wings

Gene Haas has been granted entry into the F1 World Championship in 2015 following the FIA World Motorsport Council (WMSC) meeting in April.

The American, who was on the periphery of the aborted USF1 team in 2010, is one of two teams mentioned in the WMSC meeting in Marrakech, the other being Forza Rossa, headed by Colin Kolles, formerly boss of the Force India and HRT teams.

The FIA made it known in December that it was inviting tenders from teams wishing to compete in F1. 'The FIA has launched a selection procedure for an additional F1 team(s), and applications of a high standard have been received,' said the statement from the FIA following the WMSC meeting. 'In close consultation with the CRH, the FIA has accepted the candidature of Haas Formula LLC and are in the process of conducting further investigations for Forza Rossa.'



XPB

The Haas name is big in NASCAR and could soon be seen in Formula 1

Colles is believed to have reached a funding agreement with a Monaco-based Romanian consortium. Zoran Stefanovic, of the stillborn Stefan GP venture, has also been mentioned in connection with a new F1 effort.

Haas was always a front-runner for a place on the grid as he has a war chest of some $1bn to pump into an F1 project. Haas initially made his fortune with Haas Automation, the well-known CNC machine tool manufacturer. He went on to set-up the NASCAR operation CNC Racing, which later morphed into Stewart-Haas Racing. Haas also owns the impressive Windshear rolling road wind tunnel in Concord, North Carolina, a facility that has already been used for F1 development.

Ecclestone said: 'They [Haas] will be accepted. We have also accepted another team as well. Whether they will make it or not is another story.'

Meanwhile, it's been confirmed that Marussia is no longer owned by the Russian sportscar firm but by an entity called Marussia Communications, which has team founder John Booth and current CEO Graeme Lowdon listed among its directors.

A spokesperson for the Marussia team said there has been no link between it and the car company, which has now ceased operating.

GE sponsorship deal helps Caterham F1 to prosper

Caterham has seen its profits boosted on the back of its lucrative 2012 GE sponsorship deal, while its turnover rose by a cool 117 per cent in the same year.

The UK-based, Malaysian-owned team is estimated to receive $15m every year from US multinational conglomerate GE, which helped bring in £46.7m in 2012, the first year of the sponsorship deal. This figure was £26m up on the £21m it turned over in 2011.

These figures come from the recently released 2012 financial statement for Caterham Sports, as the team is commercially now known, which shows an operating profit of £4.8m for the team – £3.2m up on the previous year.

Caterham also took out a £5.3m loan from a Malaysian bank in 2012, secured on its assets – such as the Leafield factory – part of which was invested in plant and machinery (to the tune of £1.7m) and land and buildings (£6.6m).

While these results will be welcome, the team has not started the 2014 F1 season well – it's actually till to score a point after over four years of trying – and Caterham boss Tony Fernandes made it clear earlier this year that if there was no improvement in form then he could pull the plug on the F1 effort. 'If we're at the back I don't think I'm going to carry on. Nothing is set in stone but after five years with no points there is a limit to one's patience, money, motivation, etc, so it's an important year,' he said, prior to the launch of this year's challenger, the CT05.

It's been estimated that Caterham F1's owners, which include Fernandes – a man who made his fortune in the airline business – have pumped some £132m into the team since 2010, thought to be the worst point-per-pound return in F1 history.

Meanwhile, the wider Caterham group's much-vaunted relationship with Renault has been brought into doubt, with media reports suggesting the collaborative Alpine road car project has hit the rocks, although both Renault and Caterham would not confirm or deny this at the time of writing.



XPB

Despite failing to score any points in four F1 seasons, Caterham's turnover has risen 117 per cent in the last year

Peugeot looks to South American market with Dakar assault

French car-maker Peugeot will be hoping that its return to the Dakar rally will boost its South American sales as it works to find new markets outside its European heartland.

Peugeot has confirmed it will enter the rally raid classic next year, 25 years after it last competed on the event, with a car based on its 2008 crossover model. The first tests for the new car, to be called the 2008 DKR, are scheduled for the second half of this year.

Dakar, which despite the name is now held in South America due to political unrest in north-west Africa, has previously been a happy hunting ground for Peugeot, the company winning the event for four consecutive years between 1987 and 1990 with its 205 T16 and then 405 T16 Grand Raid cars.

Its 2015 assault will be backed by Red Bull and Total, in a continuation of the partnership that saw Peugeot successfully return to Pikes Peak - where it shattered the course record - last year.

The 2015 Dakar will run over a 10,000km route through Argentina, Bolivia and Chile, which should suit Peugeot's long-term aim of bolstering its presence in South America. Last year Maxime Picat, Peugeot Brand CEO, said it was focusing on selling more cars in South America, where it trails its rivals Fiat, VW and Ford in key markets.

The company has also said that it aims to reduce its reliance on the European market, which was particularly hard hit by the downturn, and where Peugeot has traditionally found two-thirds of its business. In 2012 Peugeot posted a staggering net loss of €5bn, though this decreased to a net loss of €2.3bn in 2013.



Peugeot returned to Pikes Peak last year - now it's making a Dakar comeback

Driving one of the 2008 DKRs will be Carlos Sainz, who won the Dakar in 2010. He said: 'In motorsport, you can never take anything for granted. The level of competition on the Dakar today is very high and it's an event that really isn't easy to win. We won't have much time before our first attempt, either, but I feel confident because the team is clearly extremely motivated and we will work hard to try to win.'

Williams sells on Hybrid Power arm to GKN for £8m

Global engineering group GKN has snapped up Williams Hybrid Power, the company that applies the technology developed for the F1 team's flywheel energy recovery system.

Williams sold the company, which was a subsidy of Williams Grand Prix Engineering, for just £8m ($13m), but it tells us that it expects to receive further payments based on future sales and licences. Williams will also receive a 3.5 per cent share of sales over the next five years, and 1.5 per cent for the five years following.

The company, which Williams originally bought in 2010 for £1.5m, will now be known as GKN Hybrid Power. The original company developed a flywheel energy recovery system for the 2009 Williams F1 car, although it never saw action, but under Williams' control it has since gone on to develop similar technology for Audi in LMP1 and also for mass transport projects.

Williams says that the technology offers fuel savings and emissions reductions of up to 30 per cent, by harvesting the energy that is normally lost as heat when braking and then turning it into additional power.

GKN aims to develop the public transport projects - the stop-start nature of buses and trams makes them ideal for this sort of technology, it says - and hopes to launch UK-wide by the end of this year.

Mike O'Driscoll, group CEO of Williams, said: 'The Williams Hybrid Power business has been developed very successfully over the last few years, and is now at the point of broader market commercialisation. GKN has the resources and expertise to fully realise the enormous potential of the motorsport-proven flywheel technology.'

However, O'Driscoll stressed that this sell-off does not mean the end for the company's successful diversification projects. 'Williams Advanced Engineering continues to focus on delivering energy-efficient solutions through incubating and developing new technologies that primarily originate within our Formula 1 operations, to a broad range of industry sectors including automotive, aerospace, and energy,' he said.

SEEN: STRAKKA DOME S103 LMP2

The new Strakka Dome LMP car, a joint effort between Strakka Racing and Japanese racecar producer Dome, has broken cover. The car missed the WEC pre-season test, and the opening round at Silverstone. The car, which is powered by Nissan's VK45 4.5-litre V8, is eligible for the WEC, ELMS, Asian Le Mans Series, and the TUSCC. Strakka's Karl Patman said: 'The design engineers at Dome have done an incredible job to produce a beautifully engineered car with real attention to detail.' He added that Dome brings 'incredible resources' to the partnership, particularly its wind tunnel and CFD capability.



NASCAR working on new engine formula for Sprint Cup

Changes to Sprint Cup's powerplant are being considered, which could mean a reduction in power. NASCAR is working with manufacturers to arrive at a new formula that suits all involved.

Brian France, NASCAR chairman and CEO, told a radio show that the aim of any future engine changes in the Sprint Cup were to control costs and improve the racing, but he also said that the engine change would be 'significant'. France went on to say he was unsure when the changes would come into force.



XPB

NASCAR Sprint Cup engines currently develop 850bhp

NASCAR Sprint Cup engines currently develop 850bhp, and they are built by five companies, each working for specific manufacturers: Roush-Yates Engines (Ford), Triad Racing Technologies, Toyota Racing Development (Toyota), and Earnhardt Childress Racing and Hendrick Motorsports (Chevrolet).

The manufacturers have also admitted they have been in talks with the governing body over future engine changes. They are now going forward with the process in much the same way as NASCAR and the car-makers introduced the current Gen-6 chassis concept. It's been widely rumoured that the changes will mean a drop in power, while it's also been suggested NASCAR could switch to a V6.

However, the car-makers are giving little away. Jim Campbell, US vice-president for Chevrolet Performance Vehicles and Motorsports, said: 'We're using a very collaborative approach between the manufacturers and NASCAR from the sanctioning body's perspective on really discussing what are the options and what are the ideas. In the end, depending on where that ends up, it will impact how much work happens at the manufacturer versus the teams. The key is that we keep the racing exciting, and then we make every resource we apply to the engines and the engine builds go as far possible. That's really the key.'

David Wilson, president and general manager of Toyota Racing Development, agreed: 'I think the focus right now really is about the process and the fact that – again, with some clear objectives in mind – NASCAR is talking to their stakeholders, not only us as manufacturers, but all of the engine builders that are party to this process.'

Panther misses first race as sponsorship row rages on

Panther Racing's sponsorship problems hit home as the IndyCar season kicked off in St Petersburg, Florida, with the team failing to make the opening race.

The team had already endured a difficult off-season with the loss of its primary sponsor, the US National Guard, to rival team Rahal Letterman Lanigan (RLL).

Panther has also been excluded from the list of teams eligible for the Leaders' Circle bonus prize money initiative, largely because team boss John Barnes had said he could not guarantee that the team would be at every race.

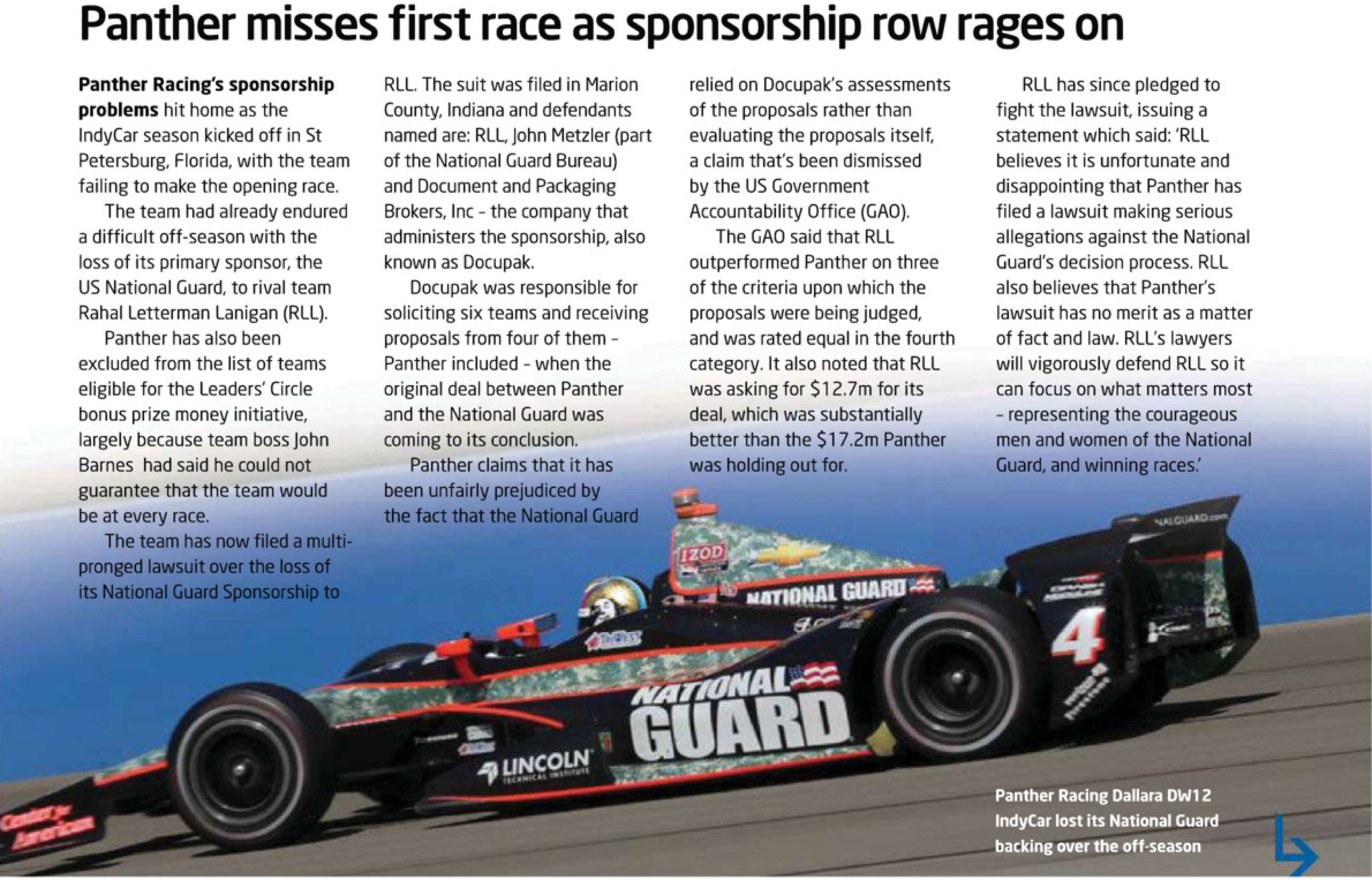
The team has now filed a multi-pronged lawsuit over the loss of its National Guard Sponsorship to RLL. The suit was filed in Marion County, Indiana and defendants named are: RLL, John Metzler (part of the National Guard Bureau) and Document and Packaging Brokers, Inc – the company that administers the sponsorship, also known as Docupak.

Docupak was responsible for soliciting six teams and receiving proposals from four of them – Panther included – when the original deal between Panther and the National Guard was coming to its conclusion.

Panther claims that it has been unfairly prejudiced by the fact that the National Guard relied on Docupak's assessments of the proposals rather than evaluating the proposals itself, a claim that's been dismissed by the US Government Accountability Office (GAO).

The GAO said that RLL outperformed Panther on three of the criteria upon which the proposals were being judged, and was rated equal in the fourth category. It also noted that RLL was asking for $12.7m for its deal, which was substantially better than the $17.2m Panther was holding out for.

RLL has since pledged to fight the lawsuit, issuing a statement which said: 'RLL believes it is unfortunate and disappointing that Panther has filed a lawsuit making serious allegations against the National Guard's decision process. RLL also believes that Panther's lawsuit has no merit as a matter of fact and law. RLL's lawyers will vigorously defend RLL so it can focus on what matters most – representing the courageous men and women of the National Guard, and winning races.'



Panther Racing Dallara DW12 IndyCar lost its National Guard backing over the off-season

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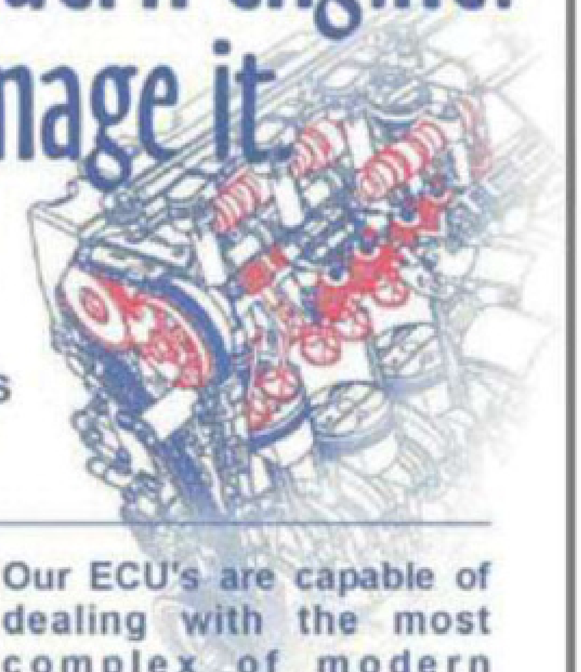
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Silverstone writes to UK PM over Welsh track funding

A war of words has emerged between Silverstone and the proposed Circuit of Wales development after the former wrote to UK prime minister David Cameron to query whether it's legal for the Ebbw Vale circuit to receive Government funding.

Silverstone is claiming that any Government aid given to the circuit would amount to illegal state backing, as it is unlawful under European law for a business to gain a competitive advantage through this kind of funding.



The proposed Circuit of Wales development in Ebbw Vale

The state aid in question would be a mooted £50m from the Welsh and UK Governments, which would actually make up a small portion of the £280m needed for the project – an infrastructure venture with the aim of kickstarting the moribund local economy.

It seems likely that Silverstone has become involved in this because Circuit of Wales is currently in talks with Dorna (the promoter of MotoGP) about hosting the British Grand Prix for bikes, which is currently run at the Northamptonshire venue.

Michael Carrick, who is behind the Ebbw Vale development though his Heads of the Valleys Development Company, has previously told this publication that his project needs a crowd-pulling event if it's to be successful. Because the costs of staging F1 has ruled it out from the start, Circuit of Wales has long seen MotoGP is its best bet.

If legal action is taken by the European Commission, it could hold up the project by at least two years, an infrastructure expert tells us.

A Silverstone statement said: 'Silverstone has no objection to competition between UK circuits, but it has to be a level playing field.

'Silverstone has been advised that an injection of funds by the Welsh and/or UK Governments to the Circuit of Wales project could also amount to illegal state aid, as a transfer of state resources would give Circuit of Wales an economic and selective advantage over other circuits (and developments).'

However, Carrick disputes this: 'We are disappointed to have heard of the content of this letter. It sounds like Silverstone is resistant to investment within the automotive sector which is vital to its continued growth and development in the UK. The suggestion of "illegal state aid" made by Silverstone also highlights they do not understand the basic process of applying for state funding of this nature.'

Zytek founder offloads Automotive business

Bill Gibson has sold off his remaining shares in Zytek Automotive in order to concentrate on the motorsport and precision engineering side of the business.

Zytek founder Gibson, who still wholly owns Repton, UK-based Zytek Engineering, has sold Zytek Automotive to German engineering giant Continental Engineering Services (CES) for an undisclosed fee. CES already owned 50 per cent of the company, which it purchased in 2008, with Gibson holding on to half of the shares until now.

Gibson said the reason for the sale was to allow him to concentrate more on Zytek's core motorsport business. 'Zytek Engineering is so busy with motorsport and precision engineering projects that I felt the need to concentrate my time and efforts on improving and expanding the facilities and business at Repton.

'Motorsport has always been a core activity of Zytek, and I intend to ensure that we remain at the forefront of the motorsport world, in both current and new technologies,' Gibson added.

Zytek Automotive employs a workforce of some 150 at its headquarters in Fradley near Birmingham, UK and is said to have particularly well-developed expertise in all areas of automotive technology and vehicle engineering.



Zytek's Fradley factory is now in the hands of engineering giant CES

Dunlop launches RaceCar Challenge vision of the future



Dunlop has launched the RaceCar Challenge that invites participants to give their thoughts on motor racing's future. After 125 years of producing tyres, the company says it now wants to look another 125 years into the future.

The driving force of the Challenge is the question: what will the drivetrains, aero, tyre and material requirements be to meet our transport and racing needs in the future?

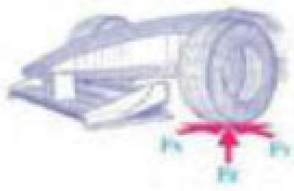
Dunlop will select the best suggestions for each category among all the entries, and a leading designer will combine them to bring the racecar of the future to life in a unique and innovative design.

Already, Dunlop has engaged with Green GT on the drivetrain, and with BAE Sytems and Imperial College of London for the aerodynamics. Dunlop will supply the tyres.

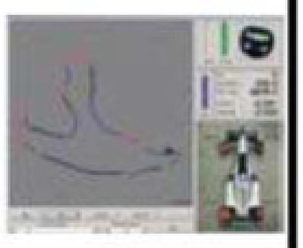
The design announcement is due to come in July, when the final car will be unveiled. The competition will take place via the firm's social media sites.

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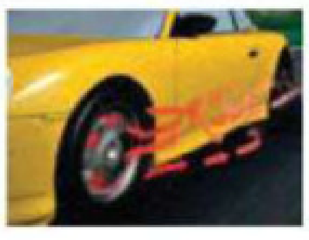
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INTERVIEW - MARTIN ANAYI

Show business

The man behind the new FIA World Rallycross Championship tells us why he believes the sport is set for a bright future



New manufacturers are on the way to World Rallycross - and Anaya claims more are waiting in the wings

If there was ever a motorsport that was right for the instant-fix age in which we live, it has to be rallycross. Short and sharp races, spectacular action, powerful yet identifiable cars, and now even big name drivers – rallycross ticks all the boxes. On top of that it's a sport that was made for TV – literally, in fact. When you add one of the world's best events promoters into the mix, and FIA world championship status, then it's easy to see why rallycross is very much on the up.

Rallycross was conceived in the UK in 1967 as a way to fill short TV slots on Saturday afternoons, but it never really grew too far beyond those original modest ambitions. Then two things happened: Global Rallycross in the US grew out of the action-sports X Games phenomenon, while at around the same time International Management Group (IMG) started to look for a way it could repeat the success it had had with motorcycles – with the FIM Speedway World Championships – in the four-wheeled arena.



COVERING THE BASES

IMG is largely known in motorsport circles for its driver management deals – Jackie Stewart was one of its clients for years – but these days it is actually far more focused on events. Martin Anayi, a former professional rugby player and a lawyer by trade, joined the organisation eight years ago. Now he heads up IMG's FIA World Rallycross Championship.

'There were enough influential people within the sport who wanted us to come in,' explained Anayi. 'That meant it was worth our time to invest in it, and thankfully we did, because I think that in a short period of time it has not just shown great potential, but it is also already showing a great output.'

But just what does IMG bring to the World RX party? 'We have a massive breadth of experience across different sports, but largely we're an events business, whether that's motorsport, mass participation sports, golf, tennis, or fashion events. So we understand how to run an event, and that's important. But another key asset is that we produce the pictures, the live TV, and we distribute them. So we have a full house of areas of expertise.'

Its expertise certainly seems to be effective, and such has been the success of IMG's push to sell the sport that it's become a world championship a year earlier than originally planned – last year it ran as the European Championship. Its calendar now includes nine rounds in Europe, then events in Argentina, Turkey and Canada. The latter is at Trois-Rivières, with Jacques Villeneuve in the field, at the very place where his father Gilles made his name in 1976 when it was a Formula Atlantic race, just one of a number of PR coups the IMG team has pulled off.

But with so much of the calendar in the sport's European heartland, is this truly a world championship? 'For an FIA world championship you have to be on three continents. Originally when I was looking at it – and being a lawyer – I was thinking North Africa, which is what World Touring Car does with Morocco, and then the other side of the Bosporus is Asia, in Turkey. But, in reality – and I think Jean Todt shares this view – to be a world championship you really need to be in North America and South America. For us just ticking an Asian box in Turkey is OK, but to go to Argentina and Canada really makes it a bona fide world championship.'

"To go to Argentina and Canada really makes World Rallycross a bona fide world championship"

COMPETITIVE SPIRIT

One place World RX doesn't go right now is the USA, which is of course the home of the Global Rallycross Championship (GRC), itself doing rather well. Which begs the question, isn't 'global' in direct competition with 'world'?

'I think they're doing a great job, actually,' Anayi says. 'But I think they've had to react to the X Games retracting back into the US. Part of their expansion plan as Global Rallycross was to move with the X Games. They were in Barcelona and Munich, they were in Brazil last year, but because the X Games went back into just doing two events in the US, that plan has had to be rethought. So I think they're a very strong national championship, whether they should be called Global, or not, is not for me to decide.'

The calendar for GRC bears up Anayi's views (it has just



one event outside the US), but World RX being the only truly global rallycross series comes with its own headaches, such as transporting cars across the world. This year IMG is able to keep the expenditure down by sending the cars by sea, but for next year Anayi says it will need to fly the cars and kit to some events, if its plans to expand come to fruition – there's talk of new rounds in Russia, south-east Asia and in the Middle East.

COST CONTROL

IMG actually pays these travel costs, which helps to keep budgets relatively low for the teams. Anayi says that teams spend anywhere between £300,000 and £700,000 – including an entry fee of £50,000 – and this is something he is keen to keep in check, chiefly through a tight policing of the technical regulations. 'That's how you can keep control of costs,' he says. 'Are we going to be a production-based race series? Yes. But we're not going to become some weird silhouette series that will have no relevance at all to a manufacturer.'

Of course, the question is: can the costs be controlled with the arrival of those manufacturers – such as Peugeot (which has teamed up with Hansen Motorsport) Ford (tied to OlsbergsMSE) and VW (Marklund)? 'I guess that's always a worry, but the nice thing is that they're supporting a team, and they're not coming in as a works entry. So they are not going to be chucking WRC-type money at this.'

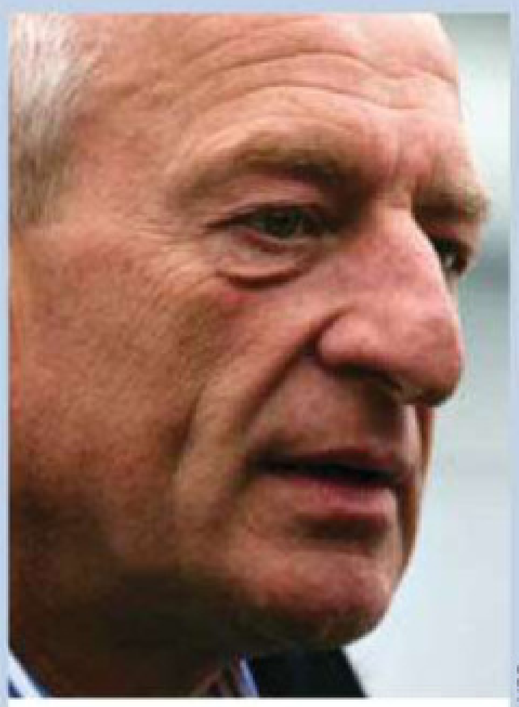
Anayi also claims that other manufacturers are waiting in the wings, although he would not be drawn on who they are, to take on VW and the like in the top 600bhp 4WD Supercar class. Yet this is not just about the fire-breathing Supercars and IMG has also taken the World RX supporting classes such as Super 1600 under its wing, while it has also devised a new spec formula – RX Lites. 'We're not taking a short-term view on this. What the television broadcasters want is the Supercar, no doubt about that, because it's one of the most spectacular things on four wheels. But what you need to do is generate a whole host of people coming through, and that's what we do through Super 1600 and now RX Lites.'

The fact that IMG is looking after and bringing on new feeder categories suggests it really is in this for the long term – but can it really transform rallycross into a bigger, better sport? 'I think this year will be transformative in terms of the TV, and there are lots of things to add over the coming years. I think the future's really great for us because we are not limited by the past. We're looking at it with fresh eyes, and we're asking people what motorsports they want to see. Hopefully we can deliver it.'

One thing is for certain – in its 47-year history, the often muddy world of rallycross has never looked quite so polished, while its future has never seemed quite so bright.

Mike Breslin

RACE MOVES



XPB

Dr Thomas Betzler (above), deputy chairman of ITR, the company behind the DTM, has died at the age of 65. An ex-race driver who drove in the forerunner of the DTM in the 1970s, Betzler was also a lawyer, responsible for much of the legal work within ITR. He had been a member of the ITR board since the company was established in 1986, and its deputy chairman since 2003.

IndyCar race engineer **Tino Belli** has joined the series' technical group as its director of aerodynamic development. In this newly created role, Belli – who was most recently technical director at Panther Racing – will oversee the implementation of the Honda and Chevrolet aero kits, among other duties. Belli's long race engineering career has included 14 years at Andretti Autosport, plus spells at F1 teams March and Larousse.

It's been reported that **Ron Walker**, the chairman of the Melbourne-based Australian Grand Prix, is to step down after next year's race. Walker, who turns 75 this year and has been chairman since the Albert Park race's inception in 1996, has already selected his replacement in the post – **John Harnden**, the current Cricket World Cup chairman.

Colin Hilton, the former chief executive of the MSA, has received the Prince Michael Award of Merit from the organisation. **Ronnie Trouton**, who is well known for his work in motorsport in Northern Ireland, also received the award.

There's been a change at the top of the management team for the Russian Grand Prix, to be run for the first time in October of this year. **Sergey Vorobyev**, who was formerly deputy director of the department responsible for the Sochi race, now takes overall charge. **Oleg Zabar**, who Vorobyev replaces in the role, has moved on to oversee other projects.

Graham Warner, who founded well-known race and rally team Chequered Flag, has died at the age of 84. Warner setup his Chequered Flag garage in 1956, before going on to compete as a driver with some success. His team went on to run cars in many formulae, including unsuccessful attempts to qualify for the 1974 US and Canadian Grands Prix with a Brabham BT42. Chequered Flag went on to become famous for its work with Lancia Stratos rally cars.

Seven **Caterham** F1 staff were hospitalised after a fire at the team's Leafield base shortly before the Bahrain Grand Prix. All were taken to hospital for smoke inhalation, but six were soon released, with one kept in for observation – Caterham has said there were no serious injuries. It's believed the fire started in a machine shop, but Caterham says: 'the machinery was operational again within hours'.

Allan McNish is to take on a new role with Audi Sport. McNish, who retired from driving at the start of this year, will principally act as a link between the drivers and the engineering staff. The Scotsman will be attending seven of this season's eight WEC rounds.

Noise measurement and control expert **Andy Watson** has received a Lifetime Achievement Award from the Motor Sport Association (MSA), the UK governing body. Watson has advised the MSA on noise issues for over 30 years and this award is said to be the organisation's highest accolade.

David Winstanley, the motorsport film-maker who died earlier this year, is to be remembered with an annual award in the RAC (Roger Albert Clark) Rally Championship, a well-supported historic series in the UK. The award will be presented to the driver who provides the best televised moment during the season.

IndyCar race director **Beaux Barfield** no longer enjoys sole jurisdiction when it comes to driver penalty decisions. These will now being taken by a panel of three stewards, although Barfield has taken on the role of senior steward.

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McLaren and Red Bull in contract dispute

A legal spat has erupted between the Red Bull and McLaren Formula 1 teams after the former announced that Dan Fallows had started work as its new head of aerodynamics.

Red Bull announced the appointment of Fallows a couple of days after the Bahrain Grand Prix in mid-April, placing him in the position vacated by Peter Prodromou – who has signed for McLaren but is now on contractually-enforced gardening leave until he can take up his post at the start of 2015.

However, following the announcement McLaren was quick to step in to say that Fallows, who previously worked at Red Bull but left last year, was actually under contract at Woking.

In fact, McLaren had mentioned Fallows coming to the team at its pre-season launch, naming him along with Prodromou and ex-Lotus men Ettore Griffini and Ciaron Pilbeam as it highlighted its 2014 recruitment drive.

McLaren has now made it clear that it believed Fallows was under contract and it has said the matter is now in the hands of its legal team.

Commenting on the situation Eric Boullier, McLaren's racing director, said: 'Fallows has a legally binding contract with McLaren and the matter is now in the hands of our lawyers.'

Before leaving the Milton Keynes-based team last year he was a team leader in the aerodynamics division.

CAUGHT

Red Bull has been the first F1 team to be hit with a stringent new penalty for an unsafe release after a pit stop. This was a result of Daniel Ricciardo's RB10 losing an unsecured wheel in the Sepang pitlane during the Malaysian Grand Prix. The Australian received a 10-place grid penalty for the following race, Bahrain, on top of a stop-go penalty during the Malaysian race.

Chris Rice, the crew chief on the No 99 RAB Racing car in the NASCAR Nationwide Series, has been fined $10,000 and placed on probation until the end of the year after the Toyota Camry he tends lost a weight during the Bristol Motor Speedway round of the series. Car chief John Guerra was also placed on probation until December 31.
FINE: $10,000

Kevin Starland, the crew chief on the No 39 RSS Racing car in the NASCAR Nationwide Series, has been fined $10,000 and placed on probation until the end of the year after the Chevrolet he looks after was found to be in excess of the rear body height limit at the Auto Club Speedway, Fontana, round of the championship. Car chief Timothy Brown was also placed on NASCAR probation until December 31.
FINE: $10,000

The crew chief for the No 31 Chevrolet in the NASCAR Camping World Truck Series, Michael Shelton, has been fined $10,000 and placed on probation until the end of the year after the Turner Scott Motorsports truck was found to be running with offset front hubs at the Martinsville round of the series.
FINE: $10,000

Also found to be running with offset front hubs at Martinsville (see above) was the No 54 Kyle Busch Motorsports Toyota truck. Crew chief Jerry Baxter was fined $10,000 and placed on NASCAR probation until December 31.
FINE: $10,000

A third truck was also found to be running with offset front hubs at Martinsville, the No 98 ThorSport Racing Toyota. Its crew chief, Gene Wachtel, was handed the same fine ($10,000) and put on probation until the end of the year.
FINE: $10,000

RACE MOVES

Lynda Petty, wife of seven-time NASCAR champion **Richard Petty**, died at the family's home in Level Cross, North Carolina in March. She was 72, and had been married to Richard for over half a century. **Brian France**, NASCAR chairman and CEO, said: 'Through the years, Lynda became an integral part of the NASCAR landscape. We have lost a true friend, who will be missed each and every day.'

Audi WEC race engineer **Leena Gade**, who has tended two of Audi's Le Mans winning entries in recent years, was on the five-member judging panel of the UK's National Science and Engineering Competition recently. She helped to select the best engineering ideas entered by 400 students between the ages of 11 and 18.

Performance Instruction and Training, a facility based in Mooresville facility to train potential NASCAR pit crew members, has received a licence from the North Carolina Board of Community Colleges. The facility was setup by Red Horse Racing truck team owner **Tom DeLoach** and former crew chief **Jeff Hammond**.

Lisa Noble is now the president and chief executive of the Sports Car Club of America, a position she's held on an interim basis since October of last year. Noble, who has raced in Formula Vee, was voted on to the SCCA board of directors in 2008.

The Society of Motor Manufacturers and Traders (SMMT, the UK trade association) has appointed **Peter Lawton** as its aftermarket development manager. Lawton,



XPB

Former Mercedes motorsport boss **Norbert Haug** (above) has signed on with German TV company ARD to provide expert analysis for its DTM coverage and other motorsport events this year. Haug, who was a motorsport journalist before he turned to management, left Mercedes in 2012.

who has 15 years' experience as an automotive journalist, replaces **Wendy Williamson** in the role.

Red Bull-backer Infiniti has named **Francois Bancon** as its new vice-president, product strategy. Bancon, who has more than 25 years of experience in the automotive industry, the last 15 with Nissan, will be based at the Nissan luxury arm's global HQ in Hong Kong.

Francois Goupil de Bouille is now Infiniti's vice president, Europe, Middle East and Africa (EMEA). He takes over from **Fintan Knight**, who has now left the company. Goupil de Bouille, who was previously vice president of global operations, will be based at Infiniti's EMEA headquarters in Rolle, Switzerland. He will report to Infiniti president **Johan de Nysschen**.

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 send an email with all the relevant information to Mike Breslin at bresmedia@hotmail.com

BRIEFLY

Bank commits to F1

Spanish bank Santander intends to remain in Formula 1 for the next decade. Emilio Botín, the banking group's executive chairman, has told the Spanish press that it is committed to the sport for the long term.

Selling time

World Rally Championship timing supplier Stage One Technology has sold its cutting-edge timing equipment to Swedish firm Racetiming.

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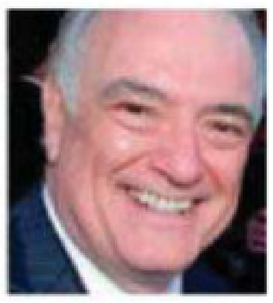
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Making all the right noises

Opportunities abound during economic recovery, with contracts up for grabs

Great news that the Haas USA F1 team has won a licence to be on the grid from 2016, and we expect more to be announced soon, one being a European project – all good news for suppliers. Each of these will operate on a budget between $60m and $80m and will start from scratch, just the boost needed to keep talented people busy in 2015 and beyond.

The demand for motorsport engineering remains at unprecedented levels, with problems arising from lack of machining capability, raw materials and the most important commodity – top class people. UK companies have started a drive to recruit from eastern Europe, with Poland the prime target. Highly-skilled, hard-working people, with good English skills, will be a welcome boost to fill technician and machining jobs.

Our motorsport leaders really puzzle me. What a time to whinge when both Formula 1 and Le Mans are showcasing to the world the energy efficiency expertise of motorsport companies. I don't care about noise as this will be fixed later if necessary, but from the endless discussion – at last – the brilliant skills and innovation of our motorsport engineers has caught media attention.

Why on Earth has the FIA not stepped forward more convincingly to promote and claim credit for these radical changes in motorsport regulations? These not only silence some criticism, but show vision and leadership helping motorsport engineering companies to meet demand from tomorrow's world of transport and the environment. Their regulation changes brought this about. For whatever reason, the F1 commercial rights holder doesn't seem interested in promoting this tremendous change, and neither does Ferrari's Luca de Montezemolo, but would his negativity change if Ferrari had the winning solution? In spite of their unbalanced criticism, the FIA should grasp this chance to catch the world's attention and celebrate the enormous gains made in energy efficiency in these global race series, F1 and Le Mans. This would bring business to the motorsport suppliers, on whom the FIA and the sport has learned to rely, to deliver their solutions when needed. We must catch the eye and budgets of the industry and others so they know ours is the one to deliver low carbon engineering solutions – and fast.

SELF-PROMOTION

The motorsport industry also needs to come together to promote itself more strongly to these potential buying sectors. A few years ago, the MIA launched its Motorsport to Automotive and Motorsport to Defence initiatives to capture business for its members. These have been enormously successful, with thousands of automotive engineers being exposed to the engineering capability of motorsport suppliers for the first time. It seems strange that the MIA is alone in championing the industry behind the sport. The industry, together with MIA members, should share this work with the FIA, and work more closely together on similar future initiatives. The FIA has the power to attract leading business executives to the valuable asset that is their motorsport industry and bring in more investment and business. Watch this space – I hope to demonstrate soon a closer relationship between our governing body and our industry, from which members of both will benefit in the years ahead.

As national economies recover, so exporting is back in political fashion, the balance of trade between import and export being critical to countries coming out of the downturn. Export opportunities abound to make up lost ground, while some economies struggle to get their acts together. The USA and the UK Governments have announced financial support for exporters, and those new to export. The USA increased exports in 2013, but the UK is flatlining, albeit with a determination to improve.



XPB

The MIA is taking UK companies to the US to vie for NASCAR business

Motorsport Valley UK companies export globally, yet strangely the large USA domestic market results in few companies exporting. But things are changing. The MIA works hard to build a better trade balance between these two countries – the USA is the largest single motorsport market in the world, and the UK is the largest exporter of motorsport engineering and services, so this natural partnership should be developed. A growing number of British companies are investing in and opening facilities in the USA, but more US companies should come into Motorsport Valley to supply UK and European companies.

Recently, the UK Government and the MIA have agreed to support a two-year drive to build international trade in motorsport, particularly with the USA. We will engage with more UK motorsport companies to help them grow their exports and – if new to export – we will put them on the road to building their international business. There is support for a full programme of training and market visits, with visits to the major USA shows – SEMA and PRI – plus attracting buyers from the USA to the UK, particularly to Autosport International in 2015.

In May, the MIA will take UK companies to Charlotte and Mooresville to secure NASCAR business, and another group to Indianapolis and the Indianapolis 500. The USA is full of new business – the United Sportscar series needs new cars from 2016, and IndyCar is starting the process of specifying a new car for when the Dallara contract ends. The boom in off-road continues, now including the Global Rally Challenge series which brings attention to rally-style cars, many of which can be supplied by British companies. There has never been a better time to visit the USA to meet the key people who are building up their budgets, and supply chains, to deliver these cars for 2016.

2015 is too late to visit as initial work will start in the next six months. Contact the MIA to join me on our ever successful, May visit to the USA and start to build your exports to the USA. Make 2014 the year that you increase your exports, or finalise if you are not here already, then make plans to join the Motorsport Valley community. Either way, we want to help you.

Exporting is back in political fashion – the balance of trade between import and export is critical to countries coming out of the downturn

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Trouble ahead for touring cars?

The World Touring Car Championship introduced new technical regulations that make the cars lower, wider, more powerful and more purposeful. As usual, it has drawn a mixed reaction, with some saying that the cars are poor cousins to the DTM, and others saying that they look better than the S2000 cars that they replace.

Among the drivers, too, there is a mixed reaction. Some say that the reliance on aero will hurt the racing, as door handle rubbing will lead to more broken carbon bits and therefore drivers will have to avoid such tactics. Others say that, as drivers, they are duty bound to go for a gap, and that while the consequences may be worse, that's what they are paid to do.

One thing that everyone agrees on, however, is that the costs have escalated significantly for the hardware – the Chevrolet Cruze is €450,000 without the engine – and the arrival of Citroën has raised the bar significantly in terms of the competition, and the level of commitment needed to beat them.

The British Touring Car Championship went down a similar route in the 1990s, and it became clear that return on investment in touring car racing, even the best in the world, is not there. The WTCC has come a long way since it started 10 years ago. Then, television audience was 80 per cent Eurosport. Now, according to KSO which promotes the series, 20 per cent of the television audience comes from the pan-European station.

"It's naive to think you can have one set of regs with which the world can compete"

The FIA held its World Council meeting in Marrakech ahead of the first race of the 2014 season, and many of the council members attended the WTCC race, including the FIA president Jean Todt, and Alan Gow, head of the touring car commission. What they had figured out was that – other than the WTCC regulations which were too expensive to adopt for national series – the FIA had no other regulations for the category.

This, says Gow, now needs to be addressed. There will be no obligation to take on the regulations, but they will be available. 'The World Touring Car Championship regulations are only for the WTCC,' said Gow. 'They are not regulations designed for other major national championships which run. It is different to how it was in the S2000 days. Now it is up to the FIA, and we are starting to come up with one or two sets of regulations that are applicable for national championships around the world. At the moment, the only touring car regulations we have got is the WTCC regulations, and that has taken our focus. Now we are setting other regulations that countries can choose or not – it is up to them. It is naive to think that you have one set of regulations that the whole world can compete with. It is like the FIA have done with F4 and F3.'

Will the NGTC be the basis of these new regulations? 'I have no idea, we haven't even started that discussion yet, we just started the planning of it.'

There are two aspects to this. The first is that the new regulations do not leave the WTCC alone at the top of the pyramid structure that the FIA is planning. It will not be the pinnacle of global touring car racing, -NASCAR, TC2000, British and Australian touring car series are all strong in their own markets, so creating a feeder to these is fanciful. However, KSO is planning to run this cheaper touring car series, with costs estimated at one quarter of the current WTCC, on the same bill, allowing teams to run multiple cars, and drivers to make the step up.

The second aspect of the FIA's responsibility to the WTCC teams is that it has to make sure that there is a market for these cars once they have finished the season. With Citroën raising the bar so high in the WTCC, the privateers are in danger of being performed out of all competition, and that could spell disaster for the series. If manufacturers are able to sell their cars to more privateers, there is a market, but no team wants to have 100 per cent write-off of machinery after the first year or two.

There is one other point to consider. While the WTCC has just taken the next step into the future, there are other steps to come, and that will be with hybrid touring cars. 'At the Geneva motor show, all the manufacturers are talking about hybrid, electric, hydrogen and downsize engines, so if you want to have a sense about racing, there must be a link,' Todt told me in Morocco. 'I had a meeting with people here at Honda about joining Formula 1. They would not have joined without the introduction of the new engine, so clearly you cannot ignore it. I have a passion for racing, and I have a passion for old cars, but you have historic racing, rallying, circuit racing, and if you speak of motor racing it must be modern technology.'

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