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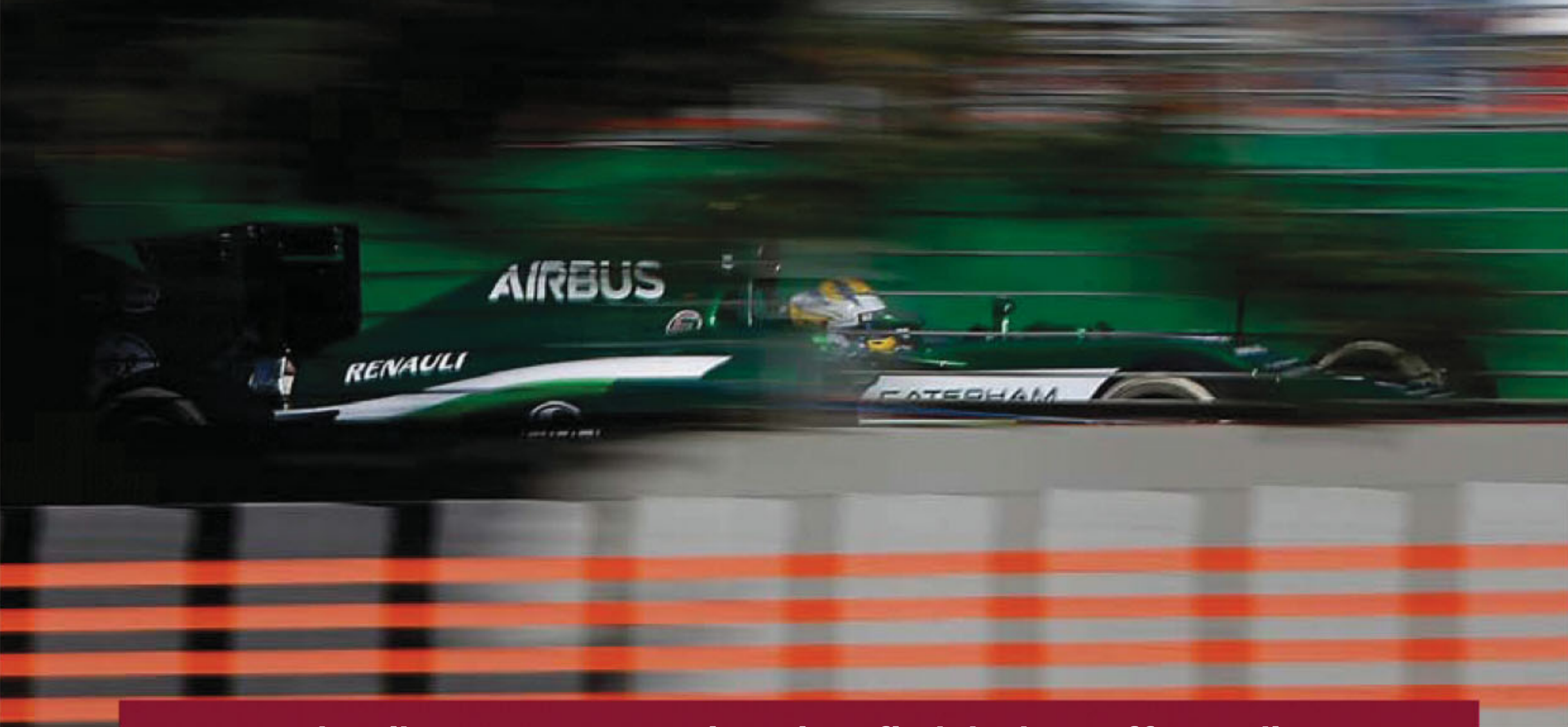
COVER STORY

COLUMNS

FEATURES

BUSINESS NEWS

TECHNICAL



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Why buy racing relics?

To an engineer, the attraction of own old cars and replicas is somewhat baffling

As Ambrose Bierce's Devil's Dictionary tells us, reliquary is: 'a receptacle for such sacred objects as pieces of the true cross, short-ribs of the saints, the ears of Balaam's ass, the lung of the cock that called Peter to repentance and so forth. Reliquaries are commonly of metal, and provided with a lock to prevent the contents from coming out and performing miracles at unseasonable times. A feather from the wing of the Angel of the Annunciation once escaped during a sermon in Saint Peter's and so tickled the noses of the congregation that they woke and sneezed with great vehemence three times each. It is related in the "Gesta Sanctorum" that a sacristan in the Canterbury cathedral surprised the head of Saint Dennis in the library. Reprimanded by its stern custodian, it explained that it was seeking a body of doctrine. This unseemly levity so raged the diocesan that the offender was publicly anathematized, thrown into the Stour and replaced by another head of Saint Dennis, brought from Rome.'

There are things that sometimes escape the perception of engineers, perhaps due to the tinge of Asperger's syndrome that they all have. One of them, to which I confess, is the tendency to be baffled by the price of some cars, specially racecars that have history. Fangio's Mercedes W196, recently sold for $29.7m, it having won two races, and apparently most importantly had the maestro's butt gracing its plaid seat.

As a practising engineer, a racecar is as valuable as the competitiveness it possesses at a given time, usually short, after which it is discarded for the next winner without a backward look. One looks back fondly on some of the cars one has won races with, but almost as an aide memoire to happy times. That it has value to someone else is always strange.

Maybe the epithet 'iconic' can explain something about the whole phenomenon, an icon being an image or representation of a sacred or sanctified Christian personage, traditionally used and venerated in the Eastern Church, or in this case an important and enduring symbol of an epoch or happening.

I have stated before the attraction that beautiful things can have, being hopelessly in love with the Ferrari 330 P3/P4, whose lines are a poem of shape even with the first spoiler tacked on its back, not part of the original design. But I have never looked upon it as a symbol of an era, after all the Ford GT40 is a contemporary and has a rich history of wins and races, but ends up being a workman-like car, that did its duty before fading into old age. Is it iconic? It must be for me, but the reasons for it are enmeshed with my perceptions of what is beauty and – I suspect – the fact that it is a racecar.

Any P3/P4 is beautiful, not because it has a history, or who drove it. But can it also have an aura of being a car that ensconced itself in my unconscious not only by its looks, but because it was what one saw as the epitome of the era?

I have a soft spot for the Maserati 250F, because it was the first racecar I worked on, but not because Fangio had his epic 1957 Nürburgring race in it, his last win. The flourishing of the 250F myth from then on has the tinge of the foreskin of Jesus relics that began appearing in Europe in the Middle Ages. The earliest mention of which was in 25 December, 800, when Charlemagne gave it to Pope Leo III. Charlemagne claimed that an angel had brought it to him while he prayed at the Holy Sepulchre, although perhaps more credibly it was a wedding gift from the Byzantine Empress Irene.

Pope Leo III placed it into the Sancta Sanctorum in the Lateran basilica in Rome with other relics.Its authenticity was later considered to be confirmed by a vision of Saint Bridget of Sweden. The foreskin was then looted during the Sack of Rome in 1527. The German soldier who stole it was captured in the village of Calcata, 47km north of Rome, later the same year. Thrown into prison, he hid the jewelled reliquary in his cell, where it remained until its rediscovery in 1557.

Multiple foreskins proliferated then – eight, 12, 14, or even 18 in various European towns during the Middle Ages. In addition to the Holy Foreskin of Rome, there were

XPB

A Maserati 250F at the Bologna Motor Show in 2008, with Gigi Baulino in the cockpit

The Maserati 250F myth has the tinge of the foreskin of Jesus relics from the Middle Ages

claims from the Cathedral of Le Puy-en-Velay, Fecamp, Santiago de Compostela, the city of Antwerp, Langres, Coulombs in the diocese of Chartres, as well as Chartres itself, and in churches at Besançon, Metz, Hildesheim, Charroux, Conques, Stoke-on-Trent, Calcata, and two in Auvergne.

And in the same vein, there are a bevy of 250Fs which are extant, some of which are rebuilt from not much more than a chassis number plate, and the 12 Cameron Millar replicas.

Beauties all, with original running gear, but replicas. The real ones can excite passions about their provenance that borders on the religious. Replica Auto Unions? There are several, impeccably made to original drawings. And what about the flourishing market for replica Cobras, GT40s or any presumably iconic cars?

The business of making scale models of cars has a echo of this enthusiasm for acquiring symbols of greatness that will then reflect on the collector's personality, bringing the essence of other peoples' achievement into their own, much as memorabilia such as helmets, racing suits, gloves and other paraphernalia does, lifting them from a mundane life to the peaks of their idols.

'What of history?' you will ask. Yes, it does that, much as statues, monuments, memorial parades and even re-enactments of historic moments do. Symbols are central to our lives, as attested by the style of clothes, watches, shoes we wear – all of them giving a status, much as cars do. And it can be a life or death matter. Try burning a flag, Bible or Koran, and see the results depending on where you are.

All the puzzlement hitherto felt about the phenomenon was cleared up by my last trip back home from the UK. Having some spare time before embarkation on the ferry, I went to The National Memorial to the Few at Capel-le-Ferne, on the white cliffs between Dover and Folkestone in Kent.

There is a monument, and one each of a Spitfire and a Hurricane. As a plane lover they have always had a visceral appeal, but standing there beside them on a sunny, windswept day, the full emotional impact of what they symbolised to England and the world truly came home to me. Go there. And go to Goodwood to see old racing cars being used in anger give you an indefinable feeling of awe.

You will not regret it.

Playing it too safe?

Prohibitively expensive classes and counter-productive regs are hurting racing

I am not going to add to the controversy about F1 snouts except to suggest that they should all be painted Red Nose Day scarlet and be done with it. At least it might raise a few quid for a worthy cause.

On a much more serious topic, is the relentless pursuit of driver safety adding too much complexity in car design and increasing the cost of racing too much, to the extent that it can become unaffordable?

Whoa, you might say, how can you put a price on a person's life? Surely you can never have enough safety, especially in a sport as inherently dangerous as motor racing?

Having not long ago written a piece about responsibility in motor racing, it may seem perverse to introduce this topic. As with most things, the trick is to achieve a balance. What has moved me to debate this subject is the recent introduction of two new International categories – the FIA's F4 single-seater and the ACO's LMP3 sports-prototype starter class.

Both have good credentials for their creation, the common aim being to provide drivers and teams with a less expensive way to compete and progress in their chosen level of motorsport. However, the other common factor is the attention paid to safety. For low(er)-cost categories, they both have a degree of driver protection mandated by the regulations that is usually associated with much higher-performance racing cars.

FIA F4, seen as a modern-day equivalent of FFord 1600 in its heyday, demands a carbon-composite monocoque. The assumption is that this is safety-driven. It contrasts with the UK's existing one-make MSV F4 machine which has a tubular steel spaceframe – the only composite chassis parts are the side-protection panels and front/rear crash structures.

Inevitably, the tooling costs as well as the more exotic materials involved make a composite tub more expensive. The traditional spaceframe, particularly using FEA stress analysis in the design and modern methods of tube-cutting etc to reduce manufacturing time, can provide a very robust, cost-effective and safe chassis well up to the demands of the performance and weight of the complete car. It is also, importantly, easier and less costly to repair, especially for a formula which is designed to go global and race in parts of the world where composite repair facilities are less common and not necessarily capable of being monitored. Unlike with a tube chassis, a poor repair cannot always be identified. Taking these factors into consideration, perhaps going composite along with a few other factors could tip the balance between affording to compete in F4, or not.

Regarding LMP3, because it is higher up the scale of motor racing, the demand for a carbon chassis is a lesser issue, although for the same reasons as mentioned above a spaceframe or an aluminium sandwich construction could still be perfectly viable. Here the point is one of mandating driver safety measures similar to those of LMP2 and LMP1 cars, which are significantly faster. In order to do this, at the time of writing these requirements have encouraged the ACO to set the minimum weight of the car at between 800 and 850kg (despite, ironically, the carbon chassis!). This is extremely heavy for a category that was originally supposed to be based on the FIA's Group CN 2.0-litre sports prototypes. Weighing less than 600kg and with 250+bhp,

CNs are fast, attractive and proven-safe affordable racing cars for 'gentlemen' (what happened to the respectable term 'amateur'?) drivers and their professional team-mates. Even putting a roof on these cars, with all the complication of screen, doors, ventilation etc and increasing the power should not add 250kg to the weight. One can understand that both the ACO and the FIA might feel obligated to make 'junior' categories as safe as their bigger brethren. Insurance and litigation matters unfortunately play a role in these decisions, but one has to draw a pragmatic line somewhere.

In setting the weight this high, the knock-on consequences are such that in order to meet the targeted performance (between LMP2 and GTE) a fairly large engine able to produce close to 400bhp with little modification is required. This in turn, coupled with the high vehicle weight, means a bigger and stronger driveline to cope with the power and torque, larger brakes to stop the thing etc, all adding significantly to cost and making the chassis running budget closer to LMP2 than CN. If the CN-based concept was adhered to and the minimum weight set at around 700kg, turbocharging the four cylinder, 2.0-litre engines would produce enough power and relatively inexpensive components could therefore be retained. Weight is mass, and mass means more energy that needs to be absorbed in an impact – it is the enemy of safety in motor racing, not the friend.

XPB

Chassis construction should relate to power output and cost

Weight is mass, and mass means more energy that needs to be absorbed in an impact

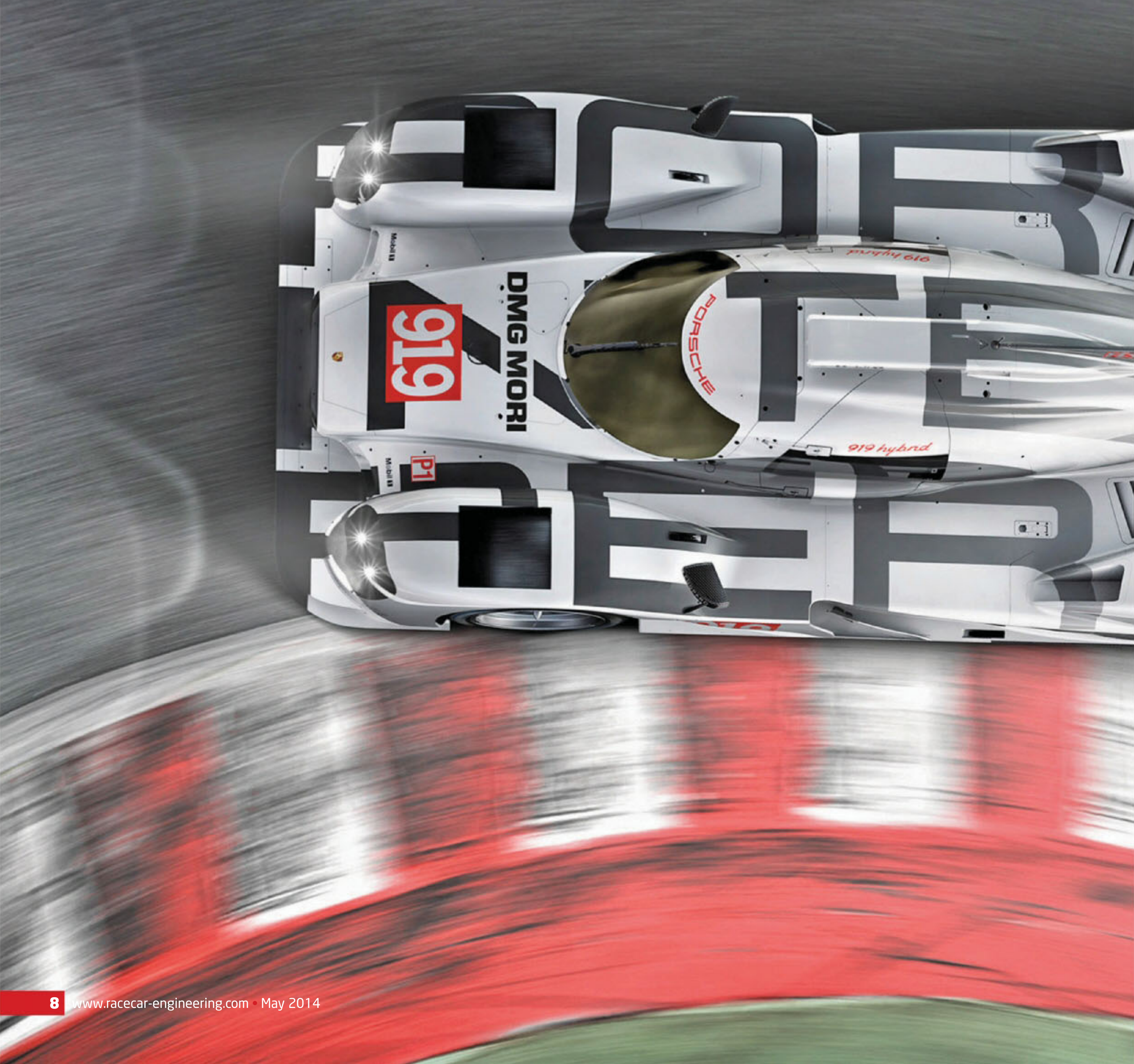
Isn't a certain level of physical risk part of the sport? As well as adding to the thrill for participants and fans alike, it might weed out what appears to be an increasing trend for motor racing to be a lifestyle choice for wealthy young drivers, rather than for dedicated racers. Without wanting to appear callous, the idea of trying to achieve 100 per cent safety is straying somewhat from the core value of race-driving, especially so if it increases the cost of competing such as to make it unviable for many of those whose talent exceeds their budget.

Motor racing is actually already one of the safest of sports, which is laudable. I have known more drivers who have been seriously injured or lost their lives prematurely to other sports, plane crashes, road car accidents, illness and other causes than through driving racecars. Nobody would wish to go back to an era when fatalities were common, but safety should perhaps not be taken so far that it is to the detriment of the sport itself. Risk is part of life, not just racing – should you want any proof of that, the plight of poor Michael Schumacher surely provides it.

Porsche back to the big time

Stuttgart manufacturer finally unveils the technical details behind its ambitious 919 Hybrid, and explains what went wrong in testing

BY ANDREW COTTON



Porsche's 919 Hybrid started testing in June 2013, but from the moment the car hit the track, it was hindered by an engine problem that, due to the long lead-time of the replacement parts, delayed performance and endurance testing until the new year.

It was a setback that has caused problems for a team that hasn't raced an LMP1 car since 1998, when the company triumphed at Le Mans. The delay has led to the team even questioning the amount of energy that it can recover, and says that despite releasing to the media that it will run in the 8MJ class, it will make a final decision after a full testing programme.

From the moment that Porsche first decided that it would return to Le Mans with its own team, excitement has been growing. More than 145 engineers are now installed at the Weissach facility near Stuttgart, work on a brand new wind tunnel is almost complete, and the learning process surrounding performance hybrids, started with the 918 Hybrid road car and continued in the 919 racecar, is well under way. In fact, the team say, the hybrid element is the least troublesome bit of the new car.

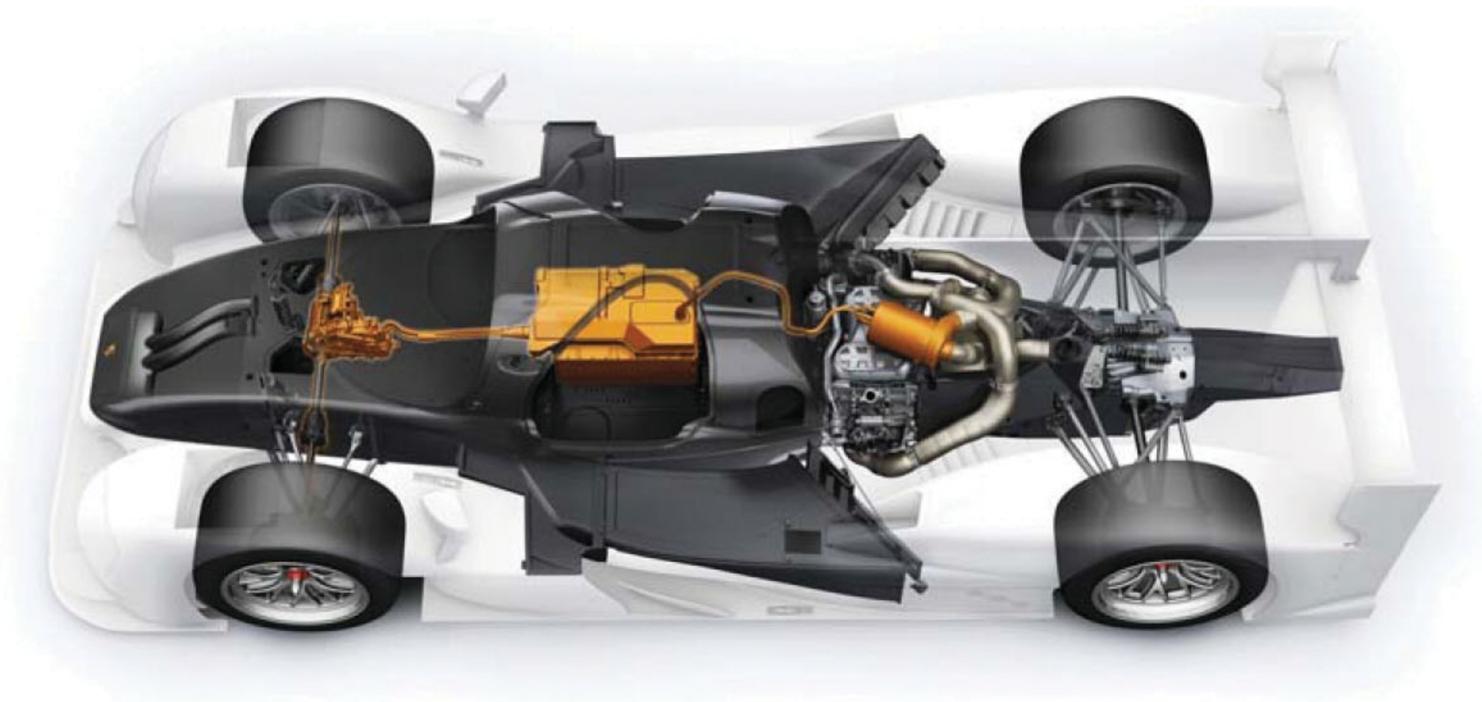
The drive system of the new LMP1 racecar is based on a four-cylinder petrol engine that is as compact as it is lightweight. It is a 2-litre, V4 configuration with direct injection and a single turbo. Powering the battery is an electric motor, which is powered by the exhaust gas stream, and a kinetic energy recovery system that is linked to a similar system used on the 918 road car. Energy is stored in water-cooled lithium-ion battery packs.

FIRST STEPS

The monocoque was finalised at the end of 2012 to meet with the company's schedule of rolling out the car in June, announced just before the Le Mans 24 hours. This meant that the front suspension concept was designed early, and the team opted for coil springs rather than the now-standard torsion bar layout in LMP1.

Porsche was extremely coy over its choice of layout, claiming that the kinematics, aerodynamics and stiffness caused them to go down this route. It is believed that the suspension is interlinked, not a major piece of news other than it was the link between front and back that was susceptible to the vibration caused by the engine difficulties in the early part of testing.

The car has been designed to be as efficient as possible, with a low frontal area, but still meeting the new visibility requirements of the regulations. The huge blind spots in the 2013 cars have been reduced significantly this year, just as teams are seeking to reduce drag.



Above: highlighting the MGU-K (front) and MGU-H (rear) on the 919 Hybrid, and how they connect to the li-ion battery. The front generator is operated as a single electric motor and drives the front wheels via a differential. This gives the car a temporary all-wheel drive system

Right: the aggressive aerodynamic solutions at the front led to a bulge in the roof to meet with new cockpit regulations

The Porsche therefore features a raised section in the roof, designed to give the drivers more height in the cockpit. 'The bubble in the roof was not an afterthought, that was the result of being very aggressive in terms of frontal area,' says Porsche's technical director Alex Hitzinger. 'You have clear templates which you have to respect in terms of cockpit internal volume and visibility templates, and you want to wrap around these templates. It is purely aerodynamic driven.'

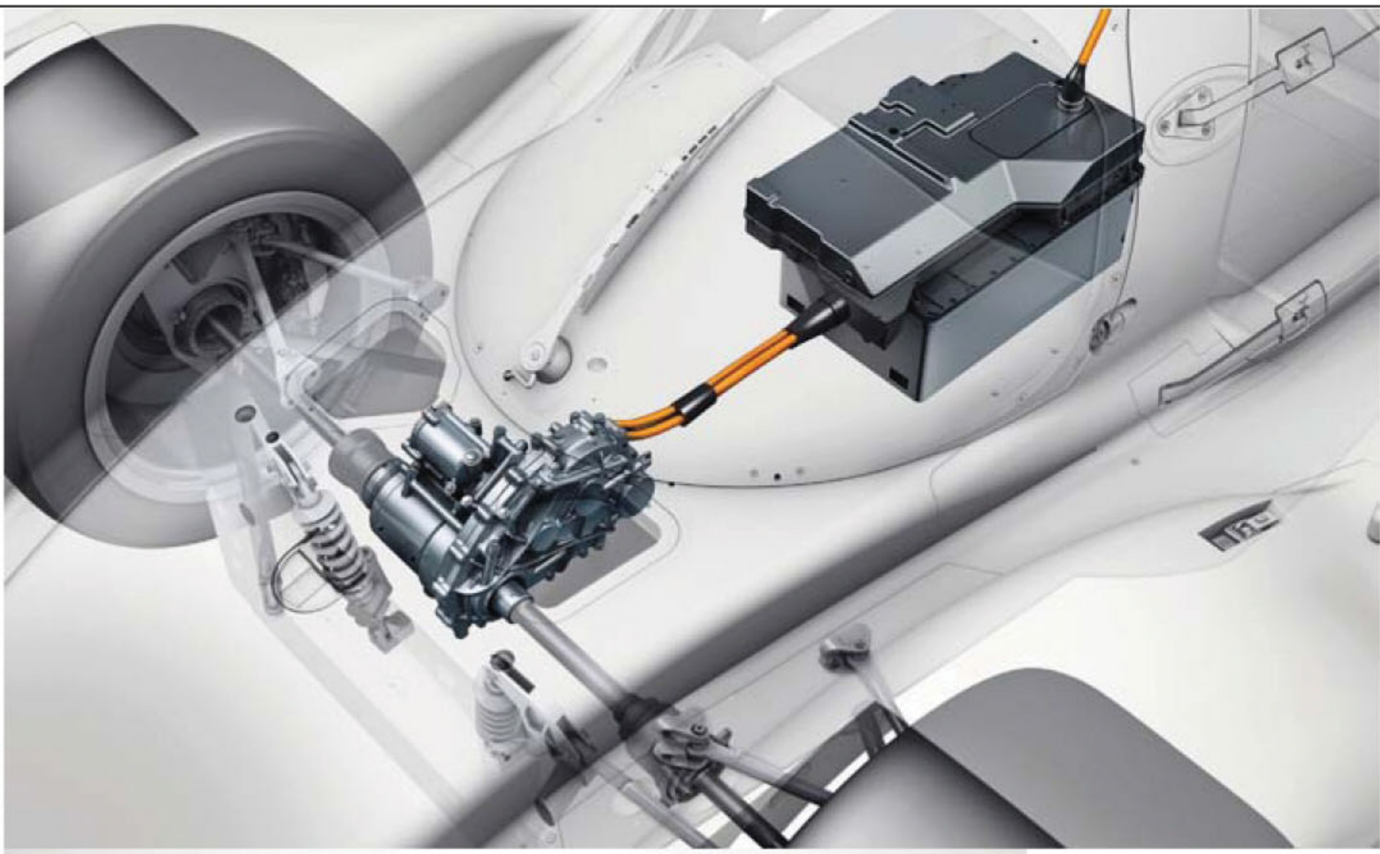
In testing, the car has run an interim aero package and the car will contest the World Endurance Championship in a completely different configuration. 'The changes are in aerodynamics and a little bit of the suspension, and after this it is finished,' says project leader Fritz Enzinger. 'It is important that we have more kilometres and more mileage. It is a normal step-by-step change, and we are targeting more downforce. We then have a freeze in specification for Le Mans. The focus is Le Mans, and we're fixing it for this big race.'

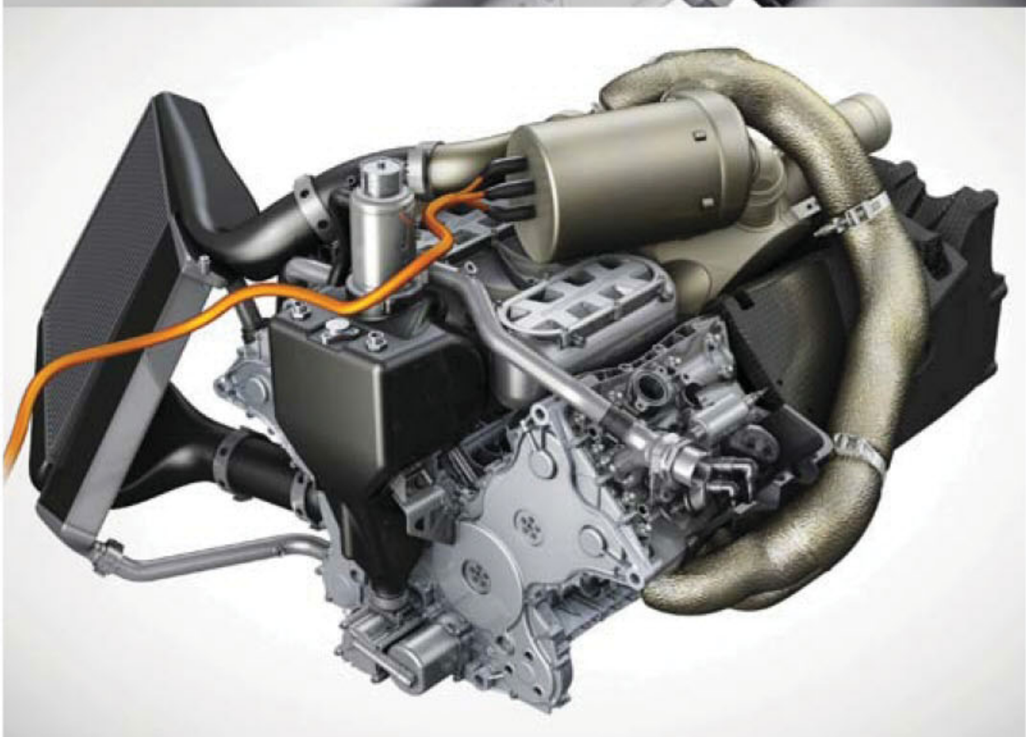
ENGINE DRAMA

Almost from the first shakedown test at the Weissach facility, Porsche realised that there was a significant vibration problem with the V4 layout, and Hitzinger immediately demanded an extensive revision, which took almost six months to put into place and deliver. The new engine was installed into the car in time for a test late in December, at Portimão in Portugal, and new driver Mark Webber put 600km on to the car first time out. The team later moved to Bahrain, and started putting race distances on to the engine.

'We had vibration issue caused by the engine configuration,' says Hitzinger. 'We changed the engine configuration and reduced the vibration level a lot by changing the firing order. Changing the firing order means a new crankshaft and camshafts, and new calibration because of the gas exchange changes. It was a big thing. We discovered the problem at the rollout. For me it was quite clear at the beginning that this was going to be a problem that would otherwise be very difficult to solve. I decided very quickly because it is such a big change that it takes a long time to implement it, but if you let it drag on before you try to solve it, you could be in trouble later on. We saw the problem, and we acted decisively.'

The vibration issue caused major problems for the interlinked suspension, and led to breakages which in turn limited early development work. However, the vibration itself was causing the drivers to register false findings. 'The driver uses certain inputs from the car in terms of feeling, through the steering for example, and through that gets the feeling for the car,' says Hitzinger. 'The vibrations clearly masked a lot of the input into the body. The





Above: Porsche has targeted the full 8MJ of energy recovery through its batteries, provided by A123 and delivered through the KERS on the front axle

Left: vibration problems with the V4 engine were identified early, but a long lead time for replacement parts – including an all-new crankshaft – meant a six month delay before performance testing could begin

feeling for the drivers was very different than what it would normally be. We felt that there were issues on the suspension side in terms of yaw behaviour and so on. The driver feels a lot, and if he doesn't have that, and relies on the steering, the car feels totally different.'

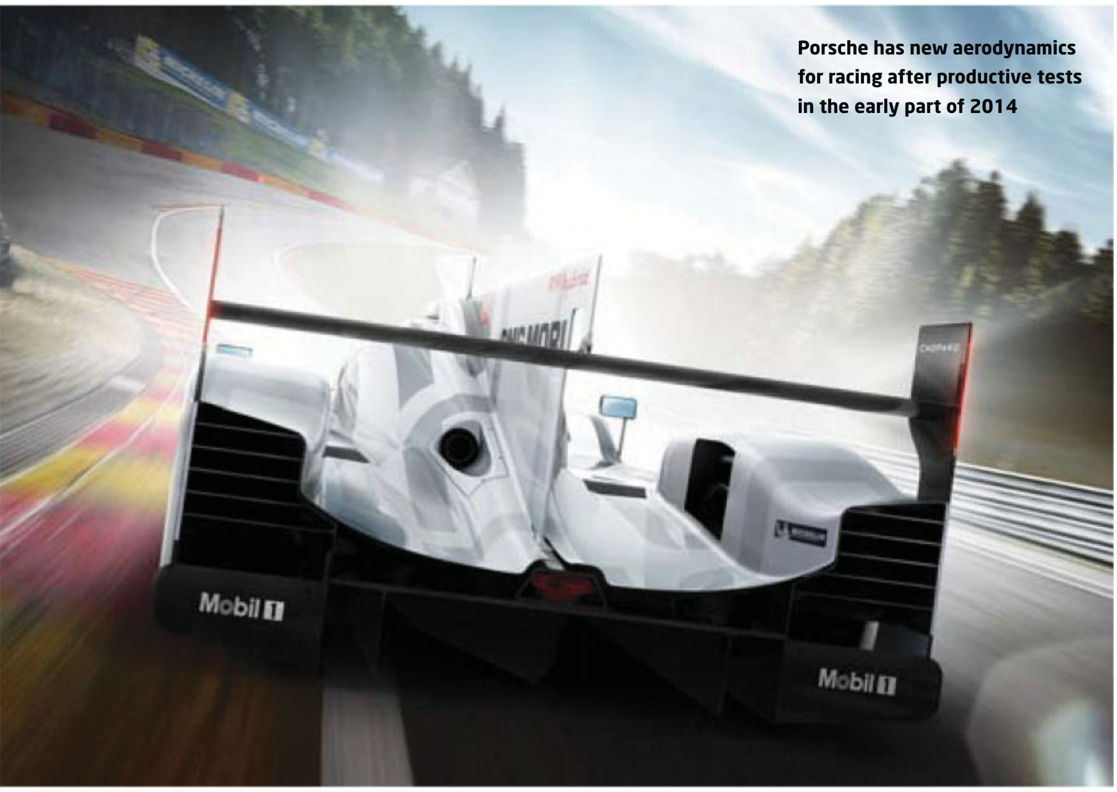
The engine is a novel concept – a two-litre, four cylinder engine in a V shape which helps with structural rigidity and offers the packaging and capacity that Porsche needed. 'From a thermodynamic point of view, you want a certain ratio between air and volume in the combustion chamber and that leads you towards a smaller number of cylinders at a given capacity,' adds Hitzinger. 'With a four cylinder V configuration, you can nicely install it in the car as a structural component, so that leads you to that solution.'

Such a short engine has left the team with a transmission casing on which the rear suspension hangs that is almost a third of the car's length. Although this is not ideal, the team says that it is almost as stiff as a longer engine.

HYBRID SYSTEM

'Fuel is like gold dust now, and you need to showcase the best way to conserve it,' said Webber at the launch of the car at the Geneva Motor Show in March. The 30 per cent reduction in fuel consumption compared to 2013, (compared to 20 per cent over the last 20 years) while retaining the speeds and distances covered by the cars last year, can only be achieved by re-using the energy otherwise wasted through exhaust gases, or kinetic energy expended under braking.

Porsche has targeted the full 8MJ of energy recovery through its batteries, provided by A123 Systems and delivered through the KERS on the front axle, and the electric motor that is linked to the exhaust gas stream. However, says Enzinger, the announcement of the 8MJ limit is no guarantee that the manufacturer will stick with this decision – it may favour a car at Le Mans, but not in the full WEC.



Porsche has new aerodynamics for racing after productive tests in the early part of 2014

You size it according to how much power and energy you need, and how safe you want to be. You cannot compare like for like [with Audi and Toyota] because you don't know what the others have done. Our investigations concluded that this would be the lightest solution for our application and our assumptions.'

For the rear ERS, the electric energy is not used as an anti-turbo-lag as, says Hitzinger, that is not as efficient as using it totally for charging the battery between braking phases. 'It is another turbine which drives an electric generator, so as soon as there is more exhaust energy than required for the turbocharger, then that surplus exhaust gas flows through the additional turbine. It is nothing to do with anti-lag. Flowing electric energy from the exhaust energy recovery system to the front is possible, or direct it to the battery.'

With a tightly-packaged engine sitting low in the chassis, and with the exhaust, turbo and ERS above it, cooling is an issue. 'It is clearly a big challenge to cool everything down, but you just have to sort it out,' says Hitzinger. 'It is difficult but it is not impossible. We had our issues in the beginning, but you have to sort it out.'

'We have a lot of simulation and we have decided on this, but maybe in one month it will be different,' he says. 'Everything is new, we have a lot of information, but technical decisions regarding what we can do, are due to be evaluate at the Sebring test [in March], and then we will have more information to work with.'

The decision to go for batteries as a storage system was a relatively simple one, says Hitzinger. While the Nissan ZEOD 1.5-litre three-cylinder engine will be required to power the car throughout the lap on a single charge, Porsche's requirements are very different. 'I think it was the smallest compromise to go with batteries,' says Hitzinger. 'It is the best compromise between energy and power density. It gives you more flexibility in terms of strategy and A123 technology is in my opinion the best out there, and we are lucky to have them. We are exclusive in LMP1 and it is a very good thing for us. I think it is a lighter solution than the others.

"The braking system eliminated the effects of energy recuperation so the driver doesn't get disturbed through the influence of the front KERS"

DRIVER'S VIEW

Porsche asked Mark Webber to join the testing programme in 2013, but the Australian felt that he wanted one more year in Formula 1 before making the switch back to sportscar racing.

When he did, at the end of the 2013 season, he brought with him 14 years of Formula 1 experience, and a return to the type of racing in which he effectively made his name with Mercedes. 'First of all it is a massive programme, a serious effort from Porsche,' said Webber at the launch of the car at the Geneva Show in March. 'The car is massively complex. It is very advanced in lots of areas, but we need to gain experience. It is early days for us.

'I particularly enjoy being back in the endurance element, I always enjoyed that when I was with Mercedes. I like driving at night, and the driver changes. The four-wheel drive is quite cool, so that's a nice feeling.'

The development of energy recovery systems is a new way of going racing, one that will require a new style of driving, and for drivers to actually accept orders from the pit wall to manage the amount of energy that they have available to them.

'We are on the curve at the moment where manufacturers are learning,' says Webber. 'They know that there is lots of fruit on the trees in the distance, but you can't get there in a couple of months. You have to go through the super-advanced technology, the packaging, and it is how big your balls are, how big do you want to go with certain things, knowing that it will benefit you in the future.

'These guys we know are world-class in the way that they will tackle things, but we have to get the balancing act right in terms of how much ambition you have, what we will learn in the future and how much we run learn now.

'In terms of driving style, it is good that it is so far away from what I had. I haven't used my right foot for braking for 14 years, and I am using it again. The car is a bit heavier, has less downforce than an F1 car, but there are sections where the power is very good.

'With the development pace, what I get used to in February is not what we are going to have at Le Mans. The stuff is coming through quite quickly. We know that it is in our best interests to stick to the regs in terms of the fuel burn. That is the way all motorsport is going at the top end. This category and Formula 1 is in the slot for new automotive technology. Fuel is like gold dust now, and you need to showcase the best way to do that and the driver has to be in the loop for that. You can't have the driver out of the loop in terms of understanding that philosophy.'

Porsche's new LMP1 entry marks a welcome return to the class after a 16-year absence, following victory in 1998

BRAKE SYSTEM

Porsche was coy about its braking system, refusing to confirm or deny that it was a brake-by-wire system, although this seems likely as Formula 1 teams are deploying similar technology due to the heat rejection in critical areas around the wheels.

The front brake system is a basic Kinetic Energy Recovery system and was a logical choice for energy recovery due to the amount of force on the front axle under braking. 'The front axle has the most potential for recuperating kinetic energy and it has traction advantages too,' says Hitzinger. 'If you have the choice, you will always go for the front axle. Basically, you have an MGU, and the energy has to go through a differential to the front axle to drive the two wheels. It is an MGU and a gearbox, which changes the speeds and split it through a diff. They are fixed ratios in the gearbox.

'The braking system basically eliminates the effects of the recuperation so that the driver doesn't get disturbed through the influence of the front KERS. It is a development with the drivers because some influences are more disturbing than others.'

To deliver 8MJ over the course of a lap (compared to 150.8MJ from the internal combustion engine over a single lap) sounds relatively simple, but this is more than double what was permitted in 2013, and management systems needed to make both work together are complicated enough, without the need to strictly regulate the amount of fuel a car may be able to use over each lap. At Le Mans, the engine is driven at full load for 75 per cent of the 13.65km lap, but has only 4.64 litres of fuel available. In the 2MJ class, the figure is 5.04 litres.

The amount of fuel that a car may use over an average of three laps is closely governed, and monitored by a fuel flow sensor that is now accurate to 0.2 per cent, although the recent problems highlighted by Red Bull and Renault have cast doubts on the system. Porsche has practised changing the sensors in the pit stop as required, as in sports car racing the sensors are mounted externally to the fuel tank. 'At this stage, no one has run a car for 24 hours,' says the ACO general manager Vincent Beaumesnil. 'You can change it in a short time in a pit stop, and there are two fuel flow meters on the car, and three on the diesel. If one is starting to go, we have another one, and we can ask them to change at the next pit stop. If the sensor doesn't work, we discussed the possibility some months ago, but now I have no more issue with that. Even if the telemetry doesn't work, you can collect the data through the transponders.'

However, Porsche does not believe that the system will work properly. 'It hasn't held us back because we did not make our development dependent on it, but there is still no robust solution in place,' says Hitzinger. 'The FIA is still very hopeful that the latest spec will work and will be reliable, but that is not proven yet. We optimise how they are mounted to give them the easiest possible life, but right now we don't know if it is all going to be robust. We should know at the end of March.'

The management of fuel allowance over an average of three laps is difficult enough in testing when a car is running alone, but in traffic, behind a safety car, and in different weather conditions, temperatures and altitudes, it will all be a different calculation.

TECH SPEC

Porsche 919 Hybrid

Class: Le Mans Prototype (LMP) 1

Monocoque: composite fibre construction made of carbon fibres with a honeycomb aluminum core

Engine
V4 engine with turbocharging
Engine management: Bosch MS5.6
Engine lubrication: dry-sump lubrication
Displacement: 2.000ccm
Power: >370 kW (>500hp)

Hybrid system
Accumulator type: lithium-ion battery, EGU on front axle
EGU power: >250hp

On-board system battery
Lithium-ion

Drive and power transmission
Drive type: rear-wheel drive, all-wheel drive via KERS on the front axle
Clutch: CFR
Transmission: sequential, hydraulically activated seven-speed racing transmission
Differential: rear differential lock
Transmission housing: hybrid construction in CFRP with titanium inserts and cast aluminum housing
Drive shafts: constant-velocity sliding tripod universal joints

Chassis, steering and brake
Chassis: front and rear multi-link pushrod independent wheel suspension with adjustable shock absorbers
Steering: hydraulically-assisted rack-and-pinion steering system
Brakes: hydraulic dual-circuit brake system, light-alloy monobloc brake calipers, internally ventilated carbon fibre rear and front brake discs
Rims: forged magnesium wheels
Tyres: Michelin radial, front and rear: 360/710-18

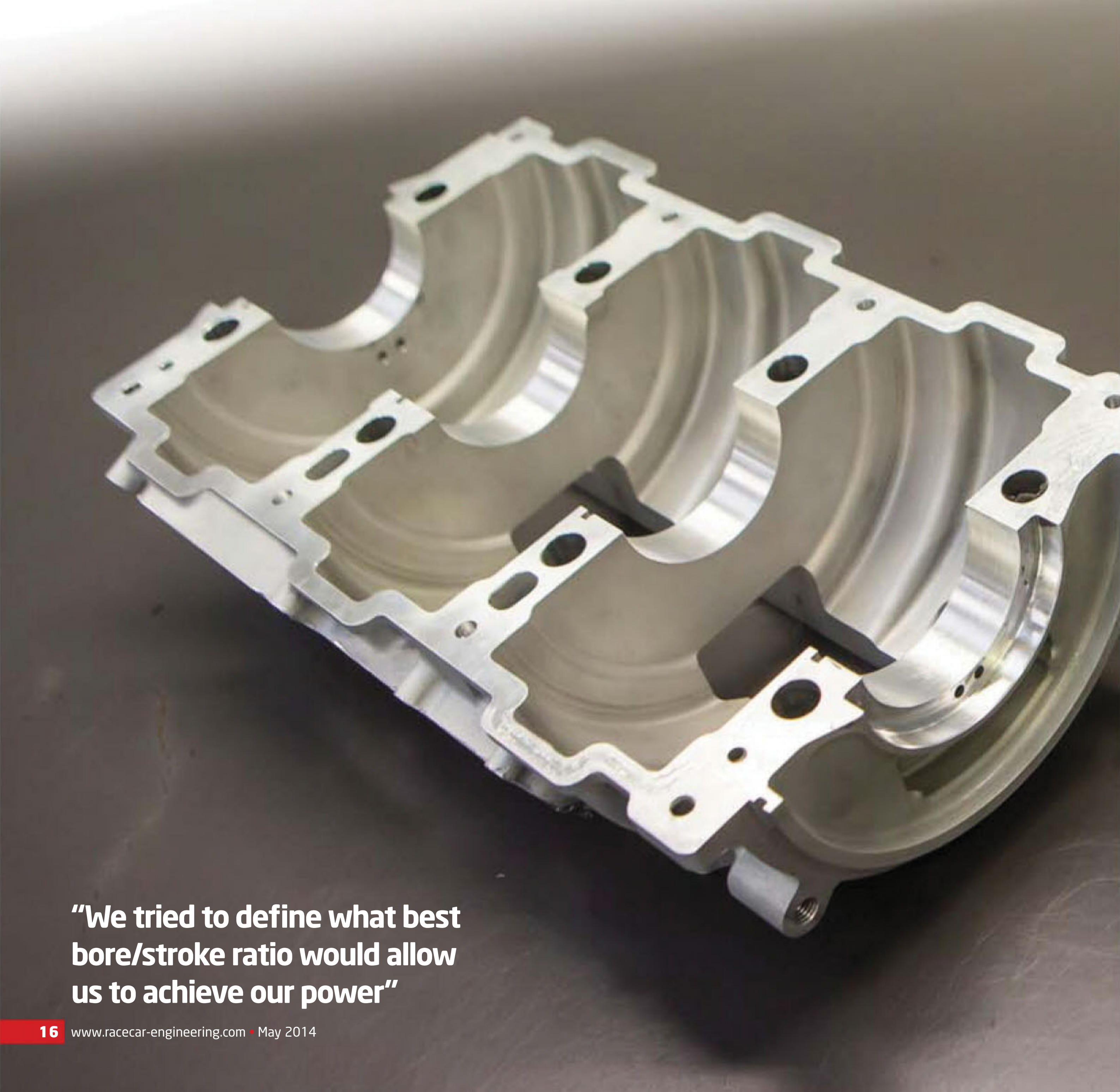
Dimensions and weight
Height: 1050mm
Width: 1900mm
Length: 4650mm
Minimum weight: 870kg
Tank capacity: 66.9 litres

"The car is massively complex, and it is very advanced in lots of areas, but we need to gain experience. It is early days for us"

Good things come in small packages

The Nissan ZEOD is all about experimental technology, and the 1.5-litre, three-cylinder engine weighs just 40kg, produces 400bhp, and has pushed all the boundaries

BY ANDREW COTTON



"We tried to define what best bore/stroke ratio would allow us to achieve our power"

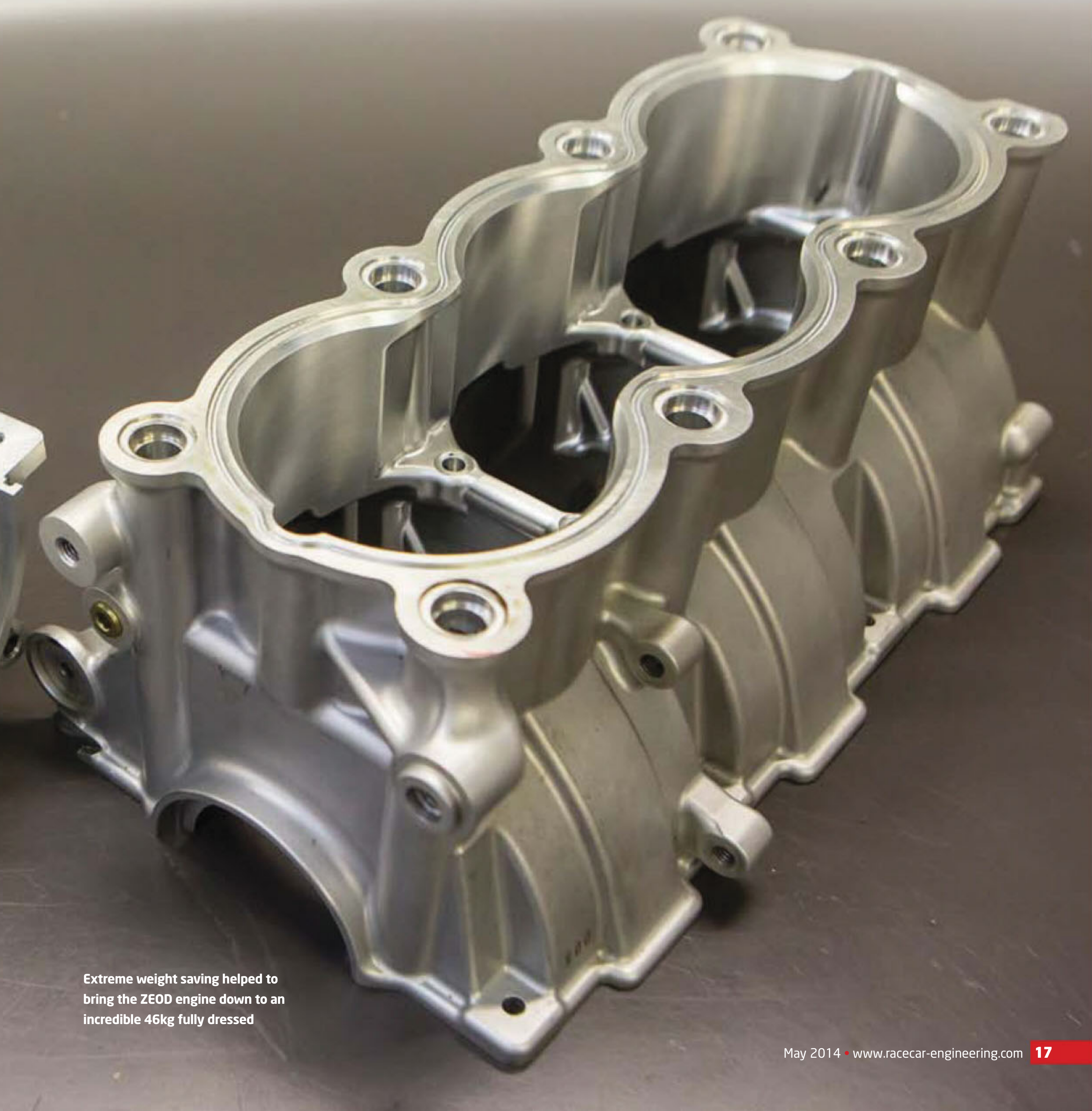
Late in January, Nissan unveiled the engine that will power the revolutionary Nissan ZEOD (Zero Emission on Demand) car at Le Mans this year. Built at Ray Mallock Limited (RML) in Wellingborough, UK, the engine's design, weight and power have all been decided by extreme targets befitting of an experimental machine.

The engine is a 1.5-litre, three-cylinder direct injection turbo engine that weighs just 40kg, although with the turbo and exhaust it is 46kg, just over half the 90kg weight of the engine that powered the lightweight DeltaWing engine in 2012. Despite the light weight, the engine is capable of producing 380Nm of torque at 7500rpm, or 400bhp, although its operating range will be closer to 360Nm of torque for efficiency.

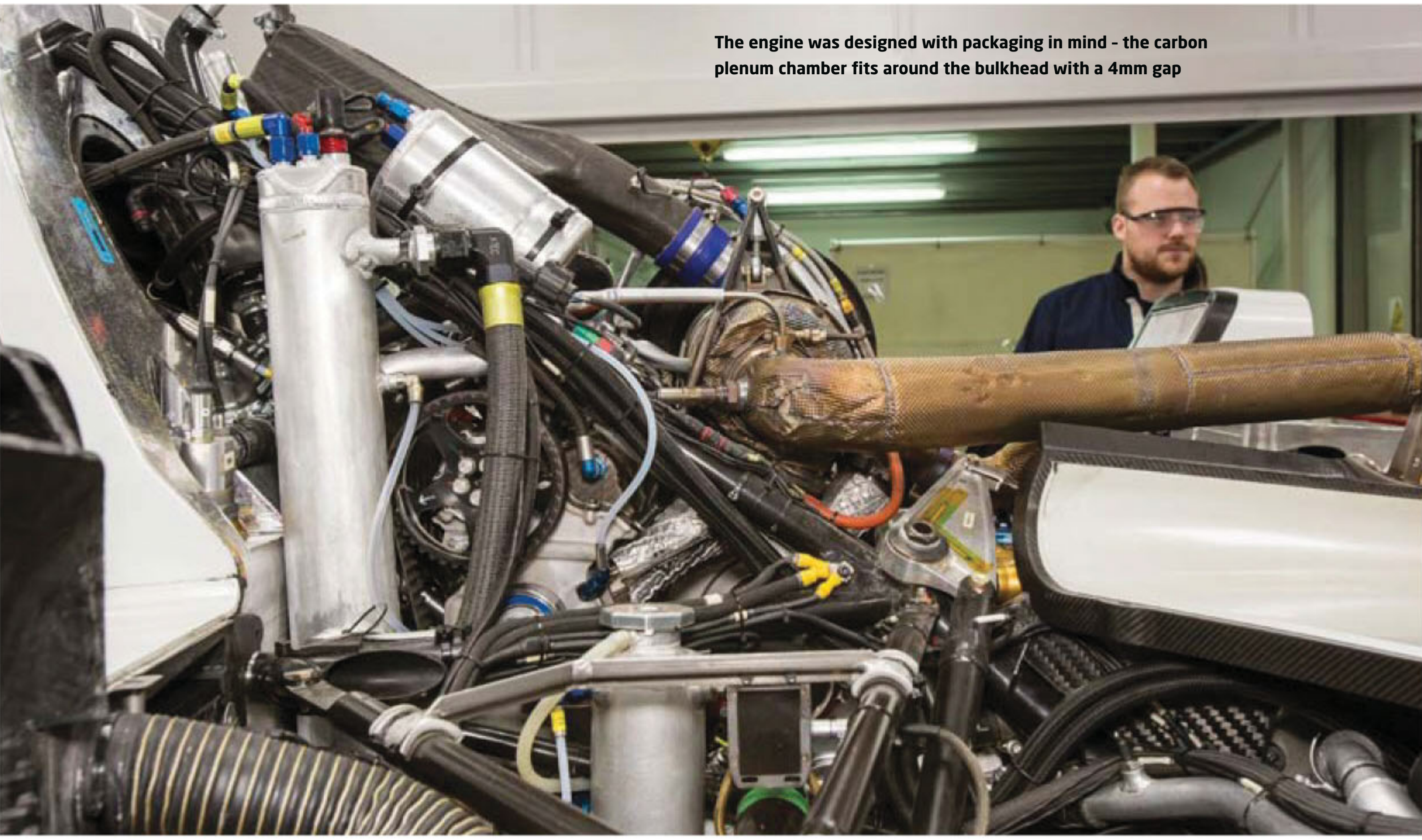
The extreme weight saving extends to all areas of the engine, from the crankshaft, the block, the configuration and even the electronics. Electronic suppliers, for example, were selected by the weight of the product rather than their applications.

'We were given a powertrain target weight,' says RML's director of powertrain, Arnaud Martin. 'Considering that we are carrying two e-motors, a huge battery, and a gearbox which is capable of housing all those items, there wasn't much weight left for the engine. We needed to design the lightest possible engine. Secondly, we wanted some efficiency targets, so what would give us the most fuel efficiency? After that, packaging, because there is hardly any room, so we needed to fit it under the rear bodywork, and they were the three driving parameters to define what the engine needed to be, which was three cylinders, 1.5-litre displacement. We defined that using 1D simulation, trying to define what best bore/stroke ratio would allow us to achieve our power.'

RML's team worked with precision engineering firm Capricorn to create the mono-block engine, which is mounted transversely and which uses 1.2 bar boost pressure. The ICE will have to run for 13 laps at Le Mans, using all the rear braking effect to charge up



Extreme weight saving helped to bring the ZEOD engine down to an incredible 46kg fully dressed



The engine was designed with packaging in mind – the carbon plenum chamber fits around the bulkhead with a 4mm gap

the batteries, which will then power the car for a 14th lap. This means that the internal combustion engine will therefore have to switch off for around four minutes, plus a minute in the pits.

'The EV motors and the controllers are still linked to the cooling system of the engine,' says Martin. 'The target is to get 50 degrees water in EV mode, and 80 degrees in ICE mode. You basically keep your components warm. You have a cool down and warm up strategy while you are out on track and then you have switch over strategies between EV and ICE, which allows you to go to EV while still cooling down the ICE until it is cool enough to be switched off. When you reach the end of the EV lap you restart it, warm it, and then at the end of the lap you switch over.'

The engine uses just 75 litres per minute of water for cooling all the systems, and the water is fed through two radiators. The right-side radiator cools the battery and the intercooler, while the left-side radiator is shared between the electrical motors, controllers, internal combustion engine, and gearbox. RML has reached an agreement with French oil manufacturer Total to develop oils for all aspects of the car, from grease for the driveshafts to battery fluids and engine and gearbox oils, to reduce friction to improve overall efficiency.

"I had an engineer spend three days trying to remove a golf ball size of material to hit the target 7kg"

The packaging of the engine is dictated by the space available in the engine bay, and even the design has the same influences. The engine is tilted backwards by five degrees and the plenum chamber specially crafted to fit around the bulkhead of the car, and even then it leads to a 4mm gap between the two.

'There is nothing from the DeltaWing engine because if you took the same concept, you would not be light enough,' says Martin. 'We worked at something new, something extreme to hit the 40kg of weight. As a result, everything has been re-engineered, and re-thought. The crank is totally different – there is no flange at the end to attach the flywheels. It is all done on the diameter of the pins, because as soon as you put on a flange, the weight increases.

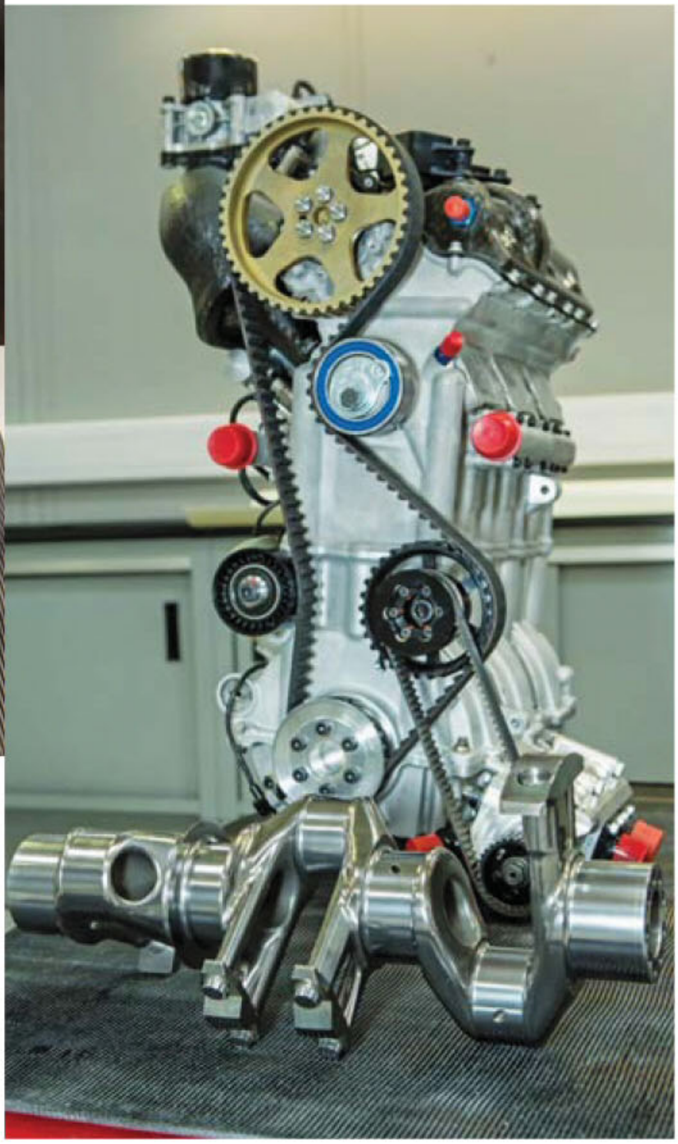
'There are a lot of things that we have never thought about using before, and as a result of this you could bore through the centre of the crank and remove all the material, and you are left with a hole, so at that point you do need to stop the oil coming out. But it can be done with aluminium or plastic bungs. Technically, if you remove those bungs you can see right through the engine.

'The crank, with tungsten balance weight, is 5.8kg compared to the DeltaWing which was 8.3kg. It is shorter, but you could take any engine from four to three, if you cut a middle cylinder – that saves you 17 per cent of weight. Even with the new crank concept we have saved 30 per cent, and it has been the same for the entire design.

'The detail in which we have gone to remove weight is mad. I had an engineer spend three days trying to remove a golf ball size of material from the cylinder head, just to be able to hit the target of 7kg.

'We have implemented a way of removing lots of material from the side of the head and then we literally have 1mm of carbon covering it all and keeping the oil in. The plenum is as light as possible, so is mainly carbon. It is small in volume just to be able to fit it in the car, and it has a weird shape to be able to put it in the car. There was no other place to put it, which is why the throttle body is above everything. You have to be uncompromising and you finish up with nothing unnecessary!'

One of the key problems with the three-cylinder engine is the vibration. By the nature of its design, the engine vibrates from side to side, and with its light weight, the effect of the vibrating force is felt all the more. 'It is quite violent, because the heavier the part, the less you feel the vibration



Top: the three-cylinder engine has undergone extensive testing and the team is confident that it will produce the magic 400bhp required
Above: the crankshaft weighs in at 5.8kg – 2.5kg lighter than that used in the DeltaWing engine
Right: the complete engine would fit into an overhead locker in an aircraft such is its size. The team is confident of reliability

as it is absorbed by the momentum of the powertrain,' says Martin. 'It is vibrating rather a lot. It doesn't seem to be such an issue. So far, it seems to have withstood the test. The battery is vibration insulated, so it is not rigidly mounted in the chassis – it is able to isolate itself from the vibration.

The engine is mounted transversely due to the packaging issue. 'In a confined space, we managed to fit the engine, gear cluster, differential, throttle body, clutch and two e-motors are housed,' adds Martin. The turbo sits between the differential and the emotors, creating an extremely hot environment. RML has created its own heat shielding which it believes works well.

The electronics for the entire car are serviced by a single ECU, provided by MoTeC but with software written in-house at RML by a code-writing specialist brought in for the project. This single ECU controls the DRS system, differential locking, the engine, and the automatic brake balance and the EV systems (e-motor controller and battery).

While brake-by-wire systems, used in Formula 1 this year, are not allowed, there is an electronic element to the braking system. By regulation, there has to be a hard link between the pedal and the brakes themselves, but with such a large amount of regeneration possible in the entire car, braking is proving to be a particular problem.

'When you do regenerative braking, there is a point where you cannot recover any more energy,' says Martin. 'This is because the battery is full or you need to reduce the pressure because of a driver request in these conditions, – you need to be able to shift the brake balance. We do that by a brake-by-wire system, which allows you to reduce the pressure on the rear brake without changing the pedal feel for the driver.'

With all of this in mind, there is also the issue of running the car on EV alone throughout the lap. The first tests of the new technology were difficult for the team, but testing is now well under way and the team has made great strides in preparation for the car's debut at the Le Mans test day on 1 June.

LEAVING THE PIT LANE

If anyone ever wondered about the complexity of a hybrid car leaving the pit lane, they should be assured that it is a complicated issue.

Within the already tight engine bay is situated a clutch. As Arnaud Martin describes, this is no ordinary clutch application.

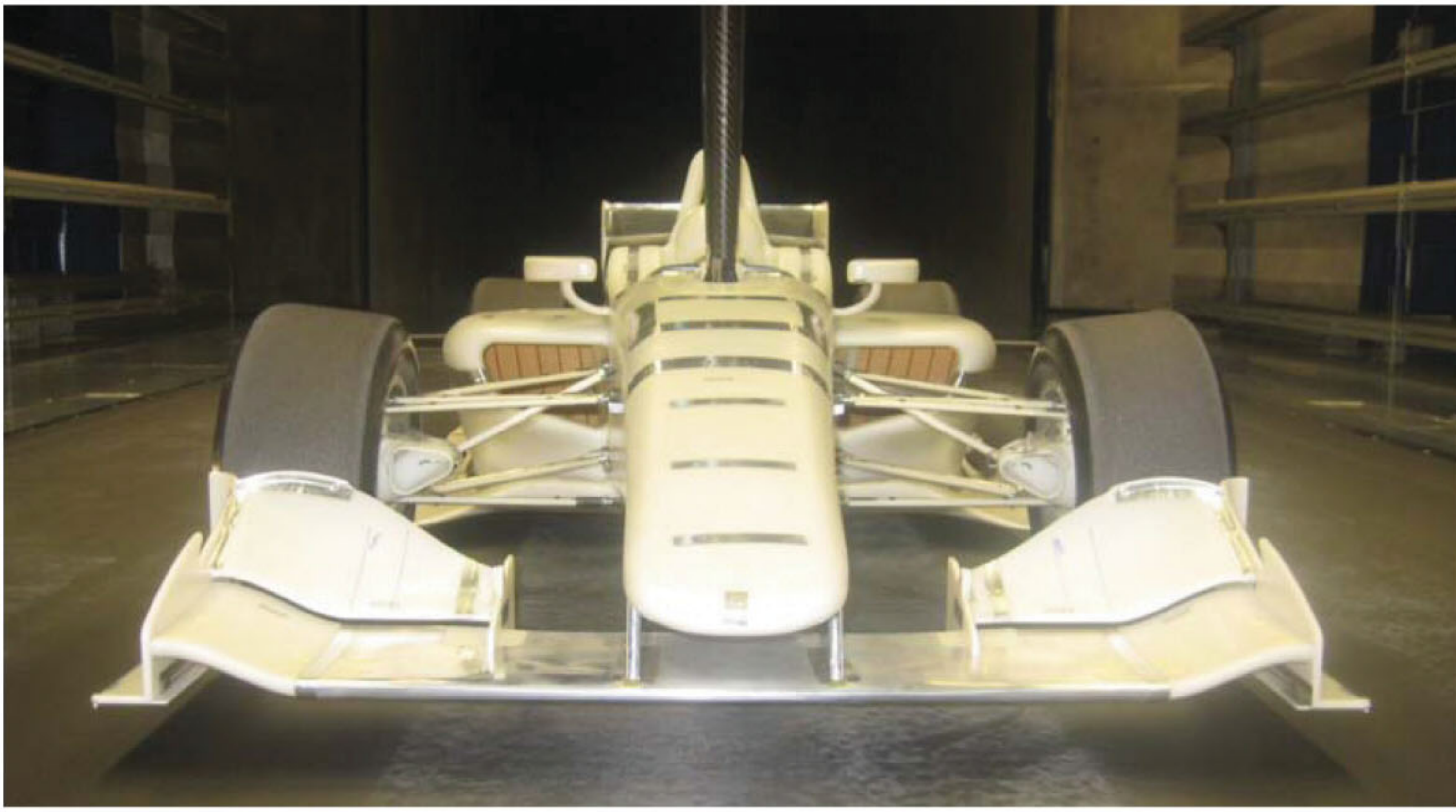
'The clutch is there to disconnect the ICE from the EV and allow us to start things and stop things,' says the Frenchman. 'It is not a clutch connected to a pedal – it is connected to the ECU and it has its own pneumatic actuator. The way the car operates, it starts driving forward on electrical power. It reaches a calculated speed, and it releases the clutch to start the ICE. The clutch closes again, the ICE continues to run on idle, and you drive on EV. You let your ICE warm up, when you reach the end of the pit lane the ICE has warmed up, and then you start to switch from EV to ICE. That is the process on a normal track. We don't use the ICE with cylinder cuts to control the car speed, we just do it on EV.

'Control for all that is done by our own software. The entire software to run this car has been written in-house. We had to find a platform because we don't make our own ECUs and found a partner in MoTeC. We use their M1.

'One lightweight ECU is controlling the whole car, so that means DRS, differential locking, we have a pneumatic locking differential so you can control a certain amount of slip, the ICE, and the brake balance.'

Raging against the dying of the Lights

Following a string of proposals from manufacturers, the organisers of the troubled Indy Lights series now feel that they've hit on a formula – together with a new Dallara chassis – that can rejuvenate the championship in 2015



Saddled with flagging interest in its top feeder category and limited funds to replace an ageing chassis, the IndyCar Series made the bold move of handing the Firestone Indy Lights Series over to a private promoter as the first step in rejuvenating the once proud championship.

BY MARSHALL PRUETT

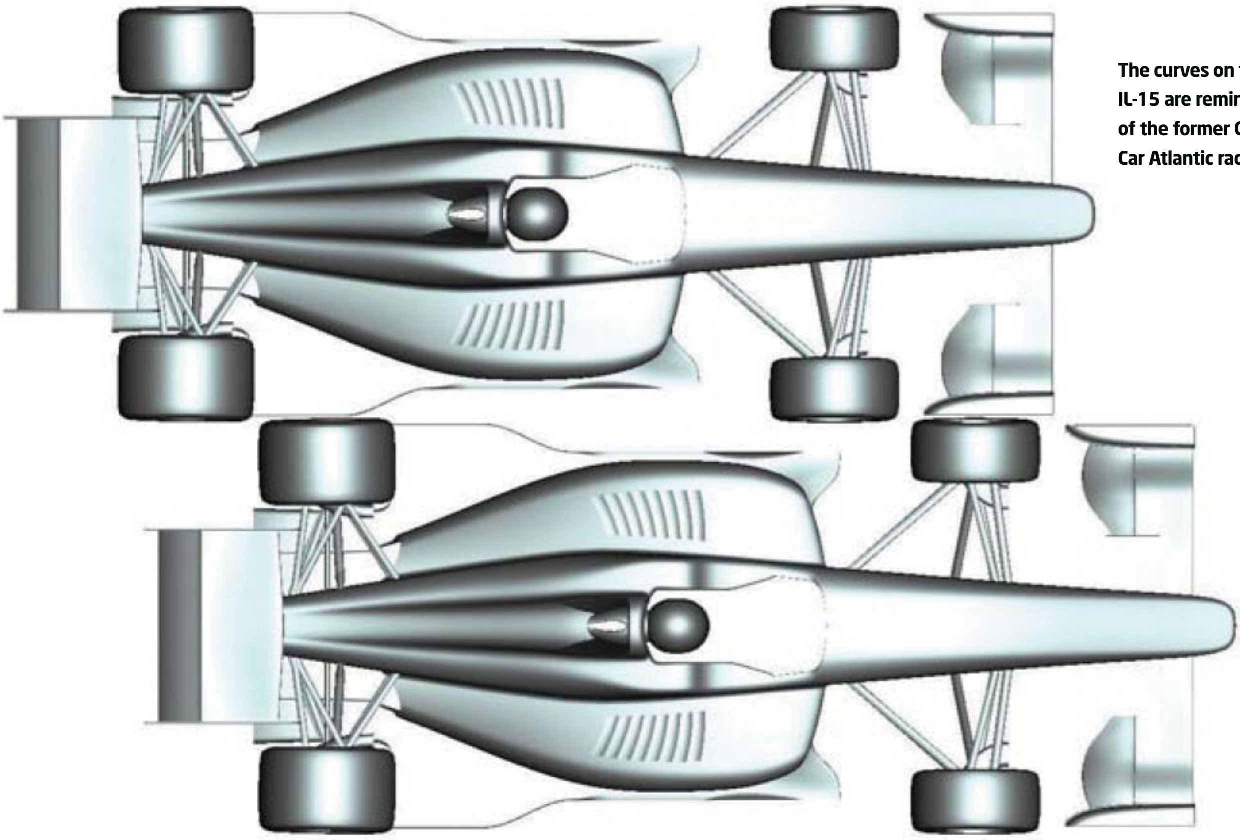
Under the control of Dan Andersen and his Andersen Promotions firm, a new plan was announced in July 2013 that would bring a brand-new chassis and engine package for the 2015 season, bringing an end to the Dallara-built, V8-powered Infiniti Pro Series chassis that went into service back in 2002.

'When we first got involved in this project, IndyCar had already gone out for new car proposals with their own request for proposal package, and they had received proposals from seven different chassis manufacturers,' says Andersen, who hired IndyCar veteran Tony Cotman to help formulate the 2015 vehicle project specs. 'When I got involved they turned all of that information over to me, I got Tony involved, we looked through it all, and decided that there were really four people that we were interested in: Multimatic, Mygale, Dallara and Swift. Multimatic were the one that IndyCar was going to choose. But then at the last minute IndyCar pulled the plug on the whole deal and Multimatic was miffed because they had kind of verbally been given a green light.'

Working through the pros and cons of the four vendors, Andersen and Cotman quickly identified which constructors would not make the grade.

'Tony wrote a new request for proposal, and our criteria were a little bit different than IndyCar's,' adds Anderson. 'We got into deep discussion with Swift. Swift's only interest was selling us all of the Formula Nippon cars that had just come off three years of usage in Japan, and refitting them to fit our criteria was an interesting proposal. We spent a lot of time on conference calls with the folks at Swift. But in the end, we decided we wanted a new car of our own. The cost was going to be similar to the Nippon cars – a fantastic car – but we decided we'd rather do a clean sheet of paper.

'Multimatic rebid, basically using the same criteria from before. And they had an interesting offer, but it was only a lease offer. In other words, teams could not own cars. Pay an annual



The curves on the Dallara IL-15 are reminiscent of the former Champ Car Atlantic racers

fee and Multimatic would lease a car each year, and they would take the car back at the end of the year. That, in my view as a former team owner, was unacceptable. At some point you need to own the car. After five years you're still paying a hundred grand a year or something like that. It just gets stupid. In the end they reluctantly agreed to give us a number to buy the car. And they had a great design, and we were comfortable with their ability, but we just were not comfortable with the price.'

A scale model of the IL-15 in the Dallara wind tunnel facility in Parma, Italy

ANDERSEN, CONSULTING

As an independent promoter, Andersen has experience running the first two steps of IndyCar's Mazda Road To Indy ladder system, as his company owns the USF2000 and Pro Mazda championship, but Dallara – despite its stature – was not an organisation he'd worked with before in any depth or detail. Once the Italian firm presented its proposal, Andersen and Cotman found some of what they were looking for.

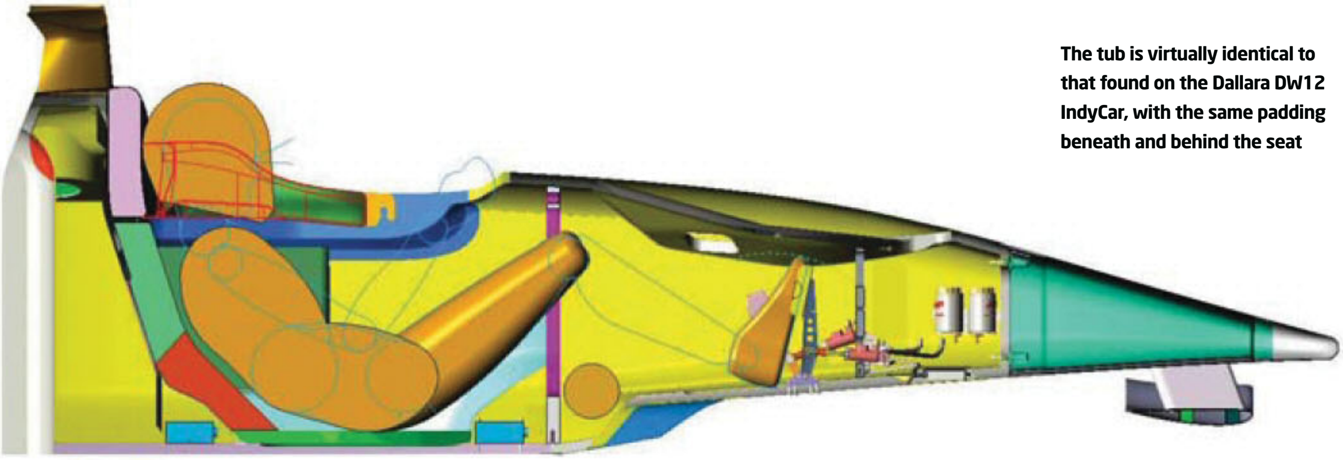
'Going into this thing I expected to not end up with Dallara,' says Andersen. 'This was no knock against the Dallara – I just thought that they were busy with so many other things. The spares pricing was an issue that we had some concerns about, based on complaints with IndyCar team owners. So we were in discussions with Dallara at the same time that we were in discussions with Mygale. The Mygale group actually gave us a really interesting proposal. They were pretty much a start-up in the US in terms of parts supply and support, and we had concerns about their costs. Designing a car is a capital investment for a company. We don't pay them for the design – we don't pay them for anything. They only get their money back when they sell racecars.

'So you need a company that has some financial strength and is able to fund probably $2m worth of design and manufacturing costs before you start seeing the money come back in. And we obviously wanted a safe racecar. I think Dallara has proven they definitely build a safe racecar. And with our criteria and hammering them at every step of the way to lower prices for our teams and drivers, I think we got pretty much everything we wanted. Since we've started working with Dallara, they have impressed me a whole lot with their engineering capabilities, and their dedication to this project.'

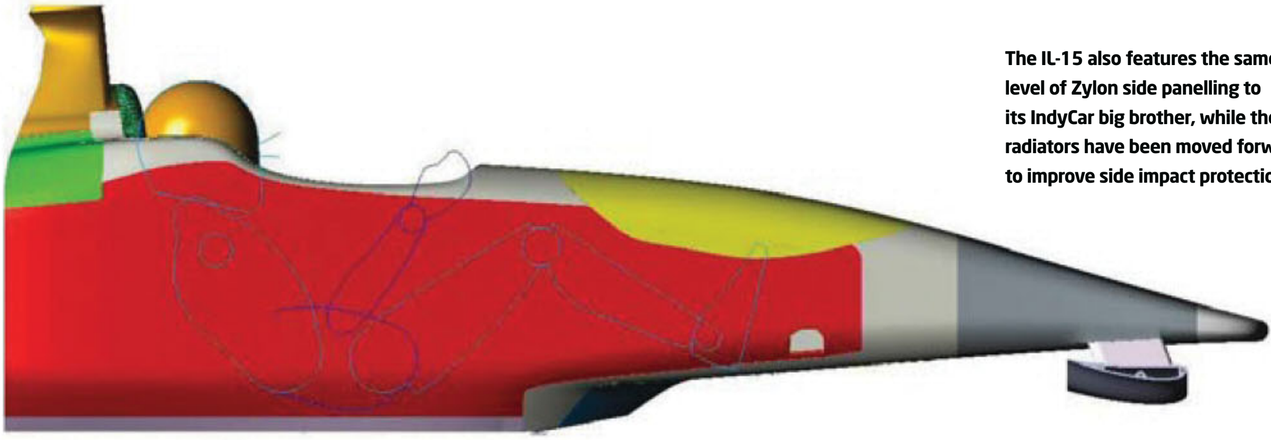
Specs for the new car differed greatly from its IPS predecessor which was crafted for exclusive use on ovals. Light weight, nimble handling, a small, powerful engine and the ability to race on IndyCar's diverse array of circuits – road, street, and ovals of various sizes – would be paramount to its success.

Although every aspect of the car's build has yet to be finalised, most of the key components and vendors have been identified. With its lack of an overhead air intake and curves that are reminiscent of the former Champ Car Atlantic cars, the shape of the Dallara IL-15 is a clear departure from anything the Indy Racing League-turned-IndyCar Series has seen.

'The first thing we really committed ourselves to was producing a modern car that could have a good lifespan of five years or so and would still be fast and relevant by the end of its lifecycle,' says Cotman. 'The old car was allowed to go on for far too long, which hurt the series, so we've been really focused on creating a car that's light, that's fast, that really pushes young drivers to learn how to get the most out of the car and themselves, and would be attractive for American kids, European kids, kids from Latin America – and indeed everywhere else – to come and drive.



The tub is virtually identical to that found on the Dallara DW12 IndyCar, with the same padding beneath and behind the seat



The IL-15 also features the same level of Zylon side panelling to its IndyCar big brother, while the radiators have been moved forward to improve side impact protection

'The series did itself a disservice in the past by marketing to its home audience, but I think the new car will be something that young drivers everywhere will want to jump in and give it try. Visually, it distinguishes itself from the [Dallara DW12] IndyCar, and we wanted something that appealed to the eye while meeting its safety and downforce criteria. I would say 85 per cent of it is as we wanted to see it and 15 per cent of it is driven by chasing data.'

Defining the IL-15's basic layout and packaging involved heavy input from Andersen and Cotman, with Dallara's Antonio Montanari leading the project from the constructor's side.

'The first thing that was quite critical was deciding what powerplant we were going to use,' says Cotman. 'And I think from the standpoint of what's relative in today's world and where we think manufacturers will be going down in the longer term, I think everybody is preaching small displacement with turbocharged engines. So that's what we told Dallara to start thinking about from a fitment standpoint. We explored a lot of options, and looked at V6s for a long time. But at the end of the day, we could build a chassis lighter, even though obviously there's a lot of weight in an engine. From the perspective of looking at it from a car that was going to be available, and a car that was going to be significantly lighter, I think the power-to-weight ratios going to be quite fantastic for drivers. But more importantly on the commercial side, what gave us the better opportunity or better positioning long-term? From that perspective we ended up with a 2-litre four-cylinder, turbocharged engine.'

Bids were received from numerous engine manufacturers, including IndyCar providers Chevy and Honda, but Andersen chose England's AER and its un-badged solution.

'I looked at the engine lease deals that everyone was proposing,' says Andersen. 'Everyone had nice motors, but there was not a lot of support being offered for the series or the champion's prizes, so I thought that if I went with AER, I'd have a bespoke engine and I could badge it with any manufacturer that wants to come along and partner with the series. It gives me options.'

"I do believe that the car will be faster. It's significantly lighter than the current car"

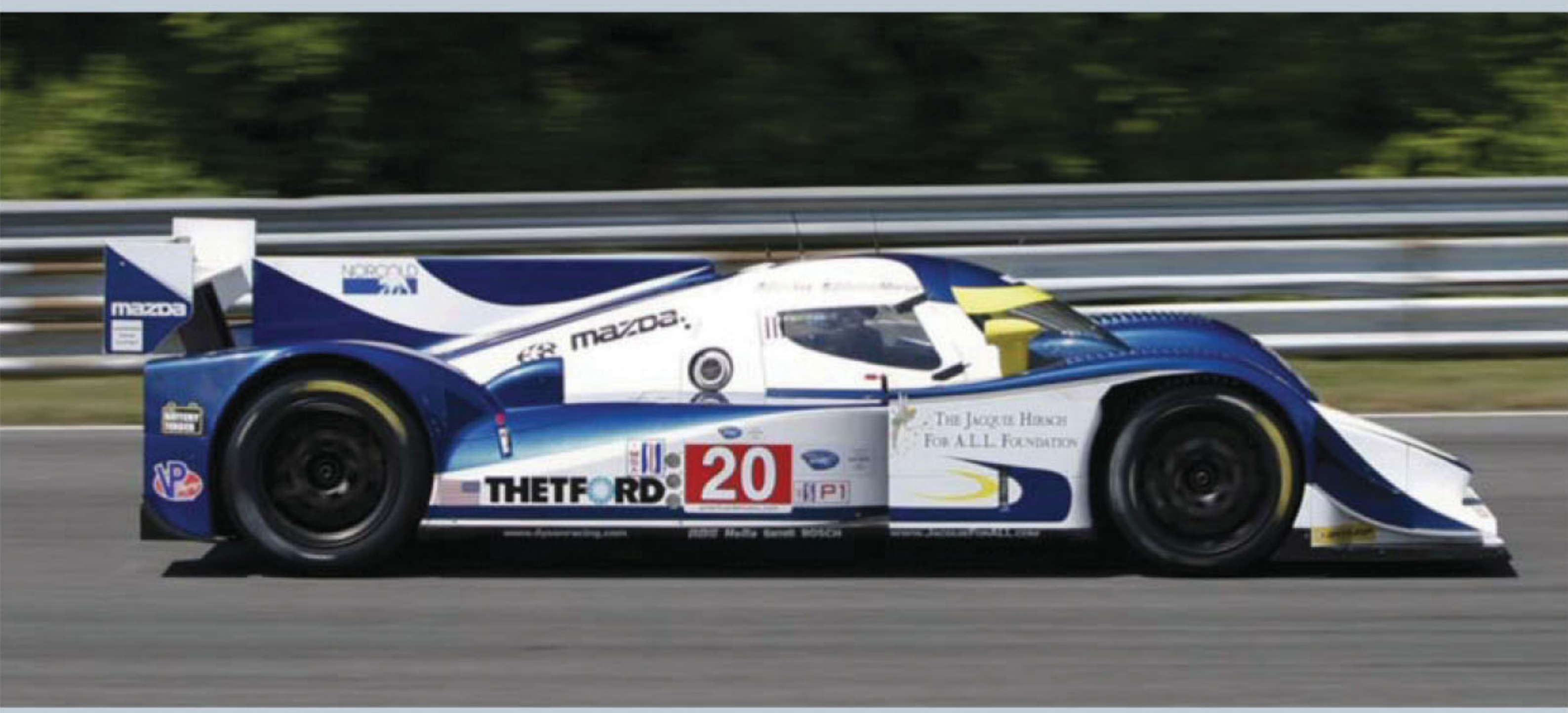
Derived from AER's P07 sportscar engine, scaleable power and longevity were key points of interest for Cotman.

'It's already light and comes from endurance racing, so those two areas are perfect for handling and keeping costs down from not having to do frequent rebuilds,' he adds. 'We're expecting to run with 450hp with an option of 50hp push-to-pass. I think we need to get out there and test, and see where we're at realistically. It's really hard to say "here's the exact amount of horsepower we're going to have". We haven't seen the final design concept of the car yet. So when we marry those two together and do a little bit of testing, I think we'll be in a position to say, okay, the final number needs to be X.

'I do believe that the car will be faster – it is significantly lighter than the current car. Therefore, lap times will decrease. We're asking to run 6000 miles between rebuilds. The boys at AER have their work cut out and I'm sure there will be some teething pains in all areas, but if you sit back for a little bit and you think of the amount of horsepower pumping out of that engine with that kind of durability, it's a pretty good achievement.'

Cotman says that the IL-15 will also feature intercooling – a system that the twin-turbo V6 IndyCar engines go without.

'We've got a lot of other challenges on this thing that we probably would never have seen before. We're running intercoolers because of the amount of boost running through a small displacement engine to achieve the horsepower we want. It's critical that the air temperature going into the engine is fixed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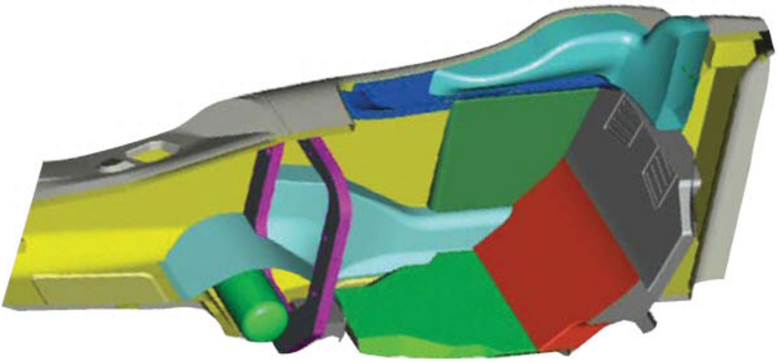
A lot of thought has been put into how the cars will interact in the event of an on-track collision



Internal impression of the bulkhead and internals, including fire extinguisher

by the manufacturer at X, so to achieve that we've got to run intercoolers. It's the standard oil and water. When you pull the top off it'll definitely be different, it's definitely designed for a reason but hopefully we end up with a clean car that is easy to work on and achieves our performance parameters.'

Downforce figures, CG, weight, weight distribution and other key numbers will be known once every component is produced and verified, but Cotman has a general idea of where the car will end up.

'Although we've targeted what we want in all those areas, it's too early to publish them as final designs are in the works,' he says. 'The big number we've been working backwards from is overall weight, which is roughly 610-615kg. I think if you compare where the current Lights car is today, or even many other top training category cars are, you can figure it's rather light.

'We've targeted the same speed of 190mph, maybe a little bit quicker, at Indianapolis. The goal long-term is to gradually increase performance. I thought it would be just absolutely the wrong thing to come out and try to plump for a big number. I just consider that stupid. So, the goal is if we can be a little faster than what they did run, fine. The goal was to run at around 190mph around the Speedway. It's a tick up from where they are now. And I think naturally, as the car is developed by teams and they get to learn it, they'll naturally increase speed. On the road and streets, I expect them to be significantly quicker.'

While many facets of the IL-15 differ from the DW12, Cotman proudly states that he and Andersen have taken what Dallara has learned about safety improvements since 2012 with its IndyCar and incorporated it into the new Lights design.

'You can basically say the tub itself is virtually identical to the Dallara IndyCar tub,' Cotman explains. 'Dimensionally, it's very spacious, it has the same thick padding beneath the seat, behind it and on the sides, and really gives the driver large cushion zones around him, exactly like the DW12. The way we looked at it, we said that it would be good if you could take your seat and jump from an Indy Lights car to IndyCar and IndyCar to Indy Lights, so that's how we've gone about the cockpit.

'Most of the cockpit specifications are really under the direction of [IndyCar medical director] Terry Trammell and [IndyCar safety chief] Jeff Horton. In the last couple of years with the IndyCar, side penetration improvements have made huge advancements, and we have the same high level of Zylon paneling going in on the new car. The DW12 is undergoing a whole range of safety updates before the season starts, and we're benefitting from this because we're taking those items and adding them in from the start.'

Cotman, along with Trammell and Horton, have also called for some changes on the IL-15 to improve upon the DW12's side impact protection.

'You'll see a lot of differences with the Lights car even to where the IndyCar's radiators are located. How the intrusion panels are fitted. The shapes of the leading edge of the underwing, the shapes of the side pod, where it's located, how it's fastened. We moved the radiators forward to add more crushable structure and have spent a lot of time making sure we're able to say this is the safest car we can make for the next generation of open-wheel stars to drive.'

"The big number we've been working backwards from is overall weight, roughly 610-615kg"

With a 40 per cent IL-15 model having begun its initial wind tunnel testing at Dallara's base in Parma, Dallara USA CEO Stefano De Ponti expects the car to accelerate towards initial track testing in July or early August.

'We also do GP3, GP2, Formula 3 and so forth, but with the IL-15, it's the first multipurpose training car we will make that is like those other categories, but will also race on ovals,' he says. 'The other Indy Lights car we made was never made for road courses, so this new car is very much a road racing car that is safe and capable for the ovals, too, and I believe that this will appeal to many people. Testing will start in summer, and everyone will have lots of chances to test and prepare for 2015.'

INTERNATIONAL PROJECT

Manufacturing of the major components will take place in Italy, while subcomponents will be produced in the company's American base in Speedway, Indiana. Andersen says that pricing on the car, the lease items and annual budgets continue to take shape, but should be an attractive option to those who aren't prepared to spend a fortune in the hopes of landing a drive with Caterham or Marussia.

'The price for the car is $232,000,' he says. 'But that doesn't include some things that you have to buy from other vendors, so we're expecting something in the $250,000 range, and things like the gearbox internals, dampers, and a few other items which carry over from the current car. The engine annual lease is $88,000 and that's all. You get a fresh engine, and more if they're needed – as many fresh engines as you need. However, AER believes that one engine will last the whole season.

'Because it's a new car and there's a capital investment involved for 2015, budgets will probably go up a little bit. It'll still be more than competitive with the European budgets, and should be just under $1m a year. Right now the budgets are running around $700,000.'

Follow us all season long on RoadToIndy.TV, the NBC Sports Network and ESPN International.

Customer Cruze

Chevrolet's new World Touring Car Championship contender is lighter, lower and faster than its predecessor, good news for its customer teams

BY ANDREW COTTON

Chevrolet enjoyed a period of dominance in the FIA World Touring Car Championship over the last few years – including titles between 2010 and 2013 – but this year the factory-blessed RML team will not be competing. Instead, it will hand over to customer teams cars that conform to new regulations, including a better power-to-weight ratio, lower ride height, and wider bodies in a bid to improve the show.

The customer cars are priced at €450,000, without the engine, which is on lease to the teams. Two teams have been confirmed to compete in the series with the Cruze. Campos Racing will run two cars, for Dusan Borkovic and Hugo Valente, while ROAL Motorsport will run cars for Tom Coronel and Tom Chilton.

The new technical regulations mean that RML's team had to almost return to a clean sheet of paper as it undertook the design process for the new car. Power has been increased from 320bhp to 380bhp, while weight has been reduced by 70kg according to the technical regulations – although the sporting regulations will change that final figure. Cars are now allowed to have carbon bonnet, roof and rear deck to help to reduce the weight, although RML engineers also managed to carve 5kg from the rollcage.

The cars have been lowered from 80mm to 60mm, leading to a complete redesign of the suspension all-round, while a more central seating position and new seat crash-testing has also led to a difference in weight distribution. The wheels have increased in size, from 17 inches to 18, leading to a new tyre from Yokohama. All of this leads to an estimated four second per lap improvement in lap time compared to the 2013 Cruze, a figure that fits with Honda's estimation of a second per km.

'The new regulations are pretty significant,' says RML's chief designer, Mark Way. 'Most noticeable from the outside is that it is a completely new aero package. The car is a lot wider – nearly 100mm – and the FIA were interested to make a car that had a more aggressive look, so the front bumper is brought forward, and the rear extended rearward.

"The FIA wanted a car with a more aggressive look, so the front bumper is brought forward, and the rear extended rearward"

JOHN BROOKS

RML streamlined their build process to reduce manufacturing time from three weeks to two. Among the WTCC regulation changes have included the seat being moved further within the chassis by 40mm. This and associated changes have affecting the position of the steering columns and pedal boxes


FIA WORLD TOURING CAR CHAMPIONS 2010, 2011, 2012 & 2013
RML GROUP

"There were some suspension geometry limitations with last year's car that we can address with a MacPherson suspension"

'The centre section of the front bumper is still standard to keep the car's identity, but it is on steroids. The centre part is as part of the Group A homologated car. From that we looked at how those changes have affected the aero around the side of the bumper and how that interacts with the rest of the car.

'We had aero numbers from the 2013 car. The numbers from the new car are significantly higher, and they will be for everybody, but overall we feel that we have done a good job to optimise to the new regulations.'

Dropping the ride height by 20mm has led to a complete redesign of the suspension both front and rear. 'There is more freedom in the front suspension,' says Way. 'You couldn't be fixed by the road car geometry, as dropping the car by 20mm you would be all over the place. The combination of a larger diameter wheel, which is also wider, and dropping the car 20mm, there are a lot of effects that have to be compensated for.'

For the rear suspension, the regulation is completely different as regulators have moved closer to the World Rally Championship philosophy, and a move to a MacPherson strut, which has allowed Cruze designers to rectify some of the issues found in the 2013 car. 'We know what last year's car's rear suspension did, and what we didn't want it to do, and we have designed out some of the failings of the old suspension,' says Way. 'There are some suspension geometry limitations with last year's car that we can address with a MacPherson suspension.

'The regulation is completely changed and is more akin to the World Rally regulations. The MacPherson strut allows you to do certain chassis modifications within the world rally regulation, and that has meant significant changes to the chassis to accommodate the suspension, such as different pick-up points. There are some limitations on the quantity of uprights that you have, and it has been designed in conjunction with the front so that there is some commonality.'

One other rally-inspired change was a new seat, moved further within the chassis by 40mm and which is now tested with the seat brackets installed. The modifications to both the location and the testing procedure led in turn to changes to the bodyshell. 'The new driver's seat has gone to the new homologation rally adopted a few years ago, and the seat can move more towards the centre line, so most of the work has been to reposition the driver, and that has some knock-on effect,' says Way. 'The move to the centre of the car – and with the seat slightly bigger and slightly further forward – knocks on to steering columns and pedal boxes.'

The regulations were supposed to be finalised in March, 2013, but delays throughout the year meant that the final version only just made it into the December World Council meeting. That left teams with little time to begin preparation of the car in time for the first race in April.

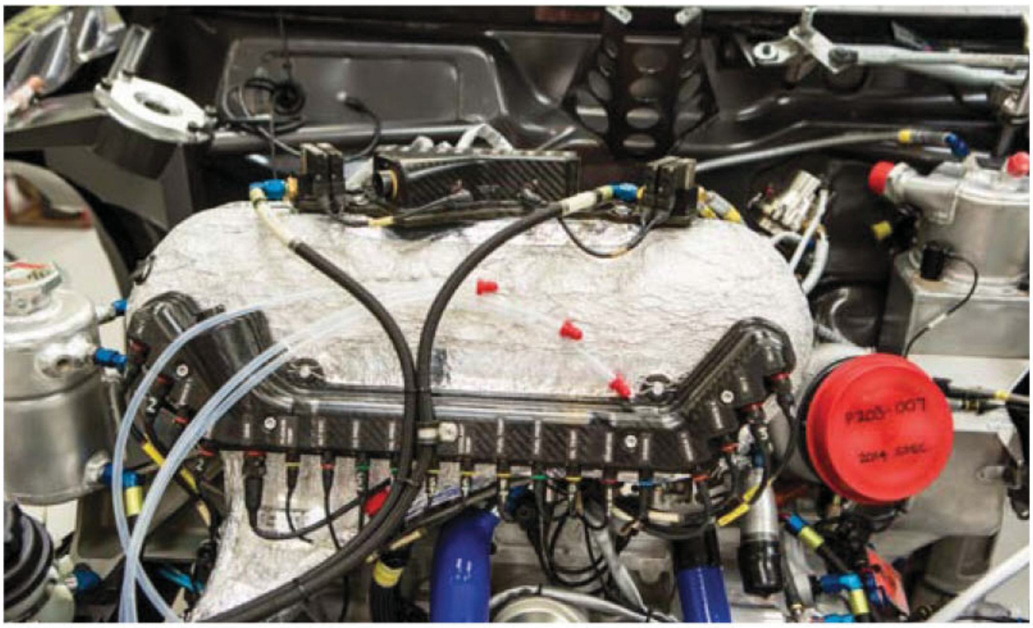
As it was, RML began the design and development process in October 2013. Homologation papers were submitted by the end of January, but it wasn't until the beginning of March that an issue with the rollcage in the 2014 Cruze was raised. A bar across the top of the windscreen was considered too far away from the roof skin, which was not a major problem to address, but did lead to a delay in the first shakedown of the car.

'The homologation issue hasn't affected us that much,' insists Way. 'We pushed the regulations as far as we could in terms of the rollcage on the 2013 car, and we were working with the FIA to make sure that

RML claim to have pushed the old regulations as far as possible on the 2013 car where the rollcage was concerned

JOHN BROOKS

An issue with a bar across the top of the windscreen resulted in a delay to the first shakedown of the car



RML tested the engine for 25 days on the dyno, before it had been installed into the car itself

they were happy with the concept for the new car. Part of that they weren't happy with, and it was to do with one of the tubes being as high as they would like to the roof skin, which we have now addressed. The process of getting the minutes of the meeting, working with the FIA and converting the cars was probably a week.'

The speed of development has been extraordinary, brought about in part thanks to a new manufacturing process at RML that substantially reduced the build time of a car. 'There are three phases to it,' explains Way. 'One is to strip all the unused bracketry, then you are on the surface plate where all the main parts get jigged, and then you start to finish everything off, and we are probably turning these cars around now in about two weeks, while normally it is three weeks. It is a significant time saving. We had to look at whether or not we had to build two jig plates and do it in parallel and we managed to do it in series.'

The increase in engine performance sounds relatively minor, but for RML's director of powertrain, Arnaud Martin, here was a new build programme that would involve more than 25 days on the dyno. The engine was validated before it was even installed in the car for its first shakedown mid-March.

'We started to do 1D simulation to make sure the basics were correct, and then we reviewed all of that,' says Martin. 'We revisited cam profiles, cam timing, updated some parts of the engine that we believed the extra duty cycle might cause to fail – like the pistons – so we changed them, tested various restrictors to make sure it was optimal, and we optimised the new turbo.

'Then we launch into endurance testing on the dyno to validate the reliability, and we validated the 2013 mileage on the dyno.

'Even when you start doing cam testing, it is a very lengthy process because you have so many cam profiles, and so many cam timings, that you say cam testing – and that is 10 days work on the dyno!'

With everything happening so late, and with the first race in Morocco on April 13, there is still a process in place that teams can update their cars this year. Using a 'joker' system, a team may change something, and then also be able to update anything else that is affected by the initial change. The only problem for RML is that – as a supplier to customer teams – it is only able to observe the FIA Technical Working Group meetings. So, while RML's influence will not have the same weight as an OEM, RML will continue to try to work constructively with the FIA for the good of the championship as the regulations and cars evolve.

'We are invited to observe the meetings, but we are not a paid up voting member of the meetings,' says Way. 'We have been actively involved in the writing of the regulations, but no matter how well you think you have written them, until someone designs a car you won't find the holes, and now we have gone through that process there will be some tightening of rules.'

Honda, Citroën and Lada – like Chevrolet – have all submitted their homologation papers to the FIA, and these have been seen by the team at RML. 'We have seen the homologation papers of our competitors – and we are confident of what we have done,' says RML director of motorsport Ron Hartvelt.

"We had to look at whether or not we had to build two jig plates and do it in parallel, and we managed to do it in series"

CHEVROLET WITHDRAWS FROM EUROPE

The customer Chevrolet Cruze WTCC programme has been signed off for three years, despite the announcement that the Chevrolet brand will not continue in Europe beyond 2015.

Chevrolet will halt deliveries in Europe as a revival in fortunes for the Opel and Vauxhall brands has rendered the brand unnecessary in Europe.

'We were working with Chevrolet trying to make this possible and we had no indication of their decision to pull out of Europe at all,' says Ron Hartvelt, RML's director of motorsport. 'We are competing in a World Championship, so from that point of view it makes no difference.'

For the RML team, the short timescale between the green light for the project and the delivery schedule meant that it had no option other than to build on an existing CAD model with the developments, and so a switch from Chevrolet would not have been possible, even if the desire was there to do so.

'For us to undertake a project like this in such a short timescale, it had to be what we have done,' says Hartvelt. 'To do something completely clean sheet would not have been possible, although this is a clean sheet design.

'We had the CFD model and have built on that, so we could put a flat floor on it, and we can then put bigger arches on it. It was a huge benefit from a timescale point of view.

'The Cruze is such an established brand in the championship that it was relatively straightforward to sell. It was the logical choice for us, and the only one available in the time when we said that we would do it!'


40
YEARS
OF INNOVATION
1974-2014

Honda's new BTCC estate

Two decades on from the Volvo 850, the Civic Tourer marks another unlikely proportioned entry into British Touring Cars

BY SAM COLLINS

One of the most iconic cars in the history of the British Touring Car Championship is the TWR Volvo 850 Estate, which contested the 1994 championship. The whole idea of racing an estate car (station wagon) was rather unlikely, and most people believed that the Volvo would be a unique oddity in the history of motorsport. But thanks to Honda, in late 2013 it was revealed that would not be the case. The Japanese firm's European arm decided that it would enter the new Civic Tourer model into the British Touring Car Championship.

Honda's works team in the series is Team Dynamics, an offshoot of Rimstock PLC and a leading supplier of aftermarket and racing wheels. The outfit had already developed the Civic into a highly successful car meeting the NGTC (Next Generation Touring Car) regulations in 2012. That design won the title in both its debut season with the works team and in 2013 with a customer outfit, so it forms the perfect basis for the new model.

'The only real change is the body shape from the B-post backwards,' explains Barry Plowman, technical director at Honda Yuasa Racing (Team Dynamics). 'Some components, like the rear door, are identical apart from the top rail. There is another 300mm of overhang on it that was not on the old car, and the shell was 25kg-35kg heavier as a base unit, so we had to kind of deal with that. The wheelbase track width and all of that was the same.'

But Plowman is rather understating the effort that has gone into adapting the estate car. Reports from the car's early shakedown runs suggested that the new design was somewhat slower than the Civic Hatch. 'Going to the longer car has its advantages as well as some disadvantages,' he says. 'We found quite early on that crossing the line for the rear to step out was much more sudden.

'With the old car, the drivers would get a lot of warning, especially in damp or cold conditions, so they could ease off the throttle to compensate for that,' adds Plowman. 'But with this car it does not give much warning, when it goes it just lets go.'

HANDLING ISSUES

Team owner Steve Neal, who has been involved in the BTCC for decades, recalls that the Volvo 850s also had the same handling issue. 'It's strange – I was reading something that reminded me about the old Volvo the other week,' he says. 'The comment from the drivers was that the back would just step out, snap oversteer for no apparent reason with very little direction change like at a chicane for example. We have found something similar with the tourer, and as we watched it we felt that there was some kind of pendulum effect taking place with all that weight at the back up high. So we played around with the roll centres a bit, but only managed to make it worse.'

This handling characteristic has now been accepted as simply part of the car's nature, and the drivers have been told to work around it. 'It's not a drama – it just means that the car is not quite as forgiving as the old one,' says Plowman. 'It's not as easy to drive as the old car – Gordon "Flash" Shedden got out of the car after the first few runs and said: "If I could have my new engine in my old car it would be perfect."'

The team say that the car is not as forgiving to drive as the old model, while particular emphasis has been placed on creating more downforce

One of the biggest differences between the Civic hatchback and the new Tourer is the engine. Under the NGTC regulations, teams have the option of fitting a spec Vauxhall-based engine supplied by TOCA and tuned by Swindon Racing Engines or developing their own. The non-TOCA supplied engines are then equalised so that in theory no engine has an advantage. As a works Honda team, it would be almost unthinkable for the Civics to be fitted with anything but a Honda-derived engine, and as a result Neil Brown Engineering (NBE) has developed a version of the 2.0-litre inline four used in the Honda Civic production car.

'This year we have introduced the VTEC [variable valve timing and lift] system, which we have never needed to do previously,' says Plowman. 'It's an attempt to get a bigger spread of torque.

"We have sacrificed outright horsepower for torque. That is what the BTCC equalisation process is based on"

We have sacrificed outright horsepower for torque. That is what the BTCC equalisation process is based on.'

Neal adds: 'The downside is that you can light the front end up easily in the wet, touch a kerb and the traction is gone. You can see why some other cars had that issue in the past with the TOCA engine, which has always had a lot of torque.'

NBE has also made some changes to the engine in the Civic hatchbacks which will be used again in 2014 by the 2013 championship winners Pirtek Racing. The camshaft has been revised, which allows the cars to have an extra 20mb of boost pressure, but the VTEC system is not used. Both the tourer and the Civic hatch engines are based around the standard Honda block.

For obvious reasons, the aerodynamic package of the Civic Tourer was a major area of focus for engineers at the Worcestershire, England HQ of Team Dynamics, which used the full-scale wind tunnel at MIRA to develop the shape of the new car. 'The Civic is a relatively high drag vehicle,' says Plowman. 'There is slightly less drag on the tourer, but the difference is very small, though the shape reduces the wake somewhat.'

All cars built to NGTC regulations have to be subjected to a standard aerodynamic test at MIRA, where the production version of the car is placed in the tunnel and TOCA officials determine where the mandatory rear wing can be fitted. This process will be further detailed in an issue of *Racecar* later this year.

However, even though a production car is used for this test, Plowman still learned about the new car's aerodynamic potential. 'When we did the TOCA rear wing test at 100mph, we found that the car had 1kg less drag for the same downforce as the hatch. It was a minuscule difference, much smaller than you would expect, though on-track at 140mph the difference would be more significant,

The Civic Tourer features a production-based 2.0-litre inline four engine developed by Neil Brown Engineering

especially on a track like Thruxton. The rear wing target figure is 27kg of downforce so its not that much but on a hot day with these cars you do not need too much. The grip is already very good with these tyres.'

Plowman feels that many teams in the championship do not realise the benefits a good aerodynamic programme, and indeed *Racecar* understands that at least one of the leading cars in the series has never been exposed to any sort of aerodynamic development at all. 'People seem to discount the aero as a performance thing in BTCC, but it's very important,' he says. 'We have always gone for as much front downforce as possible, but other people have gone for as little drag as possible, and some people just guess at it.

'The full-scale tunnel we only use to clarify what we have got, and find out where we are percentage wise front and rear and look at different wing angles. When we go to the tunnel, the drag tends to be higher than it is in CFD, and our CFD model is pretty close to the track. Thing is, once you have homologated it there is not much more you can do.'

Strictly speaking, once homologated the car's specification is fixed. 'You can adjust the cars once a year,' says Neal. 'There are regulations that govern what you can and can't do – look at the little dive planes for example. We were only allowed them as they blended in an original road car shape, but now you have people just adding dive planes on the grounds that we have them, and they let that go.

'Three-quarters of the way through last year, TOCA decided to define the shadow line of the car. Everyone understood it to be either the racecar or the road car, and you used whichever one gave the biggest advantage. So you used the road car shadow line for the undercut, and the racecar one for the overhang. In theory you could still have a 50mm undercut and a 50mm overhang, but if you measured it overall it would be over 100mm because of the way it's measured.'

Team Dynamics has been the dominant force in BTCC in recent years, and with the Tourer that shows no sign of changing. Aside from some minor teething issues at its early tests, the car has already proven very strong, lapping Brands Hatch and Thruxton faster than the old hatchback ever has. Neal believes that his team's advantage does not lie in any great secret, but is instead due to a great attention to detail.

'Mostly what we do is about negative tuning,' he says. 'In other words, we know how to get the grip out of the thing, but what you need to do is balance that grip. Sometimes you have to sacrifice grip at one end to balance it at the other. A lot of teams don't consider that – they just go for the fastest one lap setup, and they end up losing balance halfway through the race. Another thing is that we introduced a new pad from Endless to the series, because we felt that the pad we were using was not good enough. We rebuild our own dampers, and look after that for a few other teams. We take great care over every single element of the car. Some other teams can't afford that, or do not know how to do it.'

The Civic Tourer may also follow in the footsteps of the Volvo 850 Estate, which only raced for a single season. Honda will launch an all-new Civic in 2015, utilising a new VTEC Turbo engine. It seems likely that this model will be the one to contest the BTCC next season, which woud leave the Tourer as another of those almost unique oddities in the history of motorsport.

"Sometimes you sacrifice grip at one end to balance it at the other. A lot of teams don't consider that"

TECH SPEC

Honda Civic Tourer NGTC

Bodyshell: 2014 Honda Civic Tourer five-door

Front suspension: double-wishbone configuration with Penske dampers and Eibach springs

Rear suspension: double-wishbone configuration with Penske dampers and Eibach springs

Battery: Yuasa

Seat: Cobra Ultralite with Schroth harnesses

Wheels: Team Dynamics Pro Race 1.2

Engine
Model: Honda Civic Type R (K20) tuned by Neil Brown Engineering
Type: inline four cylinder turbocharged twin-overhead camshaft VTEC
Capacity (cm^3): 2000
Valves: 16 (four per cylinder)
Carburation: fuel injection – one injector per cylinder
Induction: Induction Technology Group filter and housing
Ignition: Cosworth SQ6M ECU
Power: 300+bhp
Torque: 300+Nm
Top speed: 160mph

Brakes
Make: AP Racings
Front: twin four-piston, two pad (Endless) calipers working on 362mm disc
Rear: single two-piston, two-pad (Endless) calipers working on 304mm disc
Fluid: Valvoline Dot 5.1 Brake + Clutch Fluid

Transmission
Gearbox: Xtrac 1046 six-speed sequential
Clutch: AP Racing Carbon

Lubrication: wet sump and Accusump

Tyres
Make: Dunlop
Front: 18x10inches
Rear: 18x10inches

Dimensions
Dry weight: TBC
Wheelbase: 2621mm

Fuel tank: ATL 80-litre Kevlar cell

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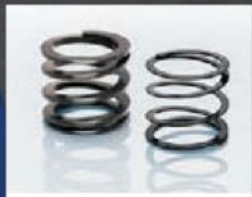
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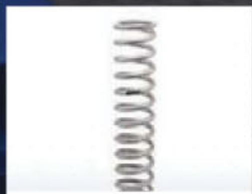
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Rotek's race against time

Faced with a short timescale to prepare for the new BTCC season, Robb Holland's firm called in a favour from Bamboo Racing

Rotek Racing took an Audi S3 and built it up to NGTC specification

BY SAM COLLINS

On the 2014 British Touring Car Championship entry list there is something of an oddity, something that midway through 2013 nobody quite saw coming. An American, Robb Holland – a native of Denver, Colorado – had raced in the BTCC before, but without much knowledge of the tracks and lacking a top line car, he struggled to be noticed. But he was not there to win – he was there quietly learning about the series and especially its Next Generation Touring Car Regulations.

At the 2013 Frankfurt Motorshow, Holland's company Rotek Racing arranged with Audi AG to have a brand-new S3 model delivered to its European HQ at the Nürburgring. Holland had decided to build the new model up to NGTC specification. His team, however, had no experience of the BTCC – when Holland had raced in the series previously it was with Team HARD. But, undeterred, he set about securing one of only 32 full season entries in the championship, signed up a list of strong commercial and technical partners – including Oakley – and started acquiring the parts needed to build a new NGTC design.

'I wanted to do everything to the best specification,' says Holland, 'I did not want to skimp on things and just take shortcuts to be able to make it to the first test – I'd much rather come when properly ready.'

"We hope we can get some engine support from Audi, but right now we need to get out and race"

NGTC STANDARD

Under the NGTC regulations, much of the car's design is standardised. The whole front and rear ends of the car are common across the grid, with tubular steel subframes all coming from a single supplier. This gives the cars identical suspension layouts with common Penske dampers and Eibach springs, though teams are free to do some rebuilding. Also mounted to the subframe (in most cases) is an Xtrac sequential gearbox – another control part – there are a host of other components used on all cars such as the brakes, wiring and onboard electronics.

Rotek has opted to use the Swindon Racing Engines spec engine supplied by TOCA. For Holland, the TOCA engine was the only realistic option and was fitted to the car just before the car was shaken down. 'The engine is one area where I hope we can get some support from Audi Sport, but that's some way down the line – right now we need to get out and race,' says Holland.

The cars all have the same width of 1875mm and use a single design front aerodynamic device incorporating flat floor, apertures for radiator, brake cooling ducts, intercooler and

Rotek opted for the spec Vauxhall-based engine, supplied by TOCA and tuned by Swindon Racing Engines

Side view of the front of the radically modified S3, demonstrating how few Audi components still exist at this end of the car

The rollcage is mated to a heavily modified production car shell, which was prepared by Willy Poole Motorsport Services

side exits. However, radiator position seems to be an area of major development for many cars, including the new Rotek Audi. The design of the rollcage is the final part of the NGTC puzzle. All of this is mated to a heavily modified production car shell, most of it having been acid dipped to reduce weight.

Willy Poole Motorsport is responsible for preparing the shells for many cars on the grid, and that includes the Rotek car. 'I was really worried when I got the shell back from there,' says Holland. 'I sent them a lovely, brand new Audi S3 and when it came back there was almost nothing left!' Around this time he was getting worried, and with little more than eight weeks before the car's scheduled shakedown run, there were major delays in the arrival of some parts. It did not look like Holland would be ready for the first race, let alone the shakedown test. So he called in some serious help.

BAMBOO SHOOTS

In 2012 Holland received an unexpected call from a young English engineer, Russell O'Hagan. Working with the Bamboo racing team, he had just arrived at Sonoma for the USA round of the World Touring Car Championship to find that the team no longer had the driver it expected to run, and the first practice session was in 24 hours time. He was advised to call Holland, who – as luck would have it – was free that weekend, and as a result became the first American to contest a World Touring Car Championship race.

Holland turned to that connection to help his BTCC effort get off the ground, and called in O'Hagan and the Bamboo engineers to get things moving faster. 'We arrived, saw what was there and what we needed, and just went round in a van and collected all that was required,' says O'Hagan. 'This is a great project as we are involved just at the right time to steer the car's development.'

The car's aerodynamics are one area yet to be fully developed. The car has done its mandatory TOCA aero run at MIRA, but its full development has yet to take place – this will be detailed in future editions of *Racecar Engineering*.

But this could actually work to the team's advantage. 'We do not have to homologate the car until later in the season,' says Holland. 'This will allow us to make changes and get data before that point. After that, we still have five jokers to use on the car's body.'

From being behind on the cars build, the combination of Rotek and Bamboo saw the car advance rapidly and it nearly shook down ahead of schedule during the BTCC media day at Donington Park. And now, Rotek hopes that once the car is fully developed that it will be able to sell versions of it to other teams.


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Into the Lites

A new open-wheel feeder series looks to offer an economical route in for drivers

High Performance Group, along with Crawford Composites, LLC, has announced the formation of the Formula Lites series and the debut of the Formula Lites Crawford (FL15) chassis.

This collaboration brings together High Performance Group's Dennis McCormack, a 43-year motorsports veteran and former IndyCar team owner, SCORE Baja Champion driver Ryan Arciero, and Max Crawford of Crawford Composites, LLC, a leader in producing autoclaved composites for the car racing industry.

The series, sanctioned by SCCA Pro Racing and scheduled to launch in 2014 at select events with a full schedule in 2015, aims to develop drivers interested in entering professional motorsports, including those who seek to make the leap from karting to open-wheel racing.

'The Formula Lites series provides economy, available resources and an emphasis on safety while giving drivers the opportunity to develop their skills to progress into higher levels of open-wheel racing,' says McCormack. 'SCCA Pro Racing was a natural partner for us, having worked so closely with them in the Volkswagen Jetta TDI Cup programme. They have a strong commitment and track record in driver development.'

Created in Crawford Composites' 48,000 sq ft facility in Denver, North Carolina by the company's design team, led by chief designer Andy Scriven, the Formula Lites carbon composite chassis is built to FIA F3 2014 technical regulations. Scriven focused on state-of-the-art technology to produce a competitively-priced, innovative and exciting chassis to pilot. The new FL15 has exceptional electronics and paddleshift designed by Crawford Composites' in-house Controls Group.

The FL15 is powered by a 2.0-litre, 210hp turbo Volkswagen engine, and tyres are being supplied by Pirelli.

'Our partner Pirelli Tires is just as excited as we are,' says McCormack. 'This is the only North American open wheel formula series they're involved in, and we all see it as a major stepping stone for young drivers towards formula racing in the US and worldwide. Formula Lites fills a huge hole in American motorsports, and the response to our announcement has been absolutely overwhelming.'

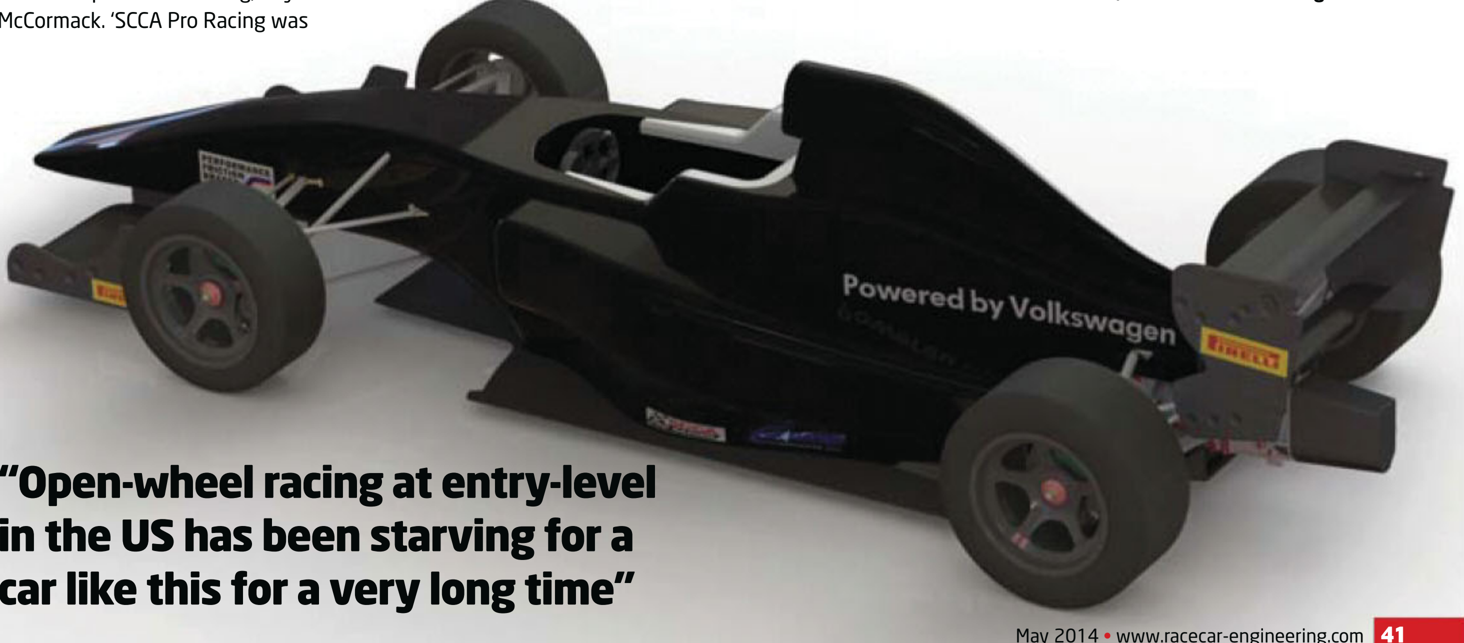
Sportscar racing legend and renowned driver, Elliott Forbes-Robinson, is overseeing the test drive programme. Each vehicle will be 100 percent ready to race when driven off from Crawford Composites' lot.

'Crawford Composites is very proud to announce the release of the new Crawford FL15 single-seater,' says Crawford. 'The Formula Lites concept has been in the making for the past two years, and we are very pleased to partner with Dennis and Felicia McCormack of High Performance Group. They have brought together very powerful partners in Pirelli and Volkswagen.'

Wolfgang Hustedt, former manager of Bosch Racing Programs, said: 'I believe that open-wheel racing at the entry level in the United States has been starving for a car like this for a very long time. We now have a platform for a hi-tech, state-of-the-art racecar at a price point that makes sense for everyone.

'Most all the open-wheel feeder series are at the point that it is just too expensive to buy and run, not to mention in cars that are outdated and not in line technology-wise with our premiere open-wheel series. Now we have that with Formula Lites.'

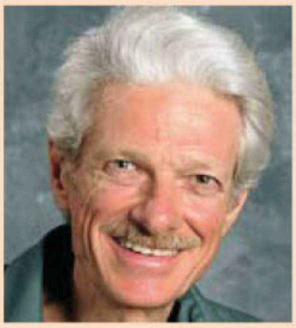
The FL15 features a carbon composite chassis, and has a 2-litre VW engine



"Open-wheel racing at entry-level in the US has been starving for a car like this for a very long time"

Rear suspension on front drive cars

Getting to the bottom of issues with a modified Nissan Tilda



Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.
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A: Mark Ortiz, 155 Wankel Drive, Kannapolis NC 28083-8200, USA

THE CORRESPONDENT SAYS

I engineer a Nissan Tiida/Versa. It's highly modified, but now I'm having issues with the rear suspension. The rear is an H-beam and it does everything I don't want it to do (toe-in in droop)!

I've been trying with stiffer and stiffer springs (front 600lb/in; rear 900 lb/in), but this solution isn't what I feel would be best. Lately I've been considering a 1100 or more rear spring rate.

So my questions revolve around the following:

- **Adjustment of an LSD with adjustable preload for less understeer in FWD**
- **How to make the car oversteer in slow corners and understeer a little in fast corners**
- **Additional links or rear H-beam redesign for racing**
- **Any tips in regards to suspension geometry to make the front end more planted?**

I feel there is very little info in regards to FWD cars and it's something a lot of people race. Maybe you could do a column in regards to FWD setup and tricks?

THE CONSULTANT SAYS

I have looked at pictures of the car's suspension online. I don't see how there could be toe change in ride. The whole thing pivots about the two bushings as a unit.

I don't see how it would have roll steer either. Such suspensions have had compliance steer, historically. Because the bushings provide lateral location and are well forward of the tyre contact patches, there is an inherent tendency for cornering force to cause the rear wheels to aim out of the turn, creating compliance oversteer. The original VW design had such compliance oversteer, but VW came up with some ingenious bushings that compensated for that, and such designs are now common in this type of suspension. I believe the original patent on the bushings has expired, allowing any manufacturer to use them without paying VW. Actually, it appears that Nissan has achieved similar effects with ordinary bushings, simply by angling them in plan view.

What are you using the car for? What sort of tyres does it run on? What is the maximum lateral acceleration you get?

I imagine you've lowered the car some. How much? What modifications to the suspension are allowed? Can you provide your rules?

THE CORRESPONDENT SAYS

Springs, bushings, uprights and bearings are free. Suspension arms must be modified from the original material but are free in shape. You can add additional links to the suspension.

All parts where the suspension arms and links mount must be original, but can be reinforced.

From reading some of your past articles and some various ideas, I think the way to go to make the car handle better would be the following:

- **Shift some weight back (we currently have 62 per cent front distribution). I was thinking of putting battery, oil cooler and others in the back**
- **Start using a front bar and reduce spring in the front. This would help with camber gain in roll**
- **Optimise rear wing to provide more downforce at required speeds. Also try to find some more downforce at the front**
- **Use a modified Watt's linkage for the rear H-beam. I would also need to modify bushing**

I think that the bushes in front, due to their angle, tend to try to bend outwards the side that is compressing. If you looked at that wheel from behind the car I think it tries to describe a circle with a centre outwards.

I might do a basic Solidworks model to test the twist and confirm this. I think VW and Nissan did this to counteract the tendency for toe out. Since the beam tends to toe in with the angle of the bushings, it cancels the toe out caused by the lateral compliance of the bushings.

The car is used for a 2-litre super touring class. We currently pull around 1.42 lat gs in the corners. Our tracks are usually twisty and depend quite a bit on cornering for good lap times.

Currently we have a 160whp motor (we are very high here in Colombia, 8000ft above sea level, and having a NA motor is very difficult). Some of the turbo cars are at around 240whp.

We use Continental Extreme Contact slicks (225/45 R15) and I might be able to pull around 1.6 to 1.7gs max. We don't have much banking and speeds are not high enough for extreme aero.

Illustration of a modified rear suspension

THE CONSULTANT SAYS

There's no harm in adding a Watt's linkage to the rear, but I'd want to do an actual bump steer test, and then a compliance steer test, to see what the system is actually doing. My guess is that in ride and in roll or one-wheel bump (no lateral force), you won't see much toe change. I expect that the steel beam is so much more rigid than the bushings that it will hold the wheels in alignment and the bushings will flex as needed to let the beam move. If the bushings were rigid, the beam would have to flex for the system to move, but hopefully you haven't tried to substitute solid cylindrical bushings for the rubber ones. You would not only get some bump steer, you'd get serious binding. Sphericals would probably work, if the angle of the mounts is within their misalignment capacity.

Ideally you'd like to get the car on a kinematics and compliance rig to see what the rear wheels actually do under a side load. In fact, I would expect that any major manufacturer has a K&C rig and has done that. As a poor man's test, however, you could try taping a bump steer plate or another nice flat piece of plate to the side of one of the rear tyres, and positioning a bump steer gauge to read toe change from that. Then use a come-along anchored to something solid to pull laterally on the roll cage at about the side view cg location to simulate lateral inertia force, and see what reading you get on the bump steer gauge.

I would also note whether the car appears to wiggle at the rear in hard cornering. If this is the case, I'd add the Watt's linkage, but I'd still want to do at least a crude compliance test before and after. If cost was no object, I'd plan on using the Watt's linkage, because there's no way it can hurt. It would probably work fine with the stock rubber bushings at the front pivots, or with sphericals. You'd only need to reposition the bushings if you want to use solid cylindrical ones.

Different or modified uprights could have real possibilities for the front. I expect you lower the car some. That always presents problems with strut suspensions, because the control arms end up with the bushings too low with respect to the ball joint.

The Nissan Tilda, which runs at altitude in Colombia

You could make new uprights with lowered pickup points for the ball joints. That would give you better camber recovery in roll, and also more geometric anti-roll. It might also be good to lower the attachment points for the strut. That might allow more suspension travel or lower ride height, provided nothing else runs out of travel. Probably the best approach would be to machine new uprights from solid. It might also be possible to build up the lower portion where the ball joint attaches by welding, and then re-machine that and reheat treat the part. Lowered billet uprights might be a part you could sell to others. You ideally want the roll centre somewhere around three inches above the ground. That might require the ball joint centre of rotation to be at least as low as the bushings, or a bit lower.You would want to lower the outer tie rod ends by a similar amount to the ball joints, to prevent bump steer. It would also be desirable to make the height of the tie rod end adjustable, so bump steer could be adjusted to suit various caster settings.

Using more front anti-roll bar and less spring will not help camber recovery, but it may make the car ride bumps better, provided nothing bottoms or runs out of travel with the softer springs. Using more spring and/or more bar, for more total front roll stiffness, will not give more camber recovery per unit of roll, but it will improve camber control by reducing roll. This will come at some cost in terms of how the car rides bumps. Other factors permitting, a reasonable rule of thumb is to try to get about half of the angular roll resistance from the bar and half from the springs.

Moving masses rearward will reduce understeer and could help braking, but will hurt forward traction. There is no escape from this dilemma with front drive. This means the optimal front percentage depends on the track. For a track with sweeping turns and no straights, more rear helps. For a track with slow turns separated by drag strips, you might want more front. Differentials for any car that pulls over 1.3g lateral acceleration are a problem. Any diff that is torque-sensitive works poorly when the inside tyre is very lightly loaded. Preloading the diff helps, but adds understeer. Making ramp angles more aggressive helps, but not as much, and adds understeer.

The only thing that works halfway decently is a locker, such as a Detroit locker. Most people don't want to put up with those for a front axle, because they create a kick in the steering when they lock. However, a front drive car with a locker can be fast, while the driver's hands hold out. Power steering offers some help as well.

This is not nearly as much of a problem when the tyres aren't so sticky. Front-drive sedans only pull around 0.85g on the tyres they're designed for. If the car has a track to cg height ratio of about 3.5, at 0.85g only about a fourth of the weight transfers to the outside tyres. The outside wheel pair then has about 75 per cent of the load.

Suppose that the car has 60 per cent of its weight on the front and 40 per cent on the rear. Then if the rear suspension has enough roll resistance to pick up the inside rear wheel, we have 40 per cent of the car's weight on the outside rear. Per cent of total on the outside front is then 75 per cent–40 per cent=35 per cent, and per cent of total on the inside front is 60 per cent–35 per cent=25 per cent. Front tyre loading is distributed 25/35, or 41.7/58.3 – fairly equal; equal enough to kill a lot of understeer and allow even an open diff to put a fair amount of power down, or allow a torque sensitive limited slip to work well.

However, if the tyres can generate as much as twice that lateral acceleration (1.7g), close to 50 per cent of the car's weight transfers. It's at the point of bicycling, or flipping. Even if the inside rear is completely unloaded, the inside front is pretty much unloaded too. At 1.5g, about 44 per cent of the weight transfers. The outside wheel pair now carries 94 per cent of the total. Assuming the car picks up the inside rear, the outside rear still has the same 40 per cent of total, but the outside front now has 54 per cent of total and the inside front only has 6 per cent of total. Front tyre loadings are now distributed 6/54, or 10/90. At this lateral acceleration, it is hard to kill understeer with rear roll stiffness. It is also very difficult to get enough load on the inside front to put power down with anything but a spool, a locker, or a clutch pack diff with a lot of preload.

Rear drive offers no real escape either. However, with rear drive at least longitudinal load transfer aids traction rather than hurting it. And a locker makes the car twitch toward oversteer when it locks – but at least it doesn't beat up the driver's hands and arms.

A front drive car with a locker can be fast, while the driver's hands hold out. Power steering can offer some help here as well

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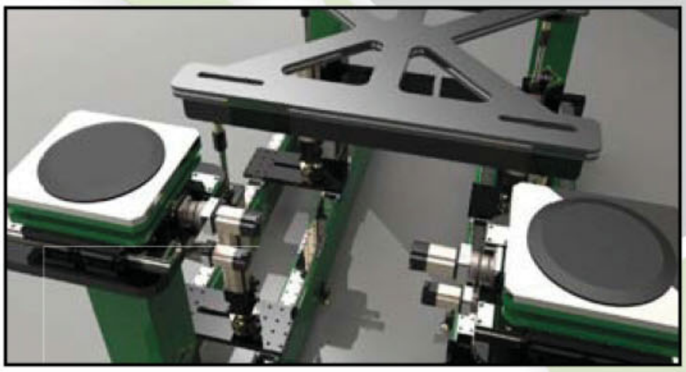

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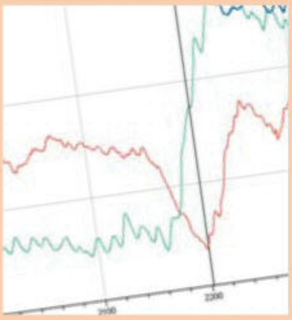

Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

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

How to deal with all the data

The World Endurance Championship relies on a mountain of data being analysed quickly – automated systems help to decipher it

Scrutineering at the top level of motorsport can be an extremely challenging exercise – regulations for race series demand a lot, and with different manufacturers and engine suppliers to contend with, there's a great deal to keep tabs on.

Looking at mechanical parts, aerodynamics and engines is difficult enough, but with advances in computer control and systems, it's increasingly difficult to monitor the electronic side of things. In some series, this has become so impractical that a single-make electronic system is the only way to make sure everything is according to the regulations.

The World Endurance Championship is a series where technical freedom is a big deal – fundamentally different technologies are allowed to compete on the same track at the same time, with excellent Equivalence of Technology. In order to monitor all competitors, each vehicle is fitted with a scrutineering data logging solution that consists of a main data logging and processing unit, data card reader and two distinct wireless telemetry solutions.

Inputs to the main processor are from CAN devices and direct sensor inputs. The scrutineering system for each vehicle is checked before every race to make sure all the systems are working as expected. As well as having the ability to send data wirelessly to the pits, the teams are expected to upload data from their systems throughout each race weekend. This applies to practice sessions, qualifying and race.

The direct sensors are used to independently monitor drivetrain

Analog Inputs (16)

Input	Conversion
An 1 Boost Sensor 1 Yellow 24 330 Ohm, Pull Down	Pressure 0-80psi Look-up Table Omega Boost Press 1 = f([x])
An 2 Boost Sensor 2 Yellow 25 330 Ohm, Pull Down	Pressure 0-80psi Look-up Table Omega Boost Press 2 = f([x])
An 3 Spares Connector Yellow 28 10000 Ohm, Pull Down	Pressure 0-2400psi Look-up Table Omega Fuel Press = f([x])
An 4 Spares Connector Yellow 29 10000 Ohm, Pull Down	Torque Sensor Look-up Table Omega Torque = f([x])
An 5 Airbox Pressure Yellow 27 No Termination	Pressure 0-20psi Look-up Table Omega Airbox Press = f([x])
An 6 Oil Catch Tank Yellow 30 No Termination	Gill Level Sensor 0-100mm Look-up Table Omega Oil Level = f([x])
An 7 Cockpit Temp Red 21 330 Ohm, Pull Down	Pi RTD Temp Coefficients Omega Cockpit T = 1146.6 - 306.1764996[x] + 1[x]^2
An 8 Sparea Connector Red 22 330 Ohm, Pull Down	EGERS Current sensor Gain & Offset Omega EGERS Amps = [x]
An 9 Hybrid Voltage Red 24 No Termination	EGERS Voltage Sensor Gain & Offset Omega EGERS Volts = [x]
An 10 Spares Connector Red 25 No Termination	Hybrid Voltage Sensor Gain & Offset Omega Hybrid Volt = [x]
An 11 Spares Connector Red 26 No Termination	Fuel Temp Look-up Table Omega Fuel Temp = f([x])
An 12 Spares Connector Red 28 No Termination	Exhaust Pressure Sensor Look-up Table Omega Exhaust Press = f([x])
An 13 Hybrid Intensity Red 23 No Termination	Hybrid ELM1 Gain & Offset Omega Hybrid Intensity = [x]
An 14 Spares Connector Red 27 No Termination	Intake Air Temperature Sen... Gain & Offset Omega Intake Temp = [x]
An 15 Spares Connector Red 29 No Termination	
An 16 Spares Connector Red 30 No Termination	

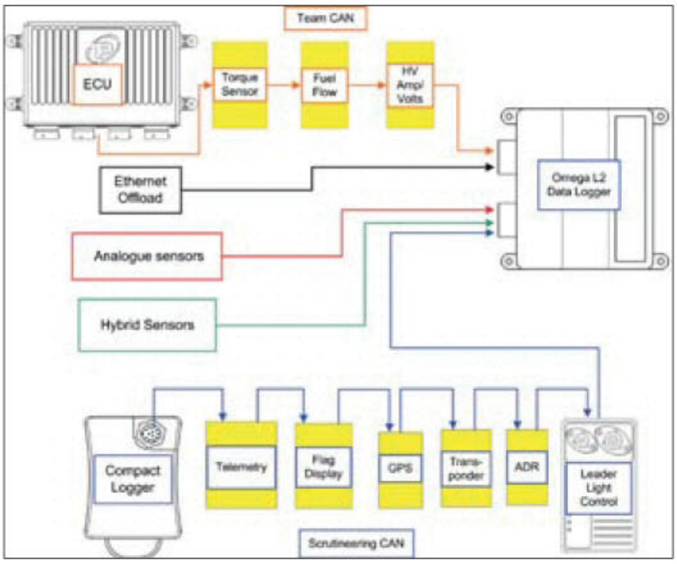

Figure 1: a simplified schematic of the scrutineering system CAN bus layout

parameters as well as the conditions inside the cockpit. Strict regulations apply related to how hot it can be inside the cars, so teams must run efficient air conditioning systems, especially for races in warmer climates. The sensors are all controlled, so that each team has an identical set of them.

CAN-DO ATTITUDE

Can buses are used extensively in the scrutineering system. There are two different buses, one is strictly for the race organiser to use and a second one connects the scrutineering solution to the vehicle control systems. A vast amount of channel data is passed on from the engine control unit on each car as well as other systems. Systems included on the CAN buses include torque sensor, fuel flow meters as well as GPS and the leader light controller.

The data gathered during each session is not only recorded in internal memory and on a removable card – there are also two wireless solutions for transmitting data. One is a conventional telemetry system that continuously streams channel data back to the pits and there is also an innovative solution which provides small data packages through the track's timing system.

In the latter case, each time the car passes a timing loop on the track, a short burst of data is triggered and data is sent back through the timing system transponder. This data is then presented on a live readout showing maximum and minimum values calculated by the main scrutineering logger.

Figure 2: example of how the main data logger calculates and then stores the maximum value of the cockpit temperature, which can then be sent to the timing system at the appropriate moment

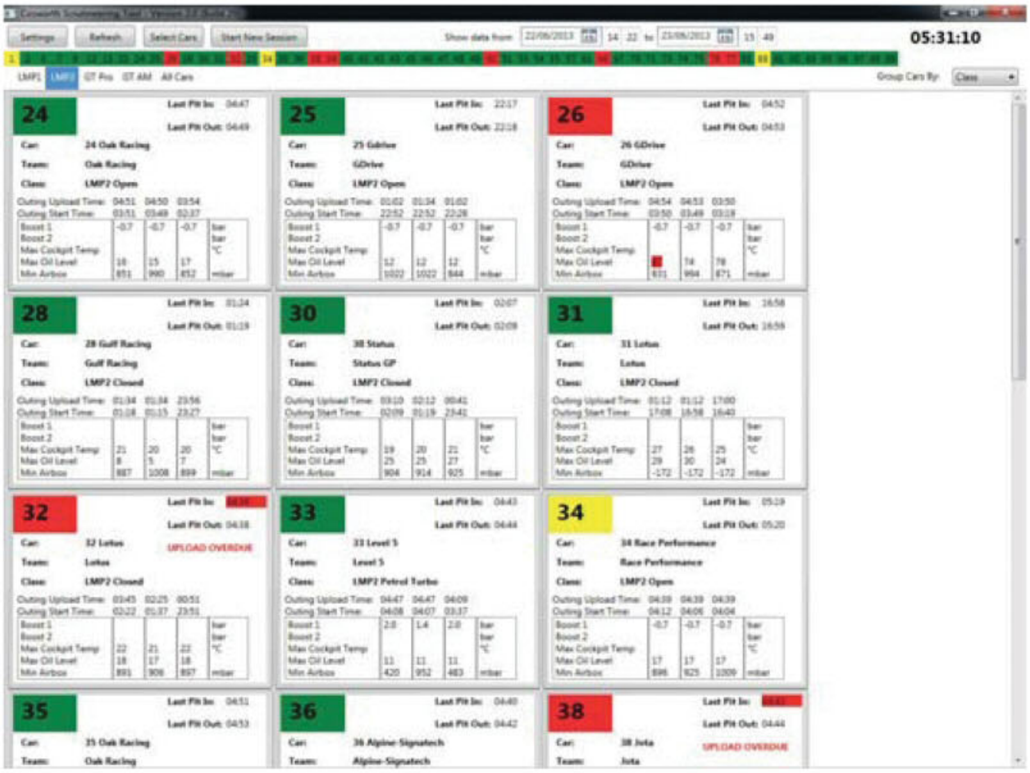

Figure 3: overview of a single class of cars – red, yellow and green indicate the status of each car. Green indicates that there is no issue or violation detected, yellow is when data is awaited, while red says a problem has been found

DROWNING IN DATA

As you might have gathered, there is an awful lot of data presented by a system such as this, and it would take an army of people to trawl through all of it. However, the data here is not only looked at by individuals but also processed automatically to produce a traffic light system which allows the scrutineers a quick overview of all the cars in order to decide which ones need a closer look.

This scrutineering solution has been in use for several years now, and has proved its value throughout its course. The above is more an introduction of its main functions and does not open the lid on many of the other very clever bits that are used to detect any anomalies. The system has grown extensively since its incarnation, but is still nowhere near reaching its technical limits.

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R1 ride heights

In the second part of our analysis of the new Praga in the MIRA wind tunnel, we examine changes in downforce

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

Produced in association with MIRA Ltd

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Website: www.mira.co.uk

Praga's stunning all-carbon R1 is set to contest the new Supercar Challenge Superlights class with normally aspirated and turbocharged versions of its 2-litre Renault powerplant. But with market forces seeing the car feature a roof, LPM coupé-style, and the company openly stating that its appearance is a blend of styling and function, what is its aerodynamic performance like? The team at Praga generously hauled one of their racecars from Slovakia to the UK Midlands so we could spend a half-day in the MIRA full-scale wind tunnel to find out.

Our baseline runs on the Praga R1 were reported in the previous issue. But to briefly recap, the car was almost on a par with the Ligier JS49 CN open sports prototype that we tested in 2009, with slightly higher drag and downforce that overlapped the lower end of the Ligier's range in our test. However, in order to facilitate quick ride height changes, the static ride height ahead of the Praga's baseline runs was said to be on the low side of practical. So let's now look at the aerodynamic performance at a more typical static ride height and also at some other ride heights and chassis rakes. First, **Table 1** compares those baseline values with those at a 10mm higher static ride height at front and rear. The change in ride height was achieved by inserting 10mm thick wood shims under the tyre contacts. And the difference between the two configurations are given in **Table 1** as 'counts' where one count = a coefficient change of 0.001.

The differences then are quite interesting, and probably the most significant change is that the front end lost 78 counts of downforce, representing about 15 per cent of the baseline value at the 10mm lower ride height. This also saw the balance change from a pretty well-balanced 36.9 per cent front in the baseline case to an 'aero speed' understeer-inducing 32.8 per cent in the +10mm case. Given that the front and rear were raised by the same amount, this loss of front downforce implies that the car's floor generates markedly forward-biased downforce. To further investigate the response to ride height changes, two further ride height increases were mapped, at +15mm and +24mm overall. The full data set is in **Table 2**.

While the general directions can be picked up from the table, plotting the data makes the trend shapes more apparent, as **Figures 1** and **2** illustrate. In **Figure 1** we can see that the drag coefficient increased linearly, if modestly, over the

Table 1: baseline coefficients compared to those at 10mm higher ride height all round

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.583	1.380	0.508	0.871	36.9	2.367
+10mm RH	0.599	1.312	0.430	0.882	32.8	2.190
Difference	+16	-68	-78	+11	-4.1	-177

Table 2: aerodynamic coefficients at four different ride heights

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.583	1.380	0.508	0.871	36.9	2.367
+10mm RH	0.599	1.312	0.430	0.882	32.8	2.190
+15mm	0.607	1.268	0.390	0.877	30.8	2.089
+24mm	0.611	1.202	0.358	0.844	29.8	1.937

Inserting shims under the Praga R1's tyres to alter ride height

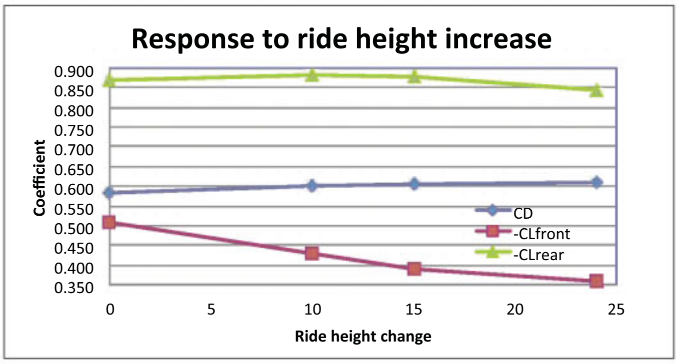


Figure 1: the effects of ride height changes on drag and downforce

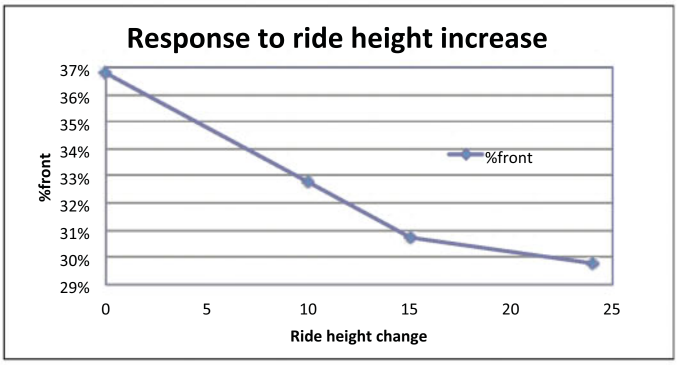


Figure 2: the effect of ride height changes on aerodynamic balance

The maximum ride height increase was 24mm at front and rear

The effect of rake was assessed by dropping the front back down to +10mm

Table 3: the effects of chassis rake, with differences in counts

	CD	-CL	-CLfront	-CLrear	%front	-L/D
+10mm F&R	0.599	1.312	0.430	0.882	32.8	2.190
+10mm F, +24mm R	0.608	1.363	0.529	0.834	38.8	2.242
Difference	+9	+51	+99	-48	+6.0	+52

first 15mm of ride height increase, but the increase then tailed off. Conversely, the front 'downforce coefficient' or -CLfront – declined quite markedly and linearly over the first 15mm then the rate of decline apparently slowed. This is the same sort of trend one would expect of a ground effect front wing, for example. Meanwhile at the rear, downforce initially increased, most probably the mechanical effect of the decrease at the front causing a modest increase at the rear that overrode any aerodynamic changes there might have been at the rear. But once above +10mm overall ride height, this trend reversed and the rate of decrease in rear downforce was steeper over the last additional 9mm of ride height, suggesting an aerodynamic cause that dominated at the rear at this point.

Figure 2 shows the response of aerodynamic balance, expressed as %front, to the changes of ride height, and it is plain that there is a linear rearwards balance shift over the first 15mm ride height increase which then declines in rate over the final 9mm measured here. Overall, however, the Praga demonstrates that generating downforce with ground proximity devices, which in this case is in essence a large plan area floor, does bring with it the sensitivity to changes in ride height.

RAKE CHANGE

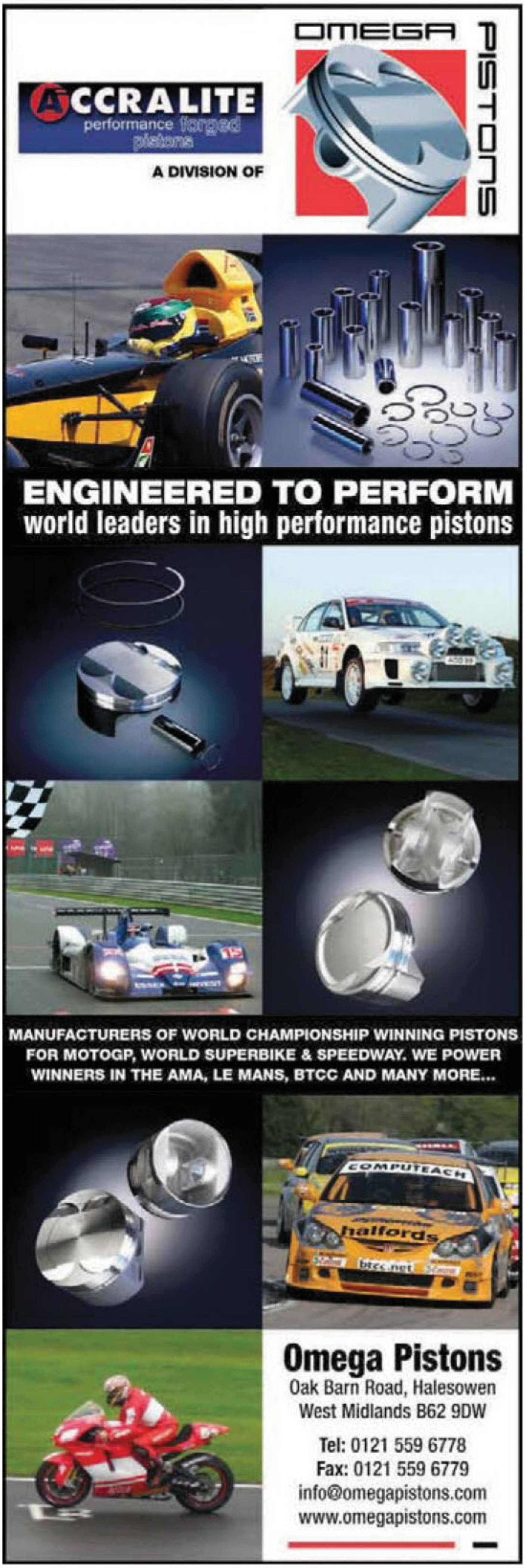
In such a short session it is neither feasible nor desirable to attempt to fully map any parameters. Instead, especially on a first visit to the wind tunnel, it is better to briefly examine a wide range of parameters for further study (and to later return to the wind tunnel for more detailed research). So after a quick look at the effects of ride heights, as explored above, one quick rake change was then made. This saw the front ride height returned to the '+10mm' setting, which realistically was the normal ride height at which the car would run, together with the rear ride height at the +24mm setting, giving a total rake between the axles of 14mm (roughly 0.3 degrees). The results compared to the +10mm setting all-round are given in **Table 3.** The key change here is the shift in balance towards the front end of the car once again, with an increase of front downforce and a simultaneous but more modest loss of rear downforce. By raising the rear at the tyre contact patches, the front splitter would of course be closer to the ground than it was in the 'zero rake' condition at +10mm ride height all-round, and this would have been partly responsible for the increase in front downforce.

But increasing the rake also generally shifts the balance forwards. And the net result here actually put a slightly greater percentage of downforce on the front end than we saw in the baseline runs at lower overall ride height, with total downforce only very slightly less than in that configuration. So running with chassis rake at the preferred front ride height of +10mm looks like a good option, and from these results it would seem that rear ride height is as useful an aerodynamic tuning tool on the Praga as it is on many other racecars. Notice, too, that as drag only increased by a small amount, overall efficiency as given by -L/D also increased.

Next month we'll examine the responses to a very varied range of configuration changes.

Racecar Engineering's thanks to the team from Praga Cars

Increasing the rake generally shifts the balance forwards, and this put a slightly greater percentage of downforce on the front end of the car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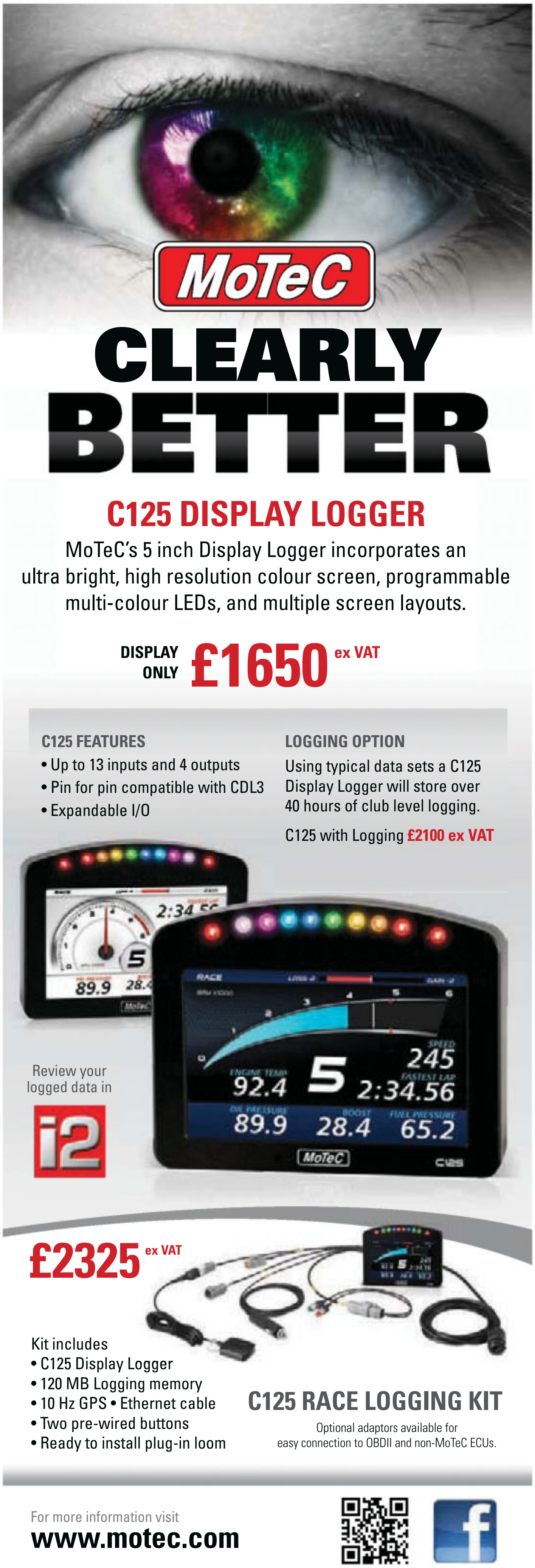
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Restarting engines

A fascinating MSc thesis from Cranfield University on the design and simulation of a Formula 1 engine as defined by 2014 regulations

BY TOM KEMPYNCK

Formula 1 is undergoing its most important transformation of the past 60 years. After an eight-year period during which engine specifications were frozen, the new regulations give engine-makers a central role in the overall performance of the car. The objective of the new regulations is to ensure closer ties between research and development in F1, the concerns of everyday car drivers and the new challenges faced on both the environmental and economic fronts. Therefore, there will be more overlapping similarities between F1 and production cars in the following areas: downsizing and turbocharging, electrification, energy efficiency and electrical energy management strategies.

This year, a Formula 1 power unit consists of a 1.6-litre V6 gasoline direct injection (GDI) turbocharged engine with two energy recovery systems. Kinetic energy is recovered during braking by the Motor Generator Unit - Kinetic (MGU-K) that is connected to the crankshaft of the engine while exhaust heat energy is recovered by the Motor Generator Unit - Heat (MGU-H) that is connected to the turbocharger. Finally to be considered, there are two important limiting parameters: a race fuel quantity of 100kg and a maximum fuel mass flow rate of 100kg/h from 10,500rpm upwards while below 10,500rpm the maximum fuel mass flow rate is defined by **Equation 1**:

$$Q\left[\frac{kg}{h}\right] = 0.009 * N[RPM] + 5.5$$

A comparison between the 2013 engine and the 2014 engine can be found in **Table 1**.

It can be concluded that efficiency, energy management and reliability are key factors of the new power unit. The reliability will be even more important in 2015 as the maximum allowed power units will be reduced to four.

AIM AND OBJECTIVES

The aim of the MSc thesis was to design and simulate a Cranfield University engine model of a 1.6-litre V6 GDI turbocharged engine that conforms with the 2014 F1 regulations by using the software AVL Boost.

The stated objectives were:

- **Study of the 2014 Formula 1 technical regulations together with a literature review**
- **Design and optimise a 1.6-litre V6 GDI turbocharged engine model**
- **Integration of the energy recovery systems MGU-K and MGU-H**
- **Create an engine spec sheet**

The methodology used to achieve the aim and objectives is represented in **Figure 1**.

PARAMETERS

There were fixed and variable parameters for the simulations as shown in **Table 2** whereby the variable parameters have been varied (eg the length, timing and lift of the camshafts).

The 2014 regulations impose limitations upon a wide range of parameters. One of these parameters is the mandatory bore (B) of 80mm and a maximum engine capacity (V_S) of 1600cc for a V6 engine that results in a maximum stroke (S) of 53.05mm by using **Equation 2**:

$$S = \frac{\frac{V_S}{6} * 1000}{\frac{\pi * B^2}{4}}$$

Table 1: comparison of 2013 F1 engine vs 2014 F1 engine (Renaultsport F1, F1 technical regs)

	2013 F1 engine	2014 F1 engine
Engine		
Displacement	2.4-litre	1.6-litre
RPM limit	18,000rpm	15,000rpm
Pressure charging	Normally aspirated, pressure charging is forbidden	Single turbocharger, unlimited boost pressure
Fuel mass flow rate limit	Unlimited (typically 170kg/h)	100kg/h (-40%)
Permitted fuel quantity per race	Unlimited (typically 160kg)	100kg (-35%)
Configuration	90deg V8	90deg V6
Number of cylinders	8	6
Bore	Max 98mm	80mm
Stroke	Not regulated	53.05mm
Crank height	Min 58mm	90mm
Number of valves	Four per cylinder, 32	Four per cylinder, 24
Exhaust	Twin exhaust outlets (one per bank of cylinders)	Single exhaust outlet (from turbine on car centre line)
Fuel	Indirect fuel injection	Direct fuel injection
Fuel pressure	Max 100 bar	Max 500 bar
Engine weight	Min 95kg	Min 145kg (engine + MGU-K + MGU-H)
Number of power units permitted per driver per year	8	5
Energy recovery systems		
MGU-K RPM	Unlimited	Max 50,000rpm
MGU-K power	Max 60kW	Max 120kW
Energy recovered by MGU-K	Max 0.4 MJ/lap	Max 2 MJ/lap
Energy released by MGU-K	Max 0.4 MJ/lap	Max 4 MJ/lap
MGU-H RPM	/	Max 125,000 RPM
Energy recovered by MGU-H	/	Unlimited

FIGURE 1: METHODOLOGY

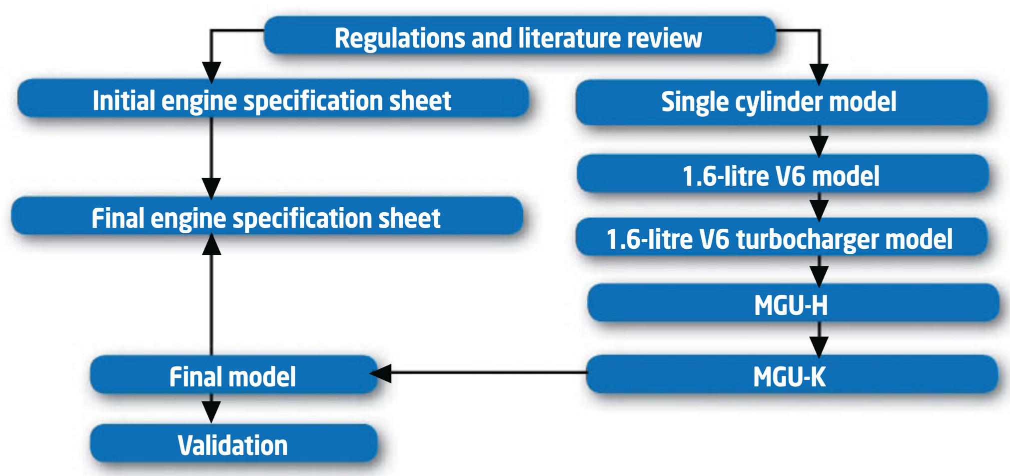
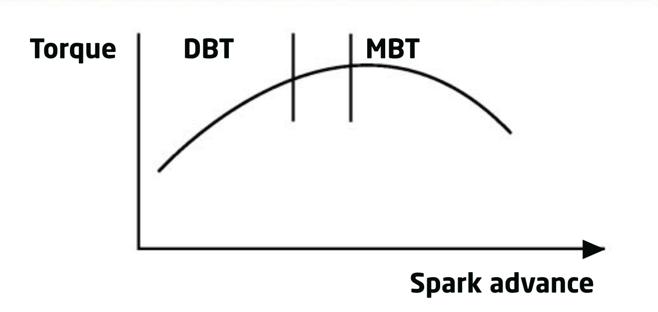


Table 2: fixed and variable parameters

Fixed	Variable
Architecture	Valve diameters
Bore and stroke	Intake and exhaust valve port lengths and diameters
Compression ratio	Intake and exhaust lengths and diameters
Con-rod length	Plenum volume
Location spark plug and injector	Intake and exhaust camshafts
Firing order	Turbocharger
Friction losses	Combustion parameters
Intercooler	PID values

FIGURE 2: SPARK ADVANCE VS TORQUE (LECTURE NOTES GLENN SHERWOOD, CRANFIELD UNIVERSITY)



The compression ratio (CR) is the ratio of the swept volume (V_S) plus the combustion chamber volume (V_{CC}) divided by this combustion chamber volume as shown by **Equation 3**.

$$CR = \frac{V_S + V_{CC}}{V_{CC}}$$

It is desirable to have a high compression ratio as it permits the engine to extract more mechanical energy from a given mass of air-fuel mixture due to its higher thermal efficiency, and hence combustion is improved by use of a compact combustion chamber. However, a higher compression ratio increases the possibility of engine knocking. This knocking or detonation can be overcome by retarding the ignition timing, but there will be always a trade-off between these two parameters.

On the one hand, the compression ratio has to be reduced compared to a NA engine in order to prevent knocking in a forced induction engine. On the other hand, a GDI engine has a higher knock-limited compression ratio compared to a port fuel injection (PFI) engine because of the cooling effect caused by the directly injected fuel into the cylinder. Therefore, it has been decided to start initially with a compression ratio of 12.

The con-rod length is controlled by the deck height of the block, pin height of the piston, crank throw and the squish height. As the power unit has to fit into a box with defined dimensions according to article 5.3.4 of the regulations, the height of the block must be limited. The following parameters have been chosen from a 3D model of this box:

- **Deck height of the block – 165mm**
- **Pin height of the piston – 22.5mm** *(influenced by the number of piston rings)*
- **Crank throw – 26.525mm** *(half of the stroke)*
- **Squish height – 1mm** *(the gap between the squish land on the piston and the fire face of the cylinder head. This results in a con-rod length of 115mm)*

A fundamental decision in GDI engines is the location of the sparkplug and the injector. There are two options for the injector: a centrally-mounted or a side-mounted injector. A side-mounted injector has been chosen because it allows a larger valve size, a lower injector tip temperature and less deposit tendency, etc. Therefore, the sparkplug is centrally located as on a conventional PFI engine. Research has been done concerning the thread of the sparkplugs that is used in F1. Webster (Technical Secrets of an F1 engine, Car and Driver, 2005) stated that the thread is about 0.3 of an inch (= 7.62mm) while Champion USA mentioned that F1 engine manufacturers will probably opt for a sparkplug thread of M8 for their 2014 engine. From these decisions, together with defined valve inclination angles and minimum required secure distances, a simple CAD model has been made to define the maximum possible valve diameters.

Something to mention here is that the simulations showed that it was beneficial to increase the exhaust valve diameter to a certain point as this allows more exhaust flow to the turbine.

The stoichiometric condition for gasoline is an air-fuel ratio (AFR) of 14.7 while the excess air ratio or lambda (λ) is the ratio of the actual AFR to the stoichiometric AFR. From practical experience and according to Bosch, maximum performance is reached with a lambda of 0.9. With richer mixtures ($\lambda<0.9$), brake mean effective pressure (BMEP) drops and brake-specific fuel consumption (BSFC) increases significantly while with leaner mixtures ($\lambda>0.9$), BMEP drops and BSFC increases slightly. For a PFI turbocharged engine, a richer AFR is used to keep the exhaust gas temperature below a certain defined limit (eg 850degC) because the materials cannot resist this high temperature.

The calibration of the lambda depends on this temperature and can vary between 0.78-0.85. In an F1 context, the engine will be made of materials that can withstand the high exhaust gas temperature, plus there is the charge cooling effect of the GDI engine. Furthermore, F1 engine manufactures will search for the optimal balance between performance and fuel consumption. Therefore, the AFR has been set to 13.23 that correspond to a lambda of 0.9.

FIGURE 3: AVL BOOST 2014 F1 ENGINE MODEL

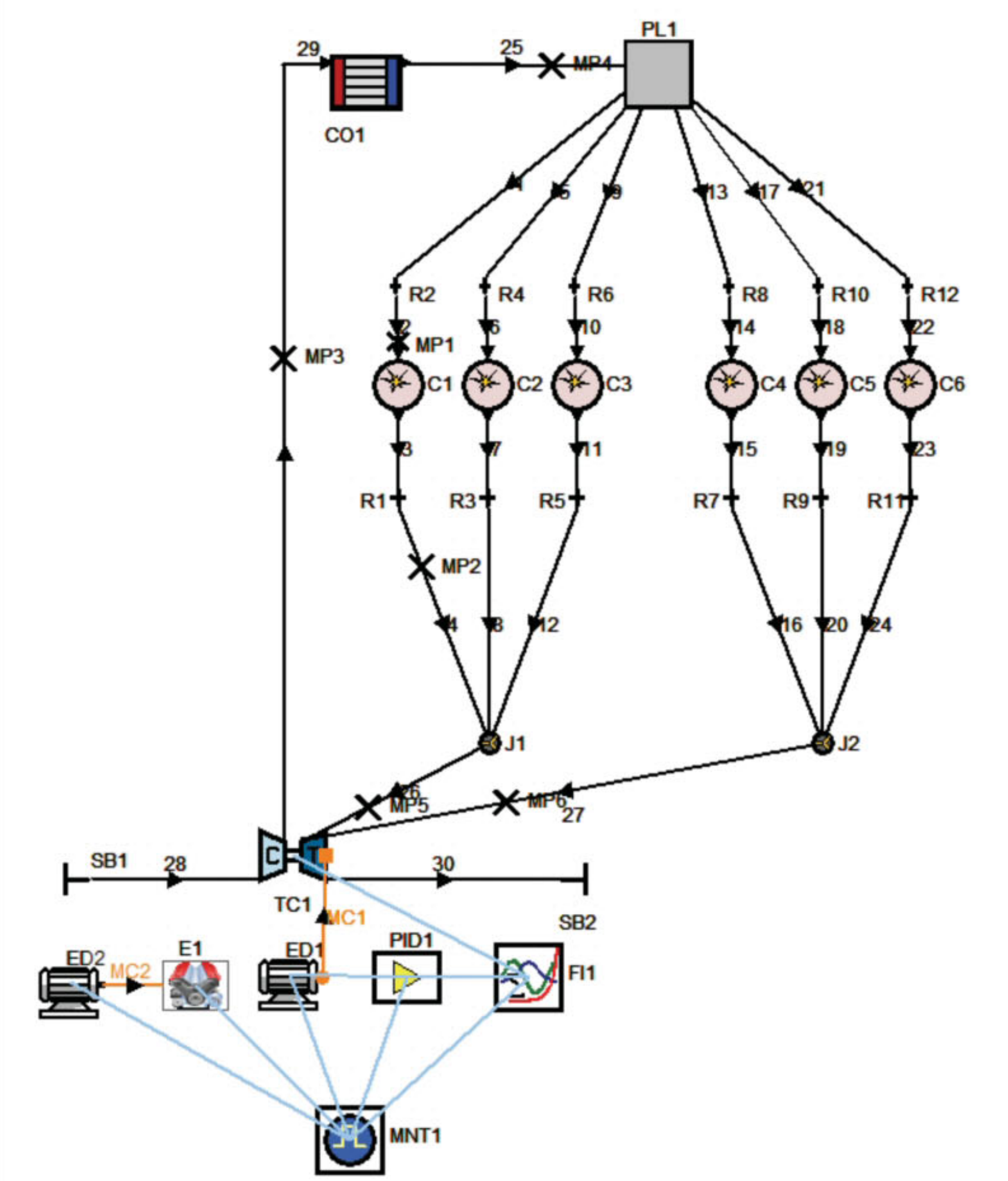


Table 3: legend AVL Boost symbols

Symbol	Name
→1-30	Pipe
C	Cylinder
C (TC)	Compressor
CO	Intercooler
E	Engine
ED	Electric device
FI	Formula interpreter
J	Junction
MC	Mechanical connection
MNT	Monitor
MP	Measuring point
PID	PID-controller
PL	Plenum
R	Restriction
SB	System boundary
T (TC)	Turbine
TC	Turbocharger

The start of combustion is the crank angle of spark advance plus ignition delay, and corresponds to 2 per cent mass fraction burned. The spark advance is the ignition timing in degrees of revolution of the crank before the piston reaches top dead centre (BTDC) as it changes with engine speed at a particular engine load. For every operating condition of an internal combustion engine, there exists an optimal spark advance that is called minimum advance for best torque (MBT), which maximises the output torque and the engine efficiency as shown in **Figure 2**.

A common way of optimising the spark advance is to advance it progressively until MBT is reached unless detonation occurs with a lesser advanced spark, then the spark advance is set to the detonation limit best torque (DBT). Detonation, or knocking, is the spontaneous ignition of the unburned gasses resulting in a rapid pressure rise. As the technical fuel partners of the F1 teams will provide a special fuel that will reduce the possibility of knocking, the SOC has been progressively increased during the WOT simulations until MBT was reached.

AVL BOOST MODEL

The AVL Boost model is shown in **Figure 3** with a legend of the symbols in **Table 3**. ED1 represents the MGU-H that is connected to the turbocharger and ED2 represents the MGU-K that is connected to the crankshaft. From the specified fuel mass flow rate limit and the specific AFR at WOT for maximum performance, it was possible to determine the maximum allowed air mass flow rate at every operating point. Therefore, it was decided to use a PID controller to manage the MGU-H that is connected to the turbocharger, therefore controlling the air mass flow rate by changing turbocharger speed.

Minimum advance for best torque maximises the output torque and the engine efficiency

The turbine has been modelled as a twin-entry turbine (one for each bank of cylinders) for the following reasons. It allows for a tidier exhaust routing keeping exhaust gas velocity higher and therefore less power loss from the combustion chamber to the turbocharger. **Figure 4** shows that Renaultsport F1 also opted for a twin-entry turbine for their 2014 F1 engine.

CHOICE OF TURBOCHARGER

Turbocharger sizing calculations were made in order to select potential turbochargers from the Garrett catalogue. The GTX3582R and the GTX3076R were chosen to be simulated because both compressors contain the most operating points within the given compressor map whereby the important operating range (10,500-13,000 RPM) falls on the high compressor efficiencies. The difference between both turbochargers is that the GTX3076R has a smaller compressor and a smaller turbine. **Figure 5** shows the calculated operating points on the compressor map of the GTX3076R. It can be seen that the compressor is operating close to the surge line at low engine speed. This surge line is the dashed line closest to the left of the compressor map. When the compressor is operating at this line, flow reversals will start to occur and the flow will become unstable. A solution for this is to


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FIGURE 4: TWIN-ENTRY TURBINE

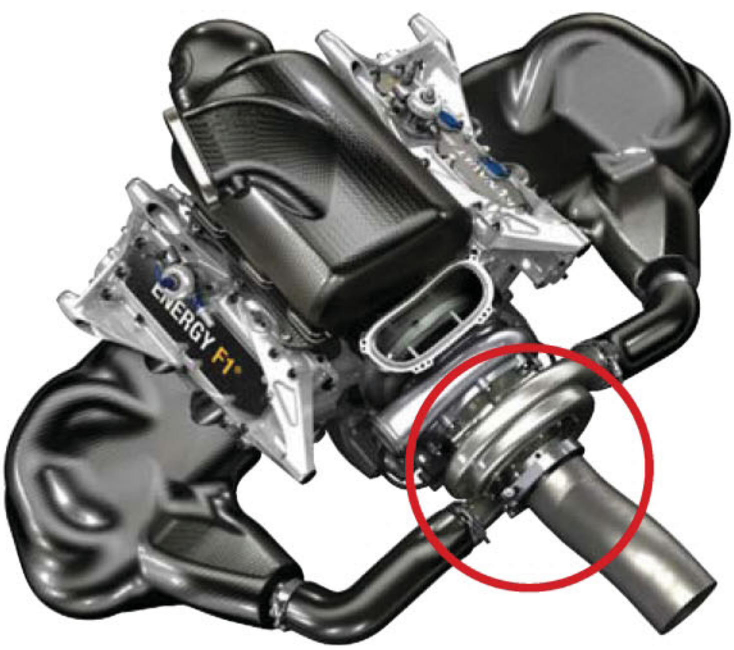


FIGURE 5: COMPRESSOR MAP GTX3076R

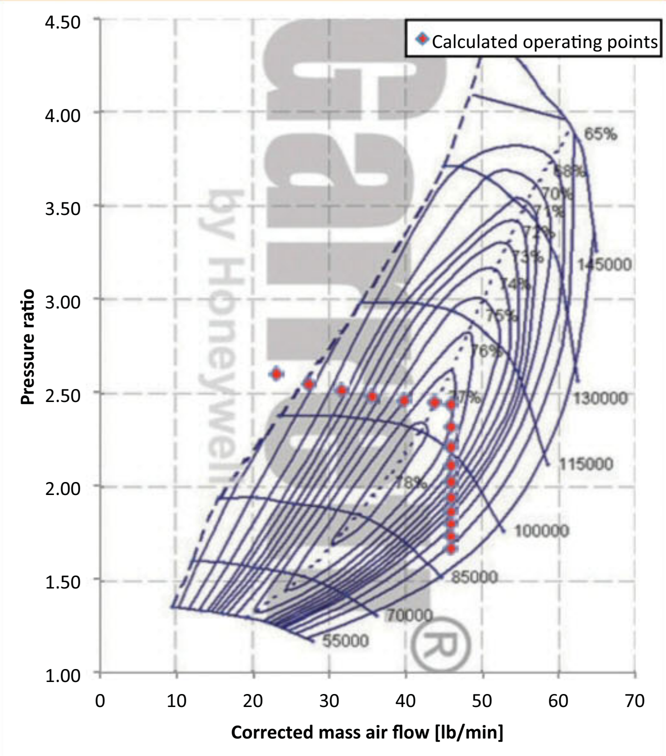
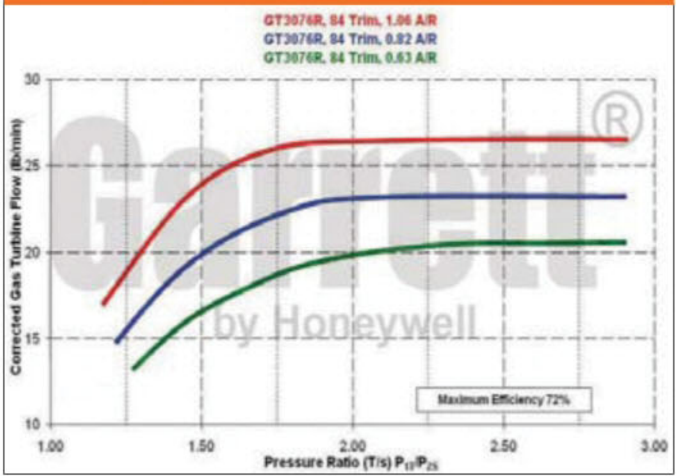


FIGURE 6: TURBINE MAP GTX3076R



use a smaller compressor or to use an inlet guide vane system to move the surge line. Finally, the GTX3076R turbocharger has been chosen because the smaller compressor was not going into surge at low engine speed while the smaller turbine made it possible to recover more energy.

When looking at the turbine map (**Figure 6**), it can be seen that it is less accurate compared to the compressor map as only the pressure ratio, turbine flow and maximum efficiency are given. So, for example, if you take a random point on the turbine curve, you do not know at which efficiency the turbine is operating at nor the rotation speed. Therefore, in order to perform a correct comparison between turbochargers, more accurate turbine maps are required.

As the turbocharger choice in the thesis was limited to those commercially available from Garrett, there is a compromise between the compressor and the turbine because if a turbine was selected whereby the calculated values are on the turbine curve, then the compressor would be too big and it would not operate at the higher efficiency (heart of the compressor map). However, a hybrid turbocharger will be used in F1 whereby the ideal compressor and turbine will be combined.

READING THE RESULTS

From the specified fuel mass flow rate limit and a specific AFR at WOT for maximum performance, it was possible to determine the maximum allowed air mass flow rate at every operating point. Therefore, it was decided to use a PID controller to manage the MGU-H that is connected to the turbocharger, therefore controlling the air mass flow rate by changing turbocharger speed. The fuel mass flow rate of the simulation perfectly matches the one specified in the regulations as shown in **Figure 7**. This proves that the target has been achieved due to the PID control.

Figure 8 shows the obtained performance values of the engine without the recovered energy of the MGU-H, but it incorporates the assistance of the MGU-H to reach the fuel mass flow rate limit. The maximum power is 454.82kW @10,500rpm, while the maximum torque is 415.48Nm @7000rpm. It can be seen that the torque remains nearly constant from 5000 until 10,500rpm due to the MGU-H assistance.

To perform a correct comparison between turbochargers, more accurate turbine maps are required

The MGU-H power curve is illustrated in **Figure 9**. Before 9200rpm the MGU-H is acting as a motor while hereafter it is operating as a generator and recovering energy.

Figure 10 displays the obtained performance with the addition of the MGU-K. The maximum power is 574.82kW @10,500rpm and maximum torque is 611.83Nm @5000rpm. It should be noted that the torque of the MGU-K @5000rpm had to be limited from 229.35 to 200Nm, because this is the maximum allowed torque according to the regulations. The power curve with MGU-K is a parallel line above the curve without MGU-K because it adds a fixed amount of 120kW. However, as the added power is constant, the added torque reduces in function of the engine speed as shown by **Equation 4**.

$$Torque\,[Nm] = \frac{Power\,[kW] * 9550}{Engine\ speed\,[RPM]}$$

Therefore, the MGU-K will be more advantageous to use at low engine speed that can

FIGURE 7: FUEL MASS FLOW RATE

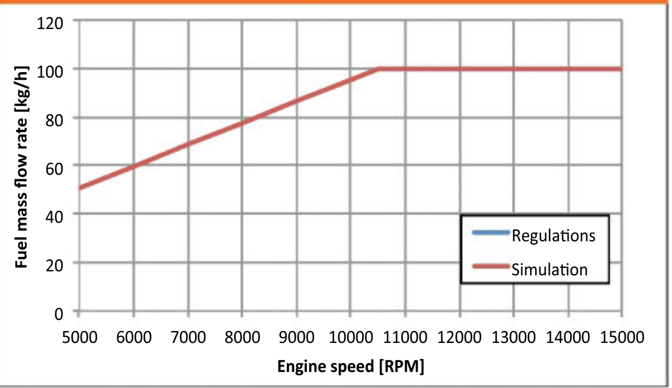


FIGURE 8: PERFORMANCE 2014 F1 ENGINE

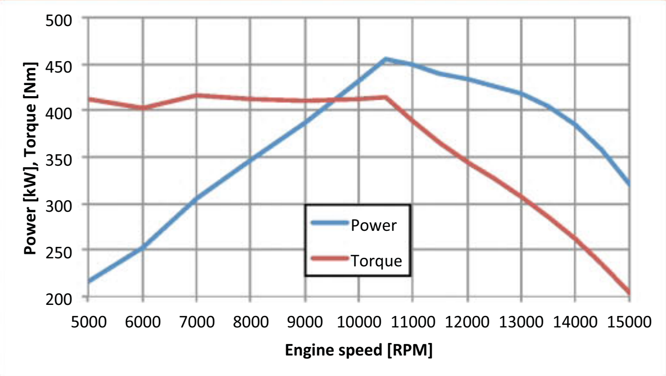


FIGURE 9: MGU-H POWER CURVE

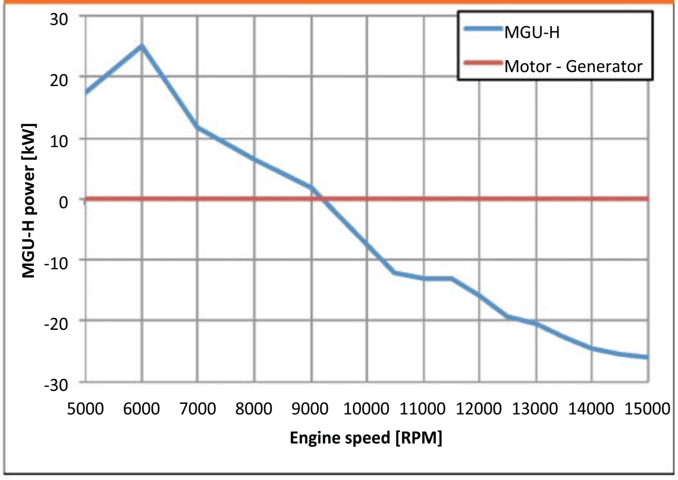
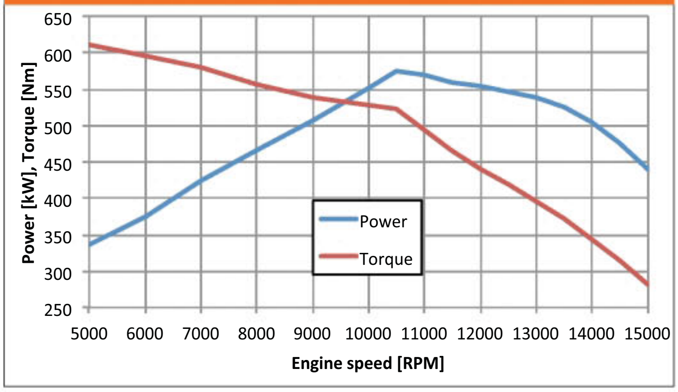


FIGURE 10: PERFORMANCE 2014 F1 ENGINE + MGU-K



then relate to a corner exit improvement. According to the 2014 regulations, the MGU-K may only release 4MJ/lap that leads to a usage of 33.33 seconds/lap (4,000,000J/120,000W) while the usage in 2013 was only 6.66 seconds/lap (400,000J/60,000W). Consequently, energy management will play a major role in performance.

RESULTS VALIDATION

Renaultsport F1 published in their press kit that the engine will deliver +/-600bhp and 760bhp with the MGU-K that corresponds to the obtained power values in the simulations of 610bhp and 771bhp with MGU-K.

CONCLUSIONS

A Cranfield University 2014 F1 engine model has been designed and correlates with the published power values of Renaultsport F1. The only drawback to the above is that the model is limited by the range of existing parts and up-to-date information.

The engine simulations showed that the maximum power is located at 10,500rpm as indicated by Renault, where the exact power curve will depend upon the real friction losses. A maximum power of 454.82kW has been attained for the model with the engine and the assistance of the MGU-H while 574.82kW has been attained combining this model with the MGU-K.

The target for arriving at a below but not above specified fuel mass flow rate limit was achieved by using a PID controller to manage the MGU-H.

It was discovered that the compressor could operate close to the surge line at low engine speed due to the fuel mass flow rate restriction. However, this surge line can be moved by using an inlet guide vane system or by using a smaller compressor.

Despite the comparison made between a smaller and a bigger turbocharger, an exhaustive comparison between turbochargers can only be made with more accurate turbine maps.

EFFECT OF LAMBDA

Following my thesis work at Cranfield, I performed simulations regarding the effect of lambda on the performance of the 2014 F1 engine at WOT. The thesis simulations have been conducted on a lambda of 0.9 as this is the lambda that delivers maximum performance. However, this is not valid when there is a fuel mass flow rate restriction and a turbocharged engine. Therefore, the lambda values from 0.8 to 1.1 in steps of 0.05 have been simulated. When the lambda is set to 0.05 leaner, the boost pressure has to increase by 0.15 bar in order to reach the fuel mass flow rate limit.

On the other side, the engine is more vulnerable to knock when the boost pressure is increased. Therefore, the spark advance has been retarded by 2 degrees for every incremental increase of 0.15 bar in boost pressure. There will be a specific point where the performance gain by increasing the boost pressure is offset by the performance loss of retarding the ignition timing and this point is lambda 1.05. Operating around lambda 1 at wide open throttle is the preferred choice as the maximum amount of energy over the entire MGU-H generator operating range may be recovered with this lambda, plus it is also more reliable for the engine to run at lambda 1 than at a leaner mixture that results in higher thermal loading. Furthermore, the amount of heat to be rejected by the charge air cooler will be less compared to that of a leaner mixture.

As mentioned before, the reliability is a key factor as only five engines are allowed for the entire season, which will be even reduced to four engines in 2015.

ACKNOWLEDGEMENTS

The MSc thesis enjoyed the support of Mr Stuart Grove as industrial supervisor (Grove Engineering Design Limited, chief engine designer F1 1994-2005 – Ilmor Engineering), Mr Clive Temple (programme director of the Cranfield Motorsport MSc) and Mr Jan Kempynck (Kempower Motorsport NV). Plus the methodology, lecture content and professional attention that I received from the lecturers at Cranfield University.

Wings at yaw

Aerodynamic performance alters when a racecar isn't running straight ahead. But what happens to the performance of wings when at yaw angles?

We have seen in some of our wind tunnel-based Aerobytes studies how aerodynamic forces and balance can alter on a racecar with yaw angles up to around 20 degrees in some instances. Aero balance can sometimes tangibly change over even quite small yaw angle shifts. But it is rarely possible to tell for certain in the wind tunnel why these changes occur, or how the forces on individual components alter. So could we use some simple CFD simulations to provide some insight?

BY SIMON MCBEATH

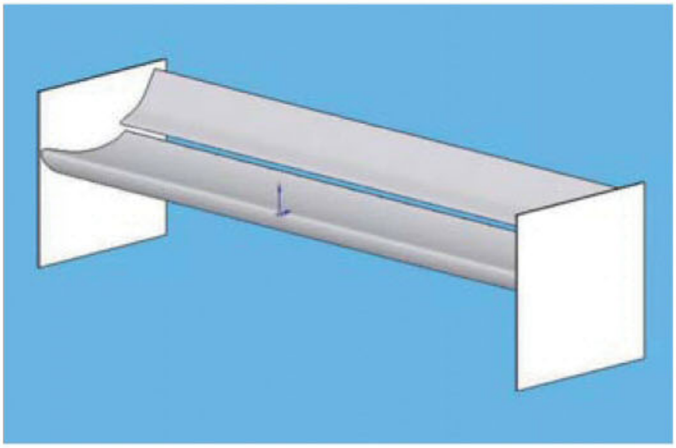
The question was catalysed by an enquiry from a category of motorsport where the objective is to maintain an extreme oversteer condition in a controlled and stylish manner, that is, 'Drifting'. But having raised that question, it seemed that looking at what happens over a wide range of yaw angles might be instructive in other on- and off-road motorsport applications.

So, a set of simple models was constructed in CAD, starting with a dual-element wing. Then a basic model of a saloon/sedan was created that utilised the dual-element wing. And finally a single-seat model with dual-element front and rear wings was examined. The plan was to see initially how the performance of an isolated wing in freestream air altered over a wide range of yaw angles, and then to look at the performance of wings on two different types of cars while also taking the opportunity to examine how the aerodynamics of the car models themselves altered with yaw angle.

The range of yaw angles used for the initial evaluations here may seem extreme. But angles of 45 degrees and more can be successfully maintained with control and 'pseudo-stability' by experienced exponents in suitably setup cars.

ISOLATED WING

The high downforce dual element wing was initially fitted with a simple, fairly deep rectangular end plate design – see **CAD 1**. This end plate depth had been shown to offer a good compromise between a useful aerodynamic benefit (at least, in a straight line) versus the inevitable extra weight



CAD 1: the dual-element wing with large end plates

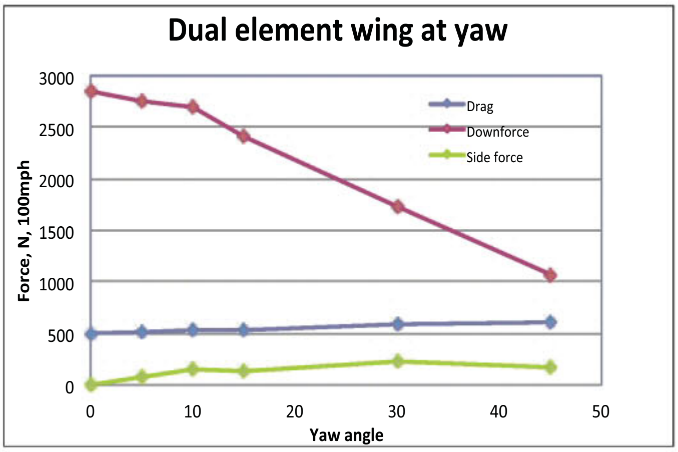


Figure 1: aerodynamic data for the 'datum' dual element wing

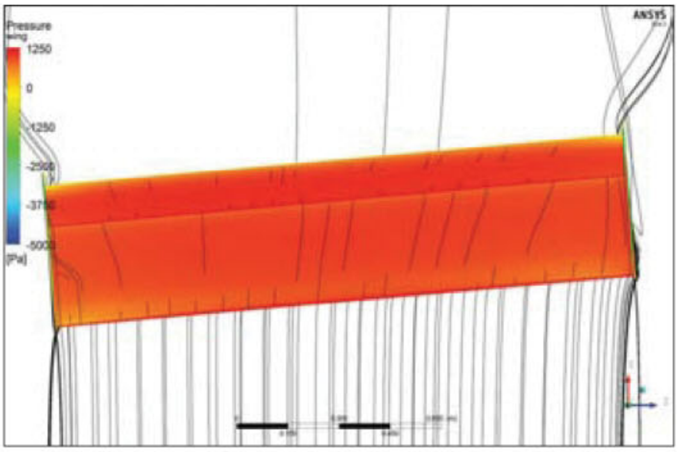


Figure 2: top view of the wing at 5 degrees yaw, flow entering from the bottom of the image; the streamlines are attached to the end plates

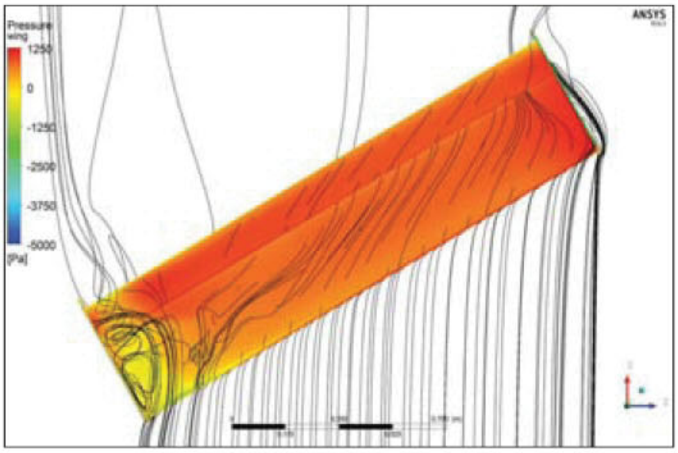


Figure 3: top view of the wing at 30 degrees yaw – note how the end plates have disrupted the aerodynamic flow

and potential loss of rigidity. But being relatively large, what would its effect be when the wing was at yaw? **Figure 1** plots downforce, drag and side force at 100mph (44.7m/s) across the yaw range up to 45 degrees.

The change to downforce saw an initial gentle decline to 15 degrees yaw, after which the decline became steeper though essentially still linear, ending up at about 38 per cent of its 'straight ahead' value. Drag initially rose gently but then somewhat more steeply, and at 60 degrees had risen by about 23 per cent from its zero yaw value. The side force was relatively modest at all angles compared to the forces on the other two axes, peaking at 30 degrees yaw on a curve that initially rose, then dipped slightly. Before attempting to comment on this slightly irregular side force pattern, we'll first examine other wing configurations, to follow shortly. But the general shape of the downforce and drag plots here do not seem unreasonable, and the changing rate of decline in downforce seemed to tally with the visualisations, which show that flow separation around the end plates only really took hold once the wing was at an appreciable yaw angle (see **Figures 2** and **3**). And at the point when separation did become marked, it was clear that parts of the wing were then in the wake of the 'upwind' end plate. And as both end plates create these wakes, it's not hard to see why drag increased.

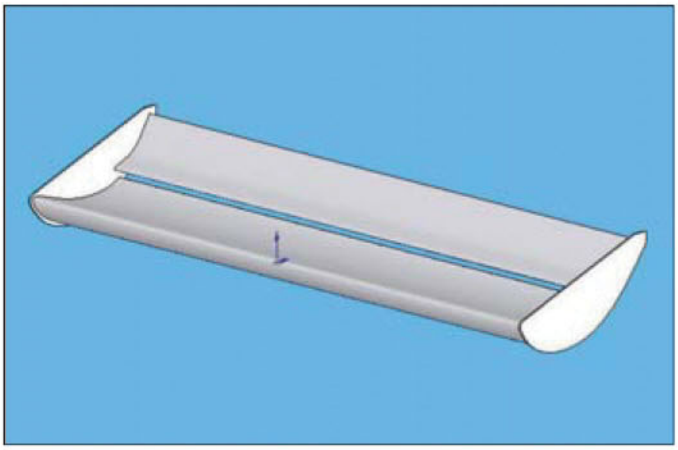
So if the end plates were at least in part responsible for the decline in downforce as yaw angle was increased, how would the wing behave with much smaller end plates? A minimalist end plate design that protruded only very slightly below the wing's suction (lower) surface, and which had less area above the pressure surface too was drawn up – see **CAD 2** – and the wing was put through the same range of yaw angles in successive CFD runs in otherwise identical conditions. The data are shown in **Figure 4**, the plot lines with the 'EPmin' suffix being those of the wing with minimalist end plates, here plotted alongside the 'datum' wing for easy comparison.

With experience, angles of over 45 degrees can be maintained with control and 'pseudo-stability'

Some quite different patterns were in evidence here. First, straight line (zero yaw) downforce was almost 15 per cent down compared to the wing with the datum end plates, which was what we would expect. Second, the decline in downforce with yaw angle was less across the full yaw range with the minimalist end plates, so that at the steeper yaw angles tested, downforce was actually higher than with the datum end plates, almost 18 per cent higher at 45 degrees and over 8 per cent higher at 30 degrees. Third, the datum end plates maintained greater downforce up to around 20 degrees even though the rate of decline with yaw angle was steeper than with the minimalist end plates. And fourth, side force – though small in magnitude at yaw – was actually in the opposite direction with the minimalist end plates, this presumably arising from a small sideways vector component from the wing's suction surface that became evident in the (effective) absence of end plates.

Already then, there could be a choice to be made here between end plates that maintained the maximum downforce at lower yaw angles, but which then saw downforce decline quite sharply once beyond 15 degrees yaw vs ones that offered a more gradual and benign response to changes in yaw angle but at an initially lower downforce level.

A device that has been seen on wings down the years is the intermediate 'fence' or 'spill plate'. Perhaps one of the best known manifestations was on WRCars, and the natural conclusion from



CAD 2: dual-element wing with minimalist end plates

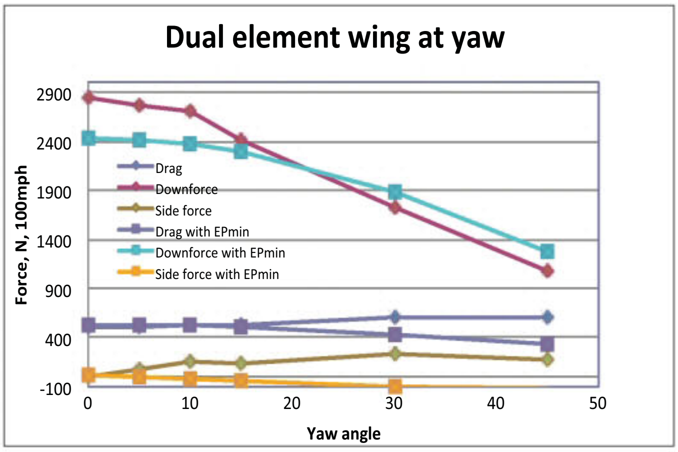
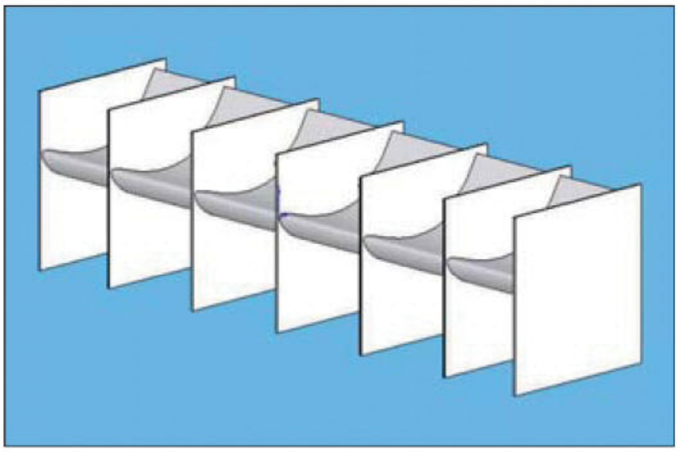


Figure 4: aero data for the wing with 'minimalist' end plates vs the datum wing



CAD 3: dual-element wing with intermediate spill plates

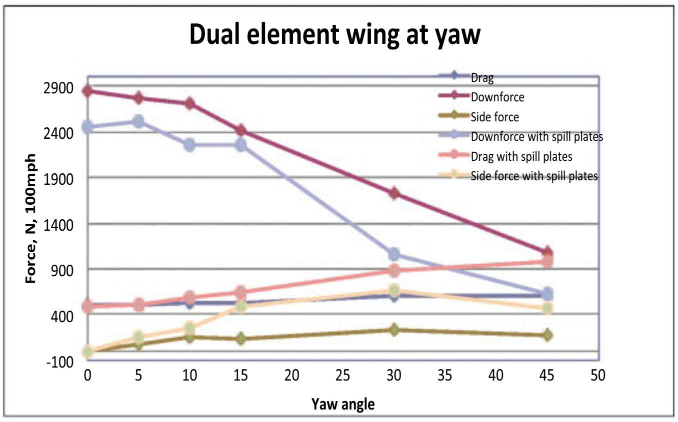


Figure 5: data for the wing with 'spill plates' compared with the datum wing

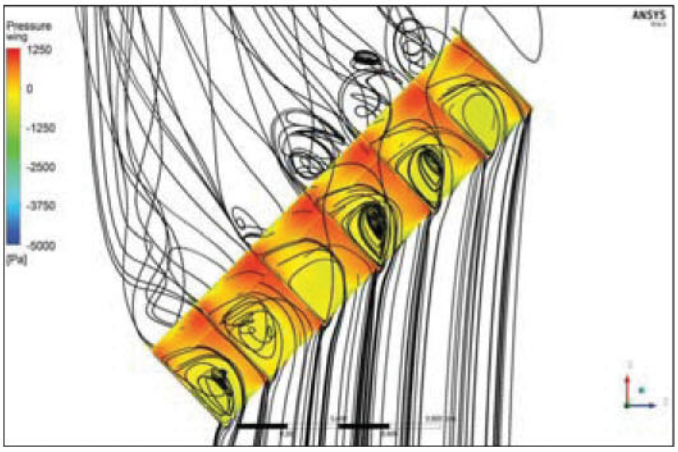


Figure 6: top view of the wing with spill plates at 45 degrees yaw, flow entering from the bottom

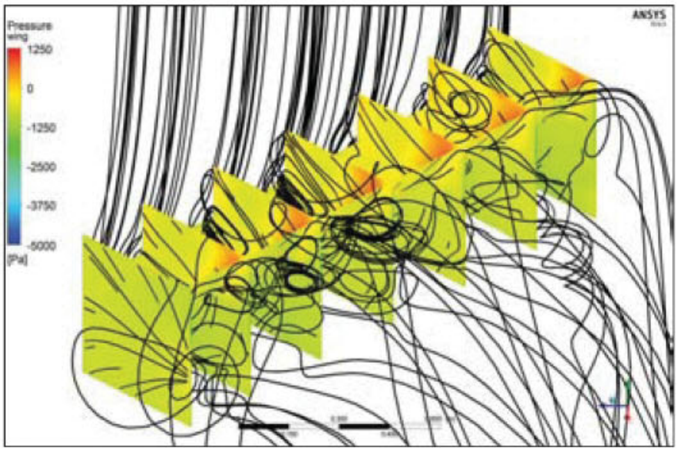
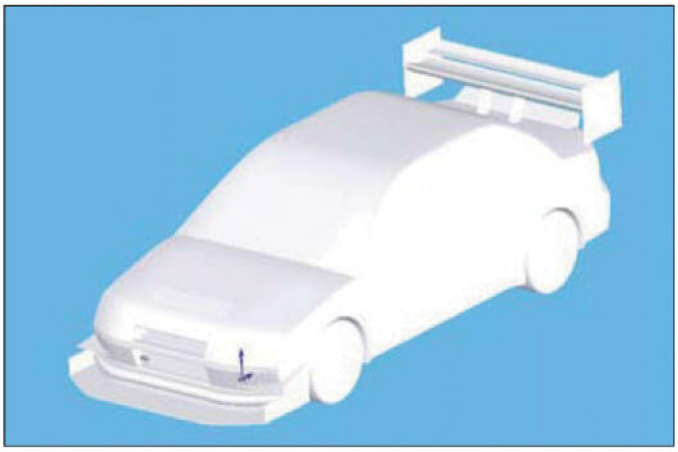


Figure 7: rear isometric view of the wing with spill plates at 45 degrees yaw, flow entering from top



CAD 4: the sedan with wing model

PREDICTING FUTURE DEVELOPMENTS

The future of F1 aero development lies with fully integrated testing development environments, with 'turn key' solutions and support – including driver-in-the-loop with hardware-in-the-loop for optimisation of the vehicle.

Efficient, correlated testing (virtual CFD/DIL to wind tunnel to track) are the main drivers which may be cost and legislation driven. I think there will be an aggressive push for enhanced efficient wind tunnel testing methodologies – things like next generation continuous motion systems, high-speed data acquisition with ultra-quick model changes and tyre shape matching.

Other areas that will grow will be shape, aeroelasticity and turbulence intensity matching of 60 per cent scale to full-scale; true cornering studies with proper interference correction methodologies (WT flap system); Flow visualisation and automatic minimal interference full flow field interrogation.

Finally I think there will be a need to closely follow regulations and development trends, such as like the likely return of full-scale tyre testing.

Professor Mark Gillan, principal R&D engineer, MTS

that application was that their role was yaw-related. Published suggestions for their purpose ranged from 'flow straighteners' to aid the wing's performance, to devices to increase the yaw-returning moment to help stabilise or to react against the oversteer condition. Another CAD model featuring five additional plates to the same dimensions as the end plates and set at regular span-wise spacings across the dual element wing was constructed – **CAD 3** – and then evaluated in CFD across the same yaw range as the previous models. The data is shown in **Figure 5** and plotted alongside the datum wing's data.

Once again, straight line (zero yaw) downforce was down compared to the datum wing, and the CFD visualisations showed that the intermediate fences created their own wakes that locally reduced the magnitude of the suction on the wing's lower surface. Then, as yaw was applied, the response with the spill plates was more irregular, but not totally dissimilar to the datum wing's response. Drag started off much the same but increased more rapidly over 10 degrees yaw, ultimately peaking at a higher magnitude than downforce at the highest yaw angle. And side force initially responded similarly to the datum wing, but then jumped to a much higher level at 15 degrees yaw and above. If one was to add the drag and side force components together to resolve the net force along the wing's span-wise axis, it would be quite significant at high yaw. See **Figures 6** and **7**.

However, these toe-in-the-water studies of a wing in isolation do not represent what happens to a wing mounted on a car. For that we need to bring in our 'racecar plus wing' models.

WING ON A SEDAN

A model of a generic sedan (**CAD 4**) was created, featuring a front aero kit comprising an airdam and a large splitter with end-fences and dive planes, on which the high downforce dual element wing seen in the previous section could then be attached. The wing was adjusted to a lower overall angle to improve aerodynamic balance. The model also featured simplistic representations of the internals of a front engine compartment to incorporate some internal flows.

To simplify the CFD setup process when at yaw, the wheels were stationary throughout, although the ground was set to move at the same speed and in the same direction as the inlet airflow in our virtual wind tunnel. The car was run first at zero yaw and then the yaw angle was increased in 5 degree increments. We'll look at the results of different aspects in turn, starting with downforce. As **Table 1** indicates, the forces on the main components have been calculated separately.

A number of interesting points spring from **Table 1**. Total downforce initially increased with yaw, primarily because of a modest increase in rear wing downforce, but it then declined increasingly rapidly and by 20 degrees had become positive lift overall. This was mainly because the car itself generated increasing amounts of positive lift once above 10 degrees yaw (see **Figure 8**). However, the wing itself also generated less downforce once above 5 degrees yaw, with quite a marked drop once over 15 degrees yaw, which matched the pattern in the isolated wing tests. Frustrating meshing issues, unresolved at copy deadline time, precluded higher yaw angles being investigated for now (on this model).

Moving on to drag, the results are shown in **Table 2**. In essence then, drag increased with yaw angle and the rate of drag increase went up as yaw angle increased, the dominant source of drag being the car body (including wheels etc) – but wing drag also became more significant at higher yaw.

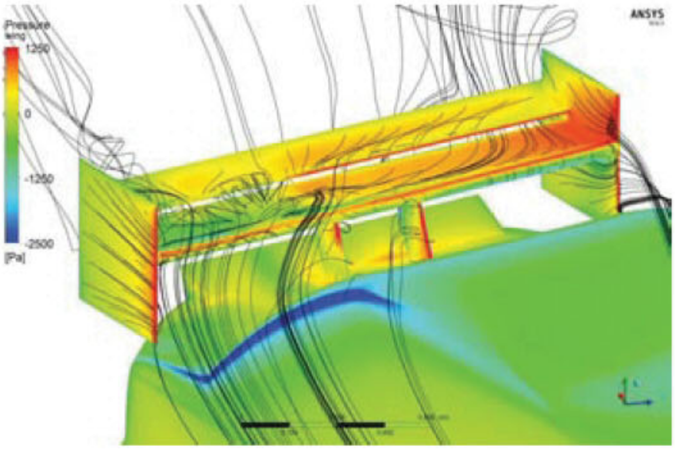


Figure 8: the rear wing on the sedan showed asymmetric pressure distributions and disruption of streamlines at 20 yaw. Notice the low pressures on the roof and the very low pressure on the rear screen pillar – sources of body lift

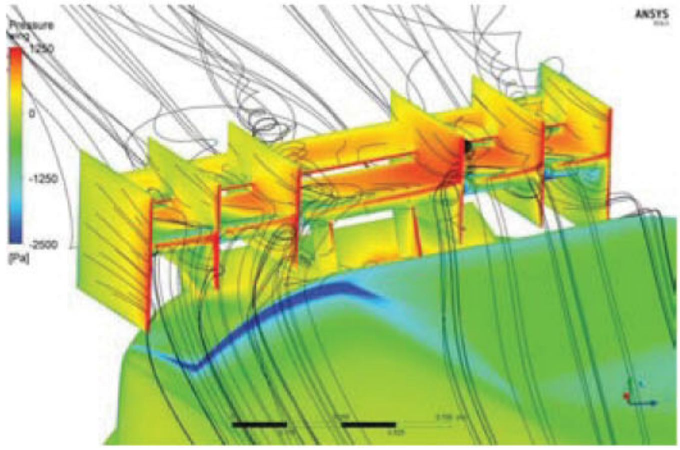


Figure 9: adding spill plates generated greater side force and yaw moment

Table 1: downforce, N at 100mph, vs yaw on the sedan plus wing model (negative downforce = positive lift here)

Yaw angle	Df, car	DF, splitter	Df, wing	Total Df
0	-788.3	1352.5	1193.8	1758.0
5	-791.2	1358.5	1239.6	1806.9
10	-739.0	1360.0	1093.0	1714.0
15	-1436.3	1291.2	973.9	828.8
20	-2593.2	1093.4	732.1	-767.7

Table 2: drag forces, N at 100mph, vs yaw on the sedan plus wing model

Yaw angle	Drag, car	Drag, splitter	Drag, wing	Total drag
0	1296.7	13.1	93.1	1402.9
5	1355.3	16.9	123.2	1495.4
10	1482.0	26.0	181.5	1689.5
15	1646.1	36.0	226.1	1908.2
20	1852.0	46.7	305.5	2204.2

Table 3: side forces, N, and yaw moments, Nm, at 100mph, on the sedan plus wing model

Yaw angle	Side, car	Side, splitter	Side, wing	Total side, N
0	-23.1	0.1	0.4	-22.6
5	333.4	35.6	116.0	485.0
10	617.7	69.0	287.9	974.6
15	1132.5	83.9	418.9	1635.3
20	1577.4	90.1	520.0	2187.5
Yaw angle	**Yaw, car**	**Yaw, splitter**	**Yaw, wing**	**Total yaw, Nm**
0	123.3	87.3	-18.1	192.5
5	-309.1	24.8	-425.1	-709.4
10	-432.1	47.8	-1053.8	-1438.1
15	-1004.5	59.8	-1548.9	-2493.6
20	-1488.6	66.2	-1989.8	-3412.2

Table 4: the balance of downforce with yaw angle

Yaw angle	Total Df, N	Total pitch, Nm	CofP, m	%front	
0	1758.0	1758.0	2.039	24.2%	
5	1806.9	1811.9	2.191	18.5%	
10	1714.0	1724.0	2.222	17.4%	
15	828.8	843.8	2.608	3.1%	
20	-767.7	-747.7	0.368	86.3%	(positive lift)

Table 3 shows the side forces and the yaw moments combined.

Once again the side forces and yaw moments showed overall increases with increasing yaw angle, both becoming quite substantial at 20 degrees. One of the interesting things in our context here is that as the wing's side force increased, obviously so too did its yaw moment. The forces and moments are calculated by the CFD at the coordinate origin of the CAD model, which in this instance is in line with the front wheel contact point and at ground level. By dividing the yaw moment by the side force at each yaw angle, it became evident that the centre of pressure of the side force moved backwards with increasing yaw angle – this the result of the increasing influence of the rear wing (and end plates).

It is also interesting to examine how the front-to-rear downforce distribution shifted with yaw. This can be done by dividing the pitch moment by the vertical force, which gives a distance in metres of the centre of pressure from the CAD origin (which, having been set at ground level means there is no pitch moment from the drag force to complicate the calculation). The distance of the centre of pressure along the wheelbase is then used to obtain the proportion of downforce exerted at the front as a measure of the aerodynamic balance. **Table 4** illustrates.

Looking at the right-hand column of **Table 4**, we can see that the aerodynamic balance shifted rearwards (%front reduced) as yaw angle increased, albeit non-linearly, but at 15 degrees nearly all the downforce was being felt at the rear. So, as well as the yaw moment centre shifting rearwards as yaw angle increased, the balance of downforce also shifted rearwards. Both of these factors would oppose the dynamic forces that generated the yaw angle in the first place, and both were related to the presence of the wing at the back of the car. Of course, we should remind ourselves that these simulations used a simplistic generic model and not a real car, but the changes we have seen here are ones that would bear investigation on a real car or a digital model that adequately represented it, in applications where large yaw angles would be routinely encountered.

It was mentioned earlier that intermediate spill plates have been said to improve a wing's performance on a car. In isolation they did not help downforce but they did increase side forces when at yaw. Two further runs were carried out – one with the wing with spill pates on the car at zero yaw, and one at 20 degrees yaw. The overall results compared to the 'no spill plates' cases are shown in **Table 5** (overleaf).

We can see that the sole benefit of the spill plates was to generate more substantial side force and yaw moment, with a further aft centre of pressure of that side force (obtained from the yaw moment divided by the side force). The wing's downforce contribution did reduce slightly. However, this was just one look at one spill plate configuration and one yaw angle, and more study would be warranted to see if the concept merited use in a specific application – see **Figure 9**.

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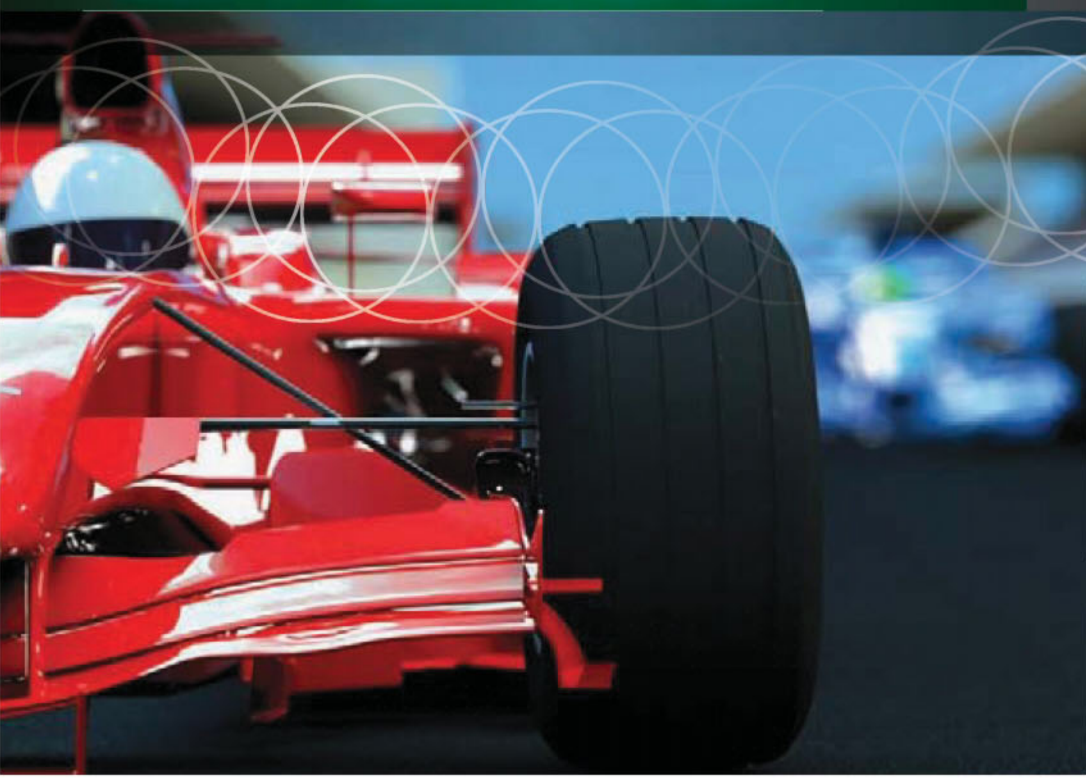

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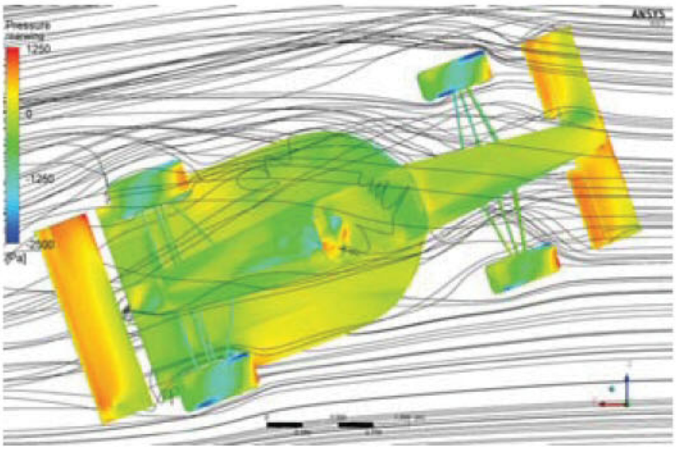


Figure 10: top view of the single-seater at 20 degrees yaw, streamlines emanating at front wing height (from the right)

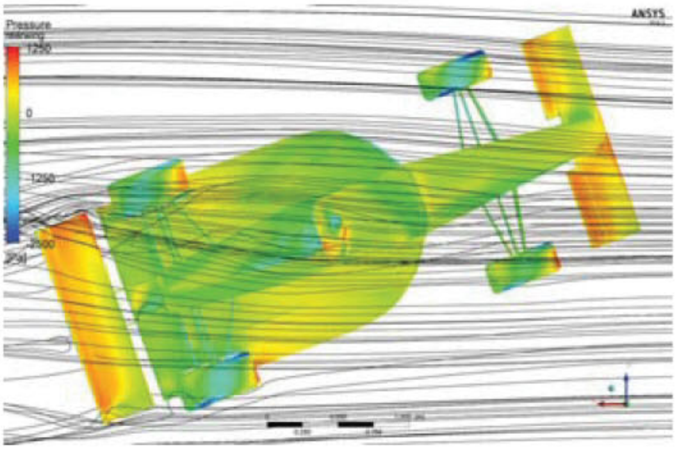


Figure 11: top view of the single-seater at 20 degrees yaw, streamlines emanating at rear wing height

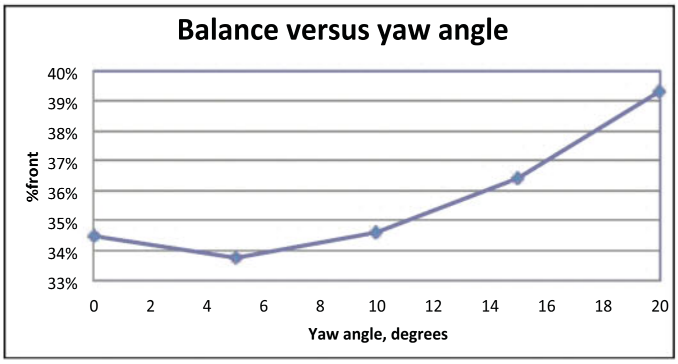
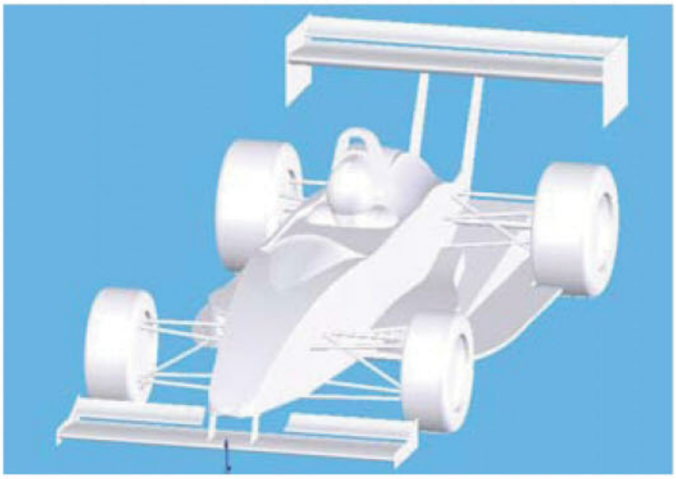


Figure 12: aerodynamic balance versus yaw for the single-seater model



CAD 5: the single-seater model with dual-element front and rear wings

Table 5: the effect of spill plates with the wing on the car model

Yaw angle		Total drag	Total Df	Total side	Total pitch	Total yaw
20	No spill plates	2204.2	-767.7	2187.5	-282.6	-3412.2
20	Spill plates	2420.9	-806.8	2646.8	-95.3	-4924.1

Table 6: downforce, N at 100mph, vs yaw on the single-seater model model (negative downforce = positive lift)

Yaw angle	Df, car	Df, f/wheels	Df, f/wing	Df, r/wheels	Df, r/wing	Total Df
0	521.7	-91.4	1057.3	-112.8	1281.6	2656.4
5	371.4	-97.8	1027.7	-129.8	1252.0	2423.5
10	405.8	-104.1	984.0	-131.9	1157.1	2310.9
15	553.5	-106.9	928.4	-152.4	1082.6	2305.2
20	554.3	-113.3	866.1	-127.8	870.4	2049.7

WINGS ON A SINGLE-SEATER

The CAD model for this part of the investigation was that of the writer's hillclimb single-seater project, as used in our study of 'front wing fundamentals' last month – see **CAD 5**. The wing setups, which featured a less cambered rear wing than on the sedan, were again chosen to create a reasonable aerodynamic balance at zero yaw. Very similar CFD conditions to those imposed upon the sedan model were used – that is, moving ground but stationary wheels – and 100mph air speed in the 'flow domain', our virtual wind tunnel. As with the sedan model, the single-seater was rotated through 5 degree yaw increments. The simulations were setup so that the forces and moments could be individually calculated on, in alphabetical order, the central car body, the front wheels, the front wing, the rear wheels and the rear wing. As with the sedan we'll first look at how downforce changed with yaw. **Table 6** shows the data.

The first thing that differed from the sedan is that the 'car' – that is, the central chassis, sidepods and underbody unit – created downforce rather than lift. The only items to create lift here were the exposed wheels. Given that they were non-rotating in these simulations their lift contribution would be slightly greater than had they been rotating, but the difference in their overall effect on net downforce was relatively small.

Looking at the right-hand column, total downforce reduced with yaw, initially at a declining rate but then more steeply from 15 degrees. The front wing's contribution declined quite slowly with yaw, whereas rear wing downforce decreased at an accelerating rate – especially after 15 degrees yaw. This mirrored the isolated wing's performance, but not that of the wing on the sedan, which initially gained downforce at 5 degrees yaw. Interestingly, the single-seater's body unit saw its downforce initially decline at 5 degrees yaw, but then increase again before levelling out at 15 degrees at a value slightly higher than the straight ahead value. See **Figures 10** and **11**.

The effect on overall balance was markedly different to the sedan case, and the plot in **Figure 12** best illustrates this. There was an initial reduction in %front at 5 degrees yaw, but then a shift to the front which increased quite markedly as yaw increased. So whereas the sedan's response was to counter the effects that would have caused high yaw angle to occur by increasing the

Table 7: drag and yaw angle on the single-seater model

Yaw angle	Drag, car	Drag, f/ wheels	Drag, f/wing	Drag r/wheels	Drag, r/wing	Total drag
0	402.5	120.3	107.5	178.0	160.9	969.2
5	403.9	123.3	105.4	183.9	161.9	978.4
10	431.4	144.4	105.4	181.6	178.7	1041.5
15	492.5	158.6	106.2	186.7	205.0	1149.0
20	573.5	165.3	106.7	214.6	251.1	1311.2

Table 8: side forces, N, and yaw moments, Nm, at 100mph, on the single-seater model

Yaw angle	Side, car	Side, f/wheels	Side, f/wing	Side, r/wheels	Side, r/wing	Total side
0	-0.4	0.6	0.1	13.5	0.1	13.9
5	75.8	63.1	5.2	-7.6	81.1	217.6
10	176.7	94.1	10.8	39.2	113.0	433.8
15	345.8	130.3	15.4	-0.2	141.2	632.5
20	486.3	136.6	18.2	53.4	220.1	914.6
Yaw angle	**Yaw, car**	**Yaw, f/wheels**	**Yaw, f/wing**	**Yaw, r/wheels**	**Yaw, r/wing**	**Total yaw**
0	14.1	-0.3	-0.1	-47.4	-0.4	-34.1
5	-151.4	-60.1	-2.5	-43.7	-357.1	-614.8
10	-351.4	-95.1	-0.6	-238.7	-538.9	-1224.7
15	-785.7	-137.3	-1.0	-161.4	-723.2	-1808.6
20	-1083.0	-141.2	-12.3	-399.5	-1113.4	-2749.4

percentage of rear downforce as yaw angle increased, the single-seater's response was the opposite, and one that would be intrinsically less stable on track.

The changes to total drag followed a similar pattern to the sedan with an accelerating increase with yaw angle, as **Table 7** demonstrates. The car and rear wing exhibited similar patterns to the overall picture, but the front wing's modest drag contribution was almost unchanged across the yaw range.

Turning to side force and yaw moments, **Table 8** shows the responses. The overall side force increased more or less linearly with yaw angle, while the yaw moment increased linearly up to 15 degrees and then slightly more rapidly to 20 degrees. The centre of pressure of the side force was fairly well back on the car, shifting more rearwards at 20 degrees. So this was a more stable response than the change in downforce balance, and it reflected the increasing effect of the rear wing and end plates as yaw angle increased.

The side force responses of the other components were quite varied; the rear wheels showing a highly variable response, and although the forces involved were small, the yaw moments were significant.

TMG TESTING

During Toyota Motorsport GmbH's F1 participation, aero was the principle focus of development. With less than four per cent performance gap between the front of the Formula 1 grid and the non-point-scoring back of the grid, aerodynamics are critical.

The hi-tech facility in Cologne, Germany, allows for both full-scale wind tunnel testing, and CFD to help simulate wings at yaw. The CFD capability is up to 80 million hexahedral cells per vehicle model, the company has a 600-CPU cluster, and can simulate cornering and overtaking. The CFD results can be correlated with wind tunnel results, as can flow fields with PIV results.

TMG's wind tunnel has a rolling road with a wheelbase range extension long enough for a full-size F1 car. The tunnels feature continuous steel belt MTS rolling road, with under-belt load cells, positioning accurate to 0.05mm and facility to simulate tyre deformation and exhaust simulations.

The firm is also installing a slotted wall to reduce blockage, allowing increased efficiency and flexibility for full-car testing, improving its fixation system to allow for a greater variety of items to be tested, and installed universal bearings on rolling roads to allow quicker and easier changes for different wheelbase vehicles.

SUMMARY

In general then, wings at yaw can be expected to yield reduced downforce, although not in all circumstances if our sedan model at 5 degrees yaw is a guide. End plate size certainly influences what happens at yaw, as does the vehicle the wing is mounted to, in terms of the way the wings themselves respond but also how significant the wing's contribution is to overall aero performance.

And, as is well-known in sprint car series around the world, the side forces and yaw moments created by a wing with sizable end plates become significant as yaw angle increases.

Racecar Engineering's thanks to ANSYS UK for the use of CFD-Flo software

Although the side forces involved were somewhat small, the yaw moments were significant

TYRE ROLE

It is important to understand aerodynamics at yaw because of the way in which tyres work with a road surface in order to generate grip. A rotating tyre operating at zero angle to the oncoming tarmac generates near zero lateral forces for our vehicle.

When driving a car, operating our front and rear tyres at varying amounts of yaw (or slip) angle, it is a matter of how we control the car in order to change its direction. We could call our steering wheel the 'yaw commander' – as we turn the wheel we are in fact yawing the front tyre contact patches relative to the direction of travel.

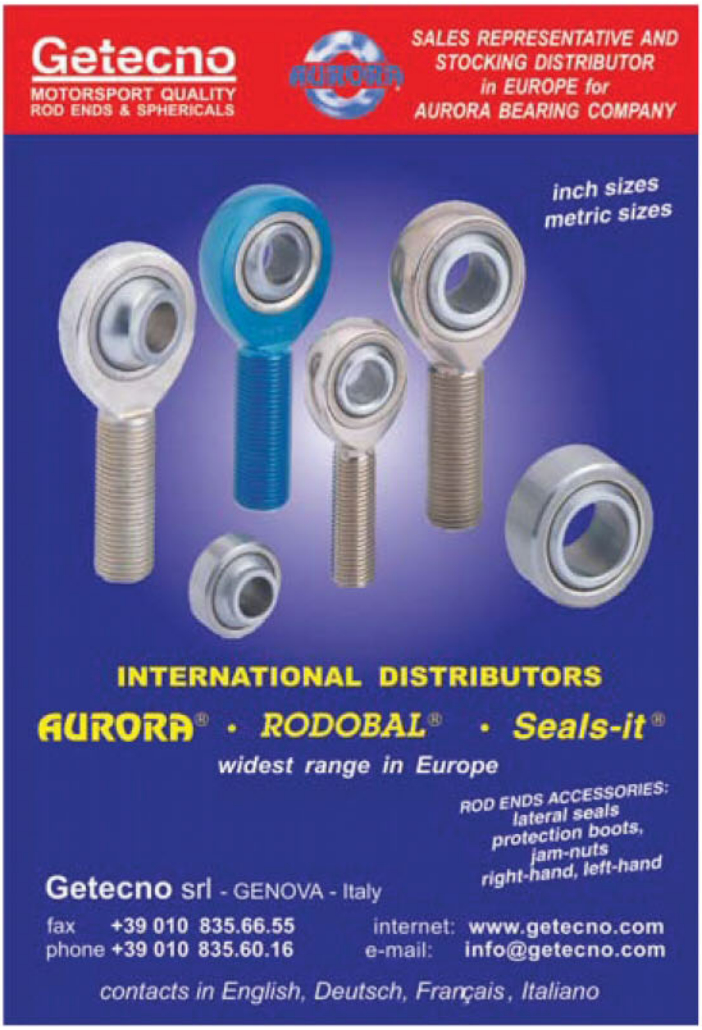
Most racecars do not utilise actively controlled four-wheel steering and as such the rear wheels of most cars have a fixed relationship with the vehicle chassis. In order for our drivers to alter the slip angles of a car's rear tyres, they must first yaw the entire vehicle. If you are generating cornering forces in a fast-moving chassis, then you will be driving in yaw – and during car control recovery situations these angles can be pretty large.

We are unlikely to ever see a situation where these yaw angles are not accompanied by chassis roll angle at the same time, even if the only suspension deflection is the tyre's sidewall.

Approaching vehicle dynamics holistically, we must understand the operational detail of the sub-systems. When making design or setup decisions, we should concentrate on the interdependence of these systems and the net effects our changes will have on the overall vehicle performance.

Aerodynamics in yaw is important, because the optimal solutions for maximum negative lift generation in a conventional zero yaw wind tunnel are unlikely to be the optimal solution for the best vehicle system performance.

Sam Borgman, Torque Developments International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The winning formula

How ChassisSim helped Maranello Motorsport lead the way at the Bathurst 12 Hour

BY DANNY NOWLAN

Being based in Australia, I don't often get to talk about what happens in my own backyard. However, when I do it's definitely worthwhile. On 9 February 2014, one of my customers, Maranello Motorsport running a Ferrari F458, won the Bathurst 12 Hour at the Mount Panorama circuit in Bathurst, in New South Wales. What made this victory even more significant was that the race engineering staff were experienced ChassisSim users. In particular, chief race engineer Pat Cahill is my Australian dealer. Consequently, I had a unique front row insight into what they did.

So here I'll look at the role that ChassisSim played in this victory, and how it was used. The motivation for this article comes from an observation of mine over a number of years. Typically, attitudes to simulation fall into two categories: there are those who doubt its effectiveness, and then the other crowd knows that simulation is a great tool, but they don't really have a clue where to start. This article is for both of these camps, because I always feel that the best way to address both concerns is by giving examples.

Also, I should state from the outset that I will not be discussing any particular setup parameters of this car. When I have a customer or colleague that divines a setup that works, as far as I am concerned it is their property and not for public consumption. Besides, my goal is to teach you how to do it so you can figure this out for yourself!

As always, any victory starts with preparation, and the case of the Ferrari F458 was no exception in this regard. The first step in

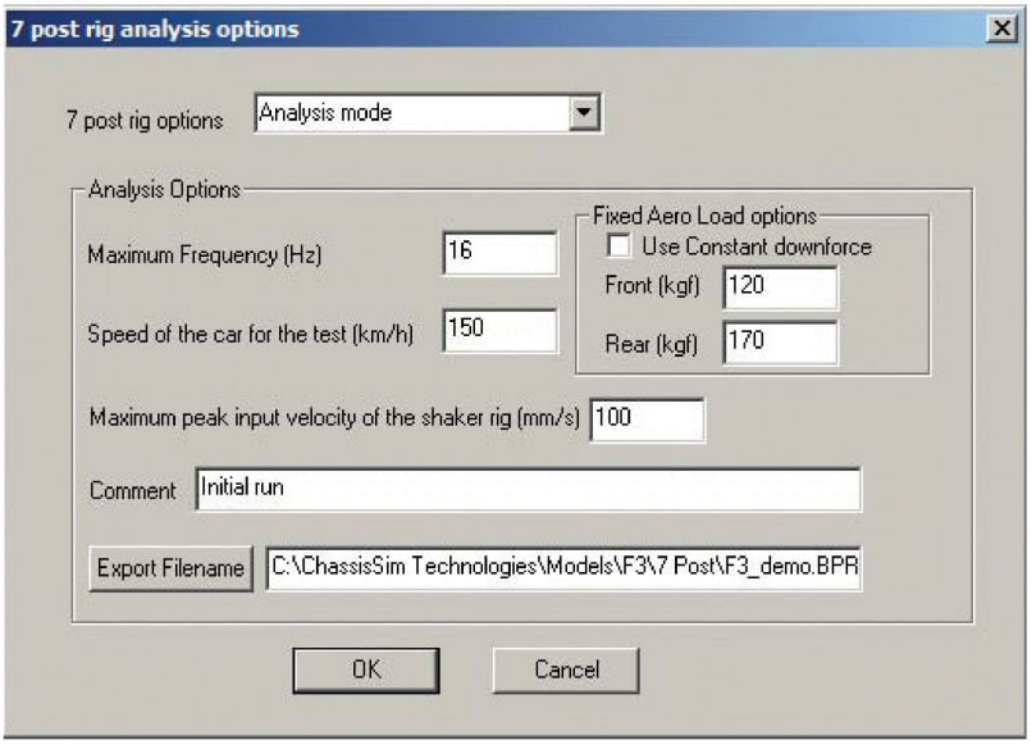


Figure 1: setting up a frequency run

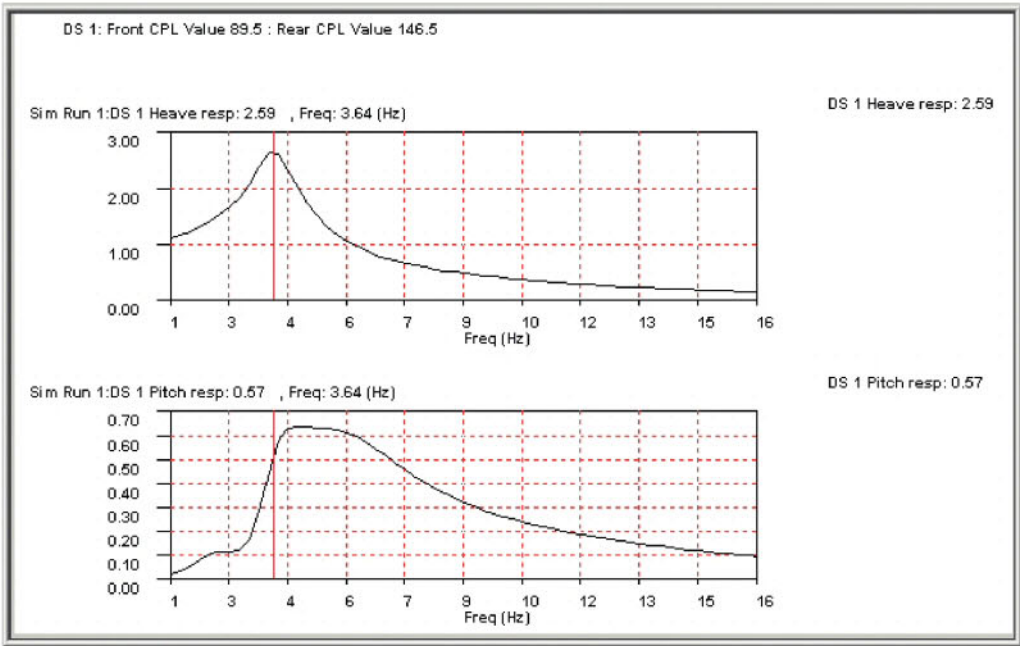


Figure 2: output of the shaker rig toolbox

There are two attitudes to simulation: those that doubt its effectiveness, and those that know it's a great tool, but don't know where to start

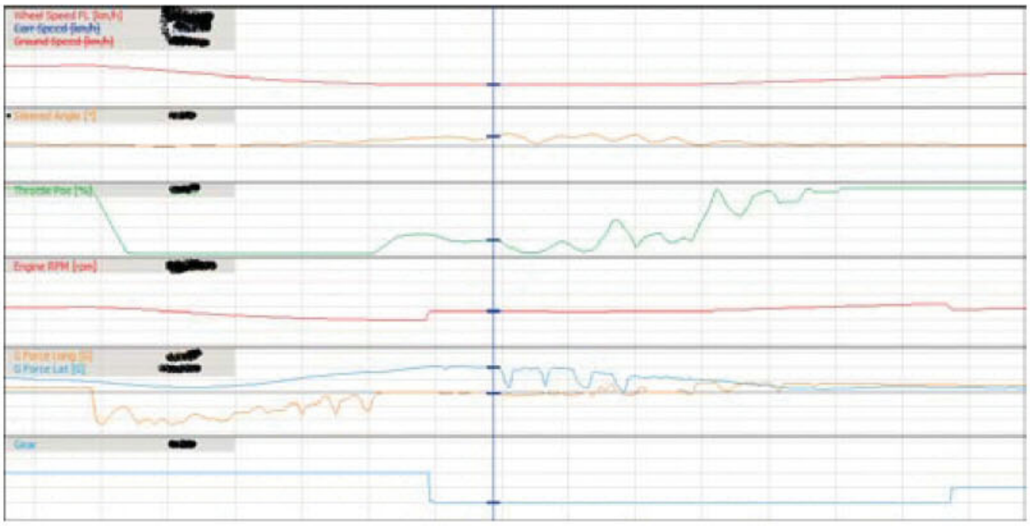


Figure 3: initial simulation results

ChassisSim was the seven-post/shaker rig toolbox. The technique that was used was pioneered by Pat, as I've covered in these pages before. That being said, it's so effective that I hope you don't mind me going over it again.

First things first, let's talk about what the seven-post/shaker rig toolbox looks like, how to set it up and what it returns. The very first part of the toolbox is setting up the frequency test. This is illustrated in **Figure 1**.

The comments and filenames are pretty self-explanatory. Just put in something relevant to the setup and store the log file for testing somewhere that you are going to remember it. Remember that the controls you need to pay particular attention to are the speed of the test and the peak input velocity of the road input.

You choose the speed of the test to choose the corners you want to simulate. If you want to simulate a low speed corner, choose – say – 100 km/h, or if you are looking at a high speed corner go for 150-170 km/h. At Bathurst and its kink at Caltex Chase, a speed of 270km/h was used, while a 210km/h test speed was used for the very fast, flowing section around McPhillamy Park. These speeds represent the apex speeds encountered. You'll also notice that you have the option to set the downforce at a fixed value. This is OK for validation work, but personally I prefer to leave this off. The reason is that the ride height

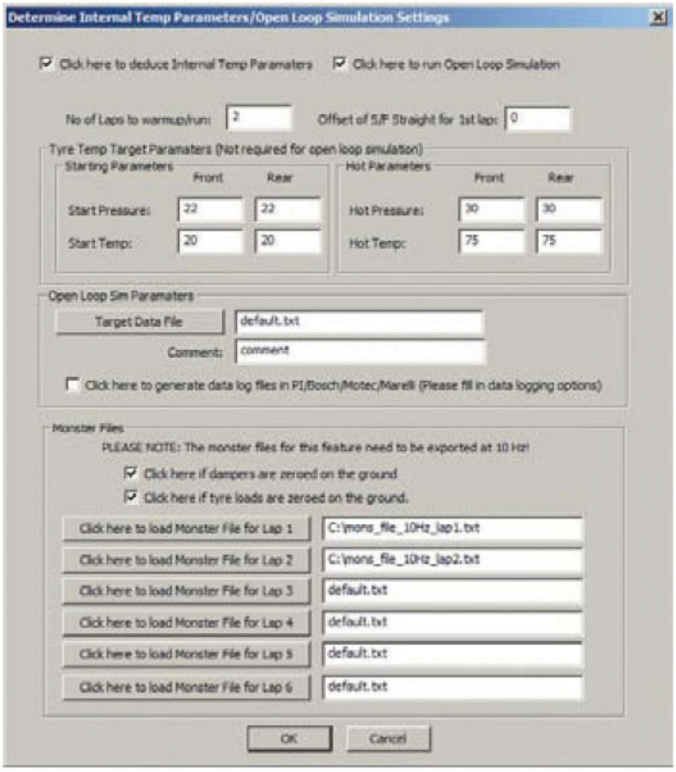


Figure 4: determining internal temperature parameters

map will affect the frequency response of the car, and in high-speed corners this will make its presence felt.

In terms of the peak input velocity, you choose a value that represents the peak input velocity that is representative of the road input. There are a number of ways you can do this. For a rough rule of thumb, 50mm/s approximates a relatively smooth surface, 100mm/s is middle of the road, and 150mm/s represents a pretty bumpy circuit.

Another way you can do it is to look at the data. Examine the peak damper velocity and divide the results by – say – about three. It's a rough measure, but it will get you by. If in doubt, start the test at 100mm/s. To quantify this approach, Mount Panorama was resurfaced over Christmas 2013 and the circuit operators claimed it was much smoother. Consequently, the input was scaled to 75 per cent of what was used on the old surface. This was an educated guess that was based on how much the Phillip Island circuit surface improved after similar refurbishments.

In terms of what this toolbox is, it will return a plot of Output Amplitude on Input Amplitude. The output of the toolbox is shown in **Figure 2**. You'll see that the Contact Patch Load variation (CPL) is shown in the top of the graph. This is averaged over the whole frequency run and the units are kg. This is the delta load variation from the static load for the conditions specified for the test. The plots below are the ratio of output vs input amplitudes. Here we have shown heave and pitch for a heave input to the car.

Now let's get to the meat of how this was used by Maranello Motorsport. The first part of the process is that you play with springs and large damper adjustments to minimise CPL. What will happen is that you will get into a zone where the CPL will hit a minimum, and actually won't vary too much. Once you hit this, you start playing with minor spring and damper changes to get the shape of the frequency response that you want. It's really that simple. This results in a marked improvement in mechanical grip without compromising driver feel. The other key thing to reiterate is that you choose a corner speed and input velocity that is appropriate for a particular corner you want to analyse.

What we have just described is the method by which the damper curves for this car was specified. I realise that a few of you might be looking at this with a level of stunned disbelief, but it really is as simple as that. All we are doing is running a bunch of shaker rig tests and looking at a combination of CPL values and frequency plots to determine what we need. It's amazing what happens when you do your homework!

The next step in the process was the lap time simulation work. In the event of a track surface being redone, Formula 1 teams would spend approximately $150,000 in creating a 3D track map. Good luck with getting hold of that kind of sum in other classes of racing! When Bathurst is not

Mount Panarama was resurfaced, with the circuit operators claiming it was much smoother. So, the input was scaled to 75% of that used previously

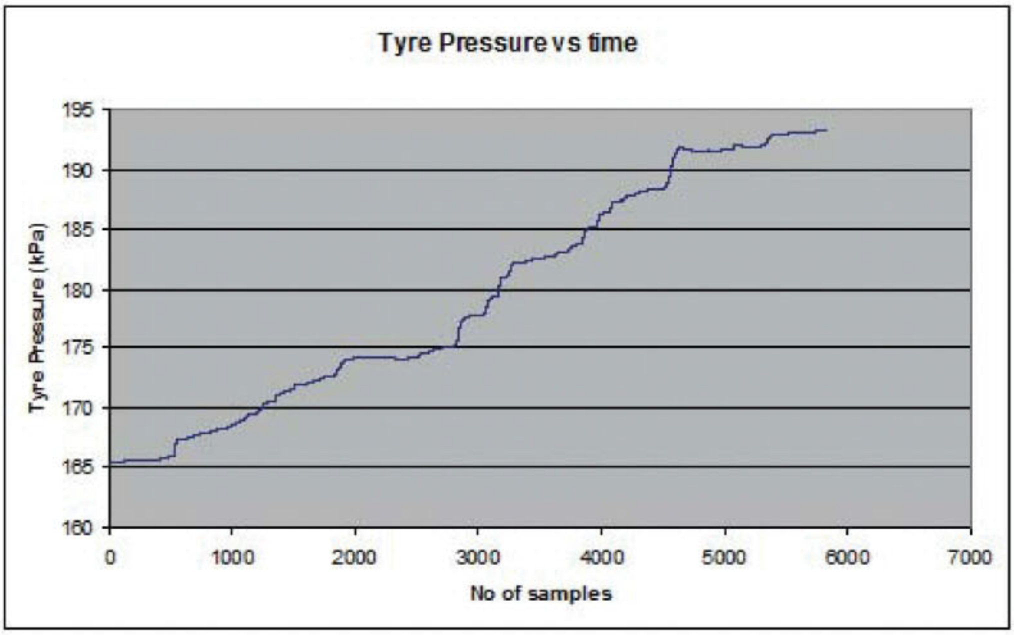


Figure 5: plot of tyre pressure vs time

being used as a racetrack, it's actually a scenic drive, with more speed cameras per kilometer than any other road in Australia. The solution adopted by Maranello was to use the ChassisSim bump profiling toolbox to grab a surface profile from the first session. For those of you not familiar with ChassisSim, this is pretty much ChassisSim 101.

However, what was particularly interesting was the results from these first simulations. This is illustrated in **Figure 3**. What can be seen here is some waviness in the steering. For confidentiality reasons, all scaling and numbers have been removed. At first this was almost dismissed as ChassisSim driving the car too hard. However, driver feedback indicated that the car was very pointy. Not so much oversteering in the classical sense, but it was very sensitive to steering input. The fact that this was mirrored in the simulation results shows you what a powerful tool you have at your hands with the bump profile modelling toolbox. It also shows you the jump between static and transient lap time simulation.

The other way that ChassisSim was employed was to use it to predict hot tyre temperatures and pressures. This has been released for over a year, but it has seen very little use in the field until now. In addition to calculating the idealised surface temperature, it will also calculate the core temperature and the core pressure. This has been under testing for the last year, and the Bathurst 12 Hour was the first time it was used in competition.

The feature is a spin on the open loop track replay simulation of ChassisSim. There are two steps to this process. The first is to grab the necessary number of laps with the appropriate monster files exported at 10Hz. The reason that these files are exported at 10Hz as opposed to 50Hz is that it allows a long stint to be replayed. Also, this is effectively the input. When the open loop simulation is running, it's effectively the same as the tyre force modelling and lap time simulation. You then specify a cold start point for temperatures and pressures, the hot end point and the number of laps you run. ChassisSim will then determine the internal temperature parameters of the tyres for you. When this is setup you'll have a dialogue that looks like **Figure 4**.

The next step is to apply them to the vehicle model and to run the open loop simulation and determine the internal tyre temps and pressures. When you have run the open loop and track replay simulation, you should have a plot that looks like **Figure 5**.

Let me state clearly that what you are seeing here shouldn't be taken as gospel to be used blindly. Predicting tyre pressures and knowing how to set them up is one of the real arts of race engineering. Use this as a tool to point you in the right direction.

Where this was used at the Bathurst 12 Hour was as a predictive tool to replicate what was happening with tyre pressure growth over a stint. The remarkably hot conditions made this an imperative and allowed the drivers to lap consistently faster than everyone in the middle part of the day, when the ambient temperature reached 39degC and the track temp was 65degC. In terms of what was found I need to remain very tight-lipped. What I can say is that it proved to be a very effective tool, and it used all of the elements discussed above.

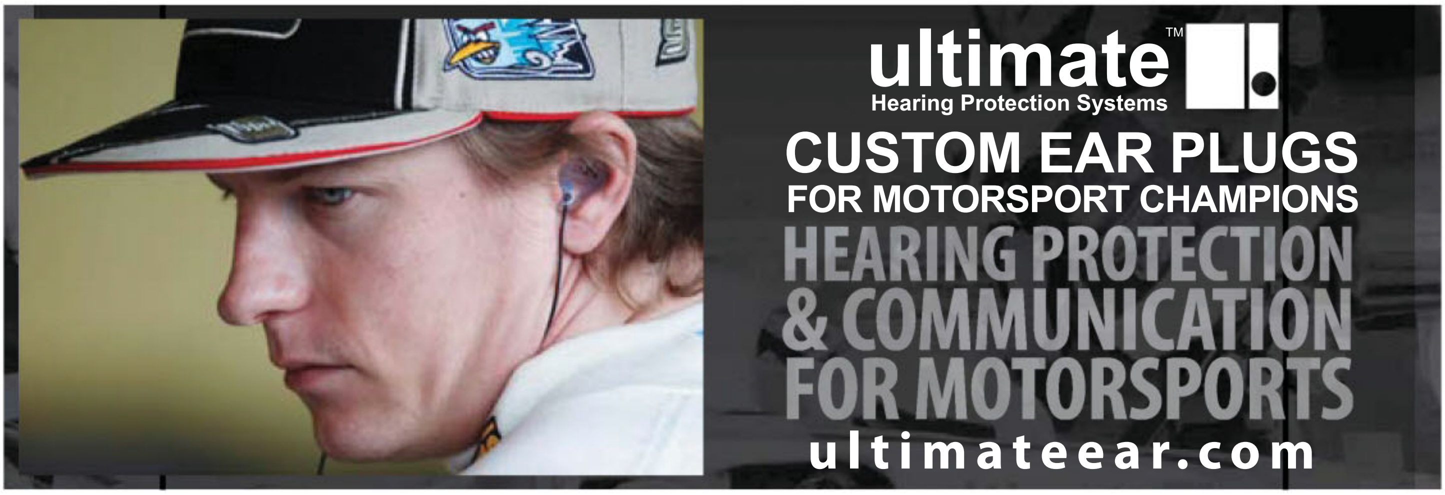
Tying this all together, what we have examined here hasn't been rocket science. By using ChassisSim as part of many tools, the race engineering staff at Maranello Motorsport were able to chip away at the car and refine the setup. However, tools such as the seven-post/shaker rig toolbox, the lap time simulation and the open loop/track replay simulation to help predict tyre pressures certainly made their presence felt.

This also illustrates the point that if you are going to use something like ChassisSim effectively, you use it as one tool of many. What we have discussed here requires you to look at the results and to use your experience and training to figure out what it is telling you. This goes to the real heart about how to use simulation. One of the greatest fallacies I see with simulation is people trying to use it blindly and in isolation. If that sounds like you, don't bother using simulation tools and I wish you well. The way you use simulation is to throw a few things at it and then sit back and consider what it is telling you.

This was the way that ChassisSim was used by the engineering team at Maranello. The model had been refined to a point where it could be trusted, even when the drivers all came back after the first practice with a bewildering myriad of handling ills. At this point, it's often the case that changes start being made in big jumps, which is understandable. Instead, the engineering team could say with confidence that it was mostly a very green and dusty track and it would be best to reserve judgment until later in the day. Consequently, more time was spent with the drivers focusing on themselves and getting up to speed on a circuit that they usually can't practice on in anger. This proved to be the most powerful advantage of ChassisSim. It was proven with a qualifying time that was only beaten by a few hundredths by a car running on softer rubber. All for a sum total of three setup changes to the car for the duration of the weekend.

So in terms of the 2014 Bathurst 12 Hour, ChassisSim was integral to victory. The shaker rig toolbox, the lap time simulation and the open loop/track replay simulation all played their part. However, the real key here is that ChassisSim was used as a calculator to inform the engineers about where to go with the car. If you use simulation in this way, you will have to access to an extremely powerful tool.

By using ChassisSim as part of many tools, the race engineering staff at Maranello were able to chip away at the car and refine the setup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Fuel flow meter debut ends with controversy

Gill's much-heralded new tech to help regulate the maximum flow rate has met with hostility in the pitlane – but the FIA are standing by it

BY SAM COLLINS

Red Bull's concerns over the Gill meter led them to running an alternative model, which resulted in disqualification

Red Bull Racing finished the Australian Grand Prix in second position, but five hours after the chequered flag fell, the car was disqualified for 'consistently exceeding' the 100kg/h fuel flow limit. Few could quite grasp how this would be possible, as every car on the grid was fitted with the same Gill Sensors ultrasonic fuel flow meter, but after lengthy discussions in the stewards' office at the Albert Park Circuit came to an end, a chronology of sorts became evident.

During the first free practice session, Red Bull noticed that there was a difference in the flow rate reading between its third run and its final run, when there should not have been any difference at all. The difference between the readings was consistent, and it is thought that the rate shown in the first three runs of FP1 said that the car was running legally, while the rate shown from the start of the fourth run said that it was not. The new flow rate reading stayed the same throughout the second free practice session.

After the second free practice session, Red Bull changed the flow meter, replacing it with a spare which it ran in the third and throughout qualifying. However, this flow meter also had some issues and did not give readings that were satisfactory to either the team or the FIA, so the sensor was again replaced this time with the original unit.

At this point the FIA technical delegate's representative emailed Red Bull instructing them to apply an offset to their fuel flow to make it legal. But the team seemed to lack confidence in the fuel flow meter, and later told the stewards that they felt it to be 'unreliable'. As a result of this, Red Bull opted to use an internal fuel flow model rather than relying on the Gill flow meter.

During the race, the FIA representative noticed that according to the fuel flow sensor, the Red Bull was continually exceeding the maximum flow rate of 100kg/h and advised the team to reduce the fuel flow so that it was within the limit according to the meter. Red Bull chose not to do this and continued to rely on the internal model, finishing second in the race.

'We advised twice after qualifying and five laps into the race to take the necessary steps to comply with the regulations,' said Charlie Whiting, Formula 1's race director. 'They chose to use their own calculations to show they complied. If they had followed the advice we gave them at the time, we would not have had a problem and they would not have been penalised.'

> **"We advised Red Bull twice after qualifying and five laps into the race to take steps to comply"**

Red Bull's use of a backup model was not unprecedented. Due to concerns over the implications of a fuel flow sensor failure, the FIA issued a technical directive at the final pre-season test in Bahrain

Gill Sensors undertook redesign work in time for the 2014 Formula 1 season opener in Melbourne. The new design (right) was homologated mid-January

detailing the process to follow in such an event. It stated that 'the homologated fuel flow sensor will be the primary measurement of the fuel flow and will be used to check compliance with the F1 technical regulations.' The technical directive goes on to state: 'If at any time we consider that the sensor has an issue which has not been detected by the system, we will communicate this to the team concerned and switch to a backup system.'

The system in question is the calculated fuel flow model with a correction factor decided by the FIA, and this is essentially what Red Bull used. However, it did so without the specific permission of the FIA. When the decision to disqualify the car was announced, this was a major factor and the race stewards said: 'Regardless of the team's assertion that the sensor was at fault, it is not within their discretion to run a different fuel flow measurement method without the permission of the FIA.'

Red Bull has appealed the decision and has openly criticised the mandated Gill product. 'These fuel-flow sensors that have been fitted by the FIA have proved problematic throughout the pit lane since the start of testing,' said Red Bull team boss Christian Horner. 'There have been discrepancies in them, and I think some cars may well have run without them during the race itself. We had a fuel flow sensor fitted to the car that we believe to be in error.'

Word in the paddock is that a number of other teams did indeed have issues with the flow meters, but either applied the offset suggested by the technical representative or used internal models but did not run the fuel flow to the maximum allowed, perhaps limiting themselves to 96kg/h.

It is certain that the flow meters used in Formula 1 do have some variance, but according to the technical representative they all fall within a known range (though that range has not been disclosed) and are individually calibrated by Calibra Technologies, a company based in Cambridge, England. The Gill fuel flow sensor was first fitted to Le Mans Prototypes on track in the winter of 2011/2012 and has gone through a number of iterations. A number of engineers left Gill Sensors in 2013, leaving a revised technical team to undertake a redesign of the sensor in time for the 2014 season. The new design was homologated in mid-January.

According to Gill Sensors, the final homologated meter is capable of a flow measurement rate of 8000ml/min and fulfils the FIA's accuracy requirements. It uses solid-state ultrasonic flow measurement technology to detect the flow rate, and can monitor both transient and steady fuel flow, flow direction, fuel temperature and cumulative fuel usage.

The late redesign meant that the mounting requirements changed slightly, leading to some teams having to modify their fuel cell designs, as this is where the sensors are mounted on F1 cars. On Le Mans Prototypes (in the LMP1 class), each car is fitted with a pair of sensors (three if diesel powered) and they are mounted on the rear of the chassis with a quick-release Staubli mechanism allowing them to be changed in pit stops.

The meters reportedly cost around £16,000 each, with around £8,000 on the purchase price, and the rest spent on service charges and calibration. *Racecar* understands that they have a 30-day warranty. The Gill Sensors fuel flow meter will remain homologated for use within Formula 1 and WEC throughout the expected lifetime of the turbocharged V6 engine and future designs. The market is apparently open for another manufacturer should anyone meet the FIA standards.

"The FIA have faith in the homologated fuel flow sensor. The regulations will not change"

VOTE OF CONFIDENCE

However, Gill Sensors has defended its product, issuing the following statement: 'Following the Australian Grand Prix, the FIA have provided Gill Sensors with positive feedback on the performance of the Fuel Flow Meter, confirming their confidence in the development and stating that the meters meet the FIA's accuracy specification. The meter development included an extensive testing programme, which involved liaising with many of the F1 teams for their valuable feedback on meter design and functionality.'

These are sentiments echoed by the FIA; 'we have faith in the homologated and calibrated fuel flow sensor,' claims Fabrice Lom, head of powertrain at the FIA. 'The regulations will not change after Melbourne – the fuel flow will be monitored by the homologated fuel flow sensor in WEC.' Lom did admit though that other fuel flow meters could be homologated as the season progresses. 'There is no exclusivity in the homologation, but granting the homologation is a long process.'

Red Bull's appeal will likely focus on the flow meter and its reliability, or indeed lack of it, and if the team can prove that it did not exceed 100kg/h during the race then it will almost certainly be reinstated in the results.

'We wouldn't be appealing if we weren't extremely confident we have a defendable case,' said Horner. 'It's just extremely disappointing that this has happened. I don't believe it's the fault of the team. We have been compliant with the rules and the documents and investigation that will be submitted within the appeal will demonstrate that.' The date for the appeal has been set for 14 April. Full details will be featured online.

Flying along rivers of air

Another example of conditions that wind tunnels cannot replicate

The article by Marco de Luca *(Tunnel Revision, RE V24N3)* is a good reminder for all race teams of some truths that need airing occasionally. There are a couple of other phenomena that are also not replicable.

A few times, I have observed some well-respected teams attempt to cure the dreaded old understeer using aerodynamics. Each time, I asked one question: does the understeer occur at low speeds as well as high? The answer came back: yes! I expressed my belief that low speed understeer should be corrected mechanically and that aerodynamics could only mask the problem to a small degree. My comments fell on deaf ears.

On five separate occasions, when driving up and down the 405 Freeway (also known as the San Diego Freeway) in southern California and going through Long Beach, CA, I observed pelicans lazily approaching the limited access highway from the harbour area (Long Beach was the home of the US Grand Prix for a time). When these pelicans reached the Freeway, they banked and flew with the traffic, with the same lazy flapping of wings they used on their approach. The first time I saw this happening, it took me a few seconds to realise the birds were lazily flapping their wings and flying along at 70-80mph! I don't believe pelicans can fly at those speeds, except in a steep dive with wings folded. In my mind's eye, I see rivers of air where multiple cars move along together, just as happens on racetracks, such as ovals and even road courses. The pelicans flew along with the traffic when it was dense and other times when the traffic was light.

I'm sure a wind tunnel cannot replicate the rivers of air that I see wherever I drive. I still haven't been able to figure out how to exploit them, however!

PS The 2014 Formula 1 cars have come out rather ugly and some seem to have taken the Proboscis monkeys of south-east Asia as models.

"Some 2014 F1 cars seem to have used Proboscis monkeys as models"

Back in the 1970s when the US federal government began talk of 'improving' the robustness of car bumpers, alarms were raised over the matter of matching the height of the front bumpers with the rear bumpers. Also, dynamics of cars under braking would compromise any mandated height. The government simply ignored the problem.

My immediate solution was to return to sword fighting. When you battle with swords, you cross them. So, my solution to allay the concern that Adrian Newey and others have expressed would require a round cross-section bar to be added to the rear crash structure (it could even attach to the end-plates). At the front, the nose cone could be raised some and the vertical wing support struts would be required to accept the forces that the present nose cone takes on. The struts could have a minimum width limit. At the front, the cars might resemble the last Arrows F1 cars that were designed by Sergio Rinland.

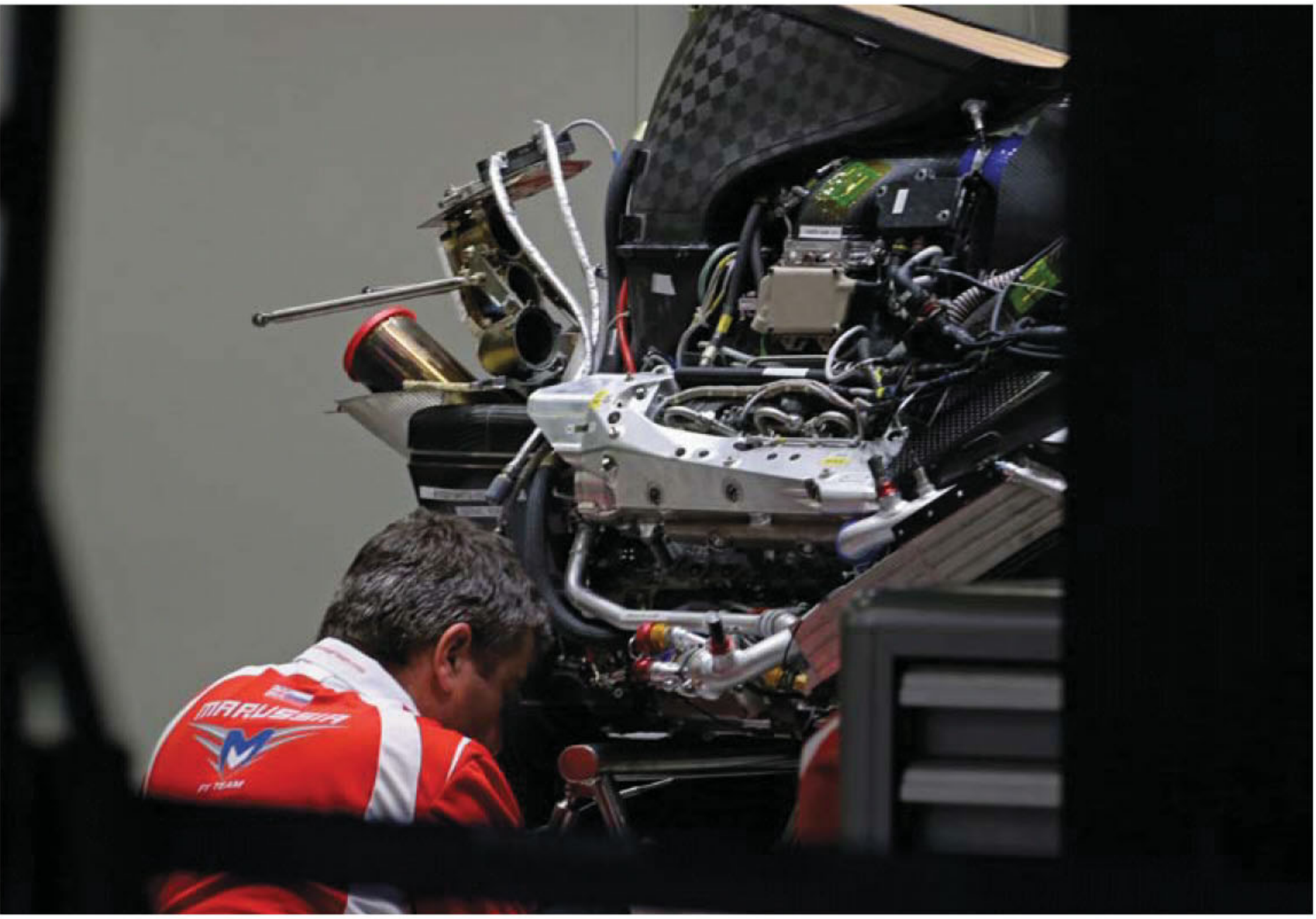
Richard H Yagami

POINTLESS ENGINEERING?

Mercedes won the Australian Grand Prix. Red Bull *finished* second, and McLaren was third. Many cars dropped out with engine trouble as the new turbo V6s are very complicated indeed. They don't call it turbo compound, but 'energy recovery'. That is because a large percentage of time a road racing car is under braking and one wants to recover that energy as well as waste exhaust energy.

That braking energy recovery does not help at all on the freeway or autobahn. It just adds a lot of unnecessary weight.

The exhaust energy is recovered by a shaft coming out of the turbocharger compressor



driving a generator. This charges a battery. This is not an efficient way of doing it in a passenger car. Say the generator is 90 per cent efficient and the motor is 90 per cent efficient, overall energy recovery is then only 81 per cent.

Again the battery is just more dead weight. Typically the electronc controller could also be 90 per cent efficient, so overall recovery efficiency could drop to 73 per cent. All this waste heat heats up the engine compartment.

There is no beating a gearbox between the exhaust turbine and the crankshaft. That would be 95 per cent efficient or higher.

The battery is also charged from the retarding force on the rear wheels under braking in a road racing car. These generators also serve as motors that provide extra torque under acceleration, and in the case of the turbocharger generator it is also used in electric motor mode to accelerate the compressor. This reduces the notorious turbocharger throttle lag.

One can imagine this is a programmer's worse nightmare. Not only is the competition among the drivers and engineers, but now programmers are competing to see who can write the best control program. I wonder what chip they are using? I would not be a bit surprised if it was an ARM variation of some sort.

That is basically like using your cellphone to control 800hp. The generator connected to the compressor shaft is particularly interesting as it must be geared down as the turbo is turning at 125,000rpm. An electric motor would probably blow up due to centrifugal loads on the copper windings if it were to run at 125,000rpm.

Or they could be using switched reluctance motor with no windings on the rotor.

"Programmers are competing, and are using the equivalent of a cellphone to control 800bhp"

WINGED BLUNDERS

The vast majority of wing drag is induced drag. The cars would get along with a lot less fuel if they doubled the width of the rear wing.

Wikipedia states: 'In aerodynamics, lift-induced drag, induced drag, vortex drag, or sometimes drag due to lift, is a drag force that occurs whenever a moving object redirects the airflow coming at it. This drag force occurs in airplanes due to wings redirecting air to cause lift and also in cars with airfoil wings that redirect air to cause a downforce.'

The wing induced drag factor is equal to the lift coefficient squared, divided by pi times to aspect ratio. Aspect ratio is width divide by cord. In Formula 1 cars aspect ratio is about 2.

So the current induced drag factor is about 0.16.

If they doubled the width and kept the downforce the same it would be one divided by four times pi or 0.08. In other words, half the wing drag.

That is why they get those enormous vortices off the wing tips in the rain.

Assume the current wing area is four square feet and C sub l is one. The downforce at 150mph is 52 times four or about 200lbs. Drag is then 32 pounds. 150mph is 220FPS. HP consumed by the wing is then 7040 foot pound second or 12.8hp. That is roughly 8.3 pounds of fuel burned, per hour, by the wing alone.

The slotted wing downforce is probably double that so that number could be as high as 33 pounds of fuel per hour. Rough calculations all.

Two hour race, 66 pounds less fuel. The current F1 fuel limit is 220 pounds.

The high end plates help, but they have their own drag associated with them.

Paul Lamar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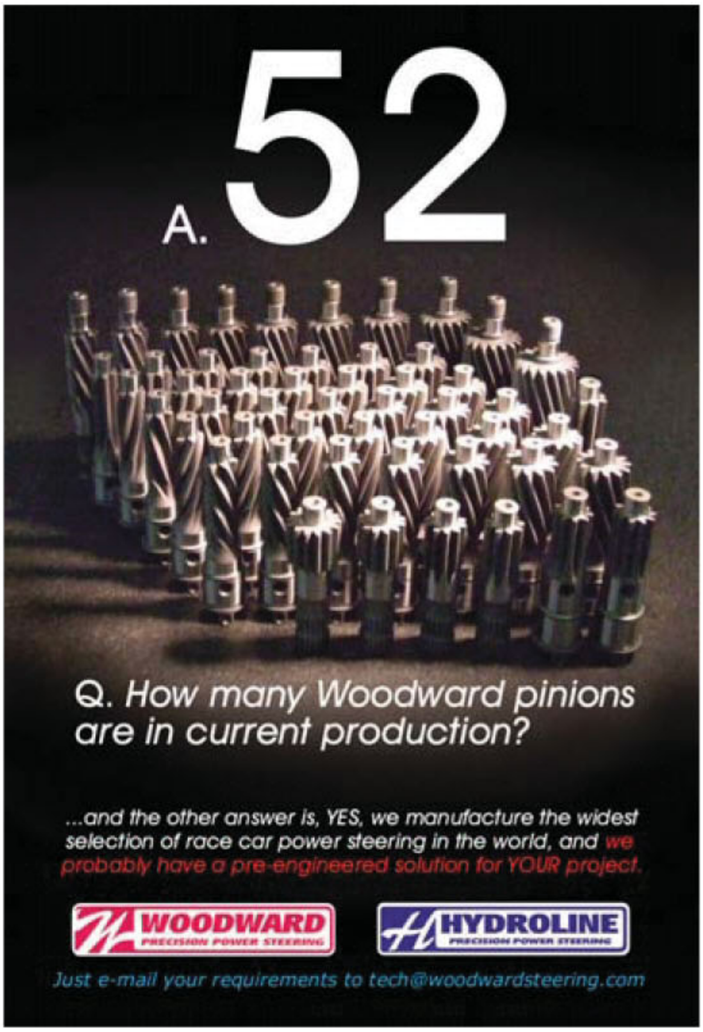
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Nürburgring sold in €100m deal with German parts supplier

The Capricorn Group, a German-based motorsport parts supplier, has purchased the Nürburgring in a deal said to worth in excess of €100m.

Capricorn's deal, which includes the two tracks – the legendary 14-mile Nordschleife plus the grand prix circuit – and supporting infrastructure, comes after an offer from Bernie Ecclestone to buy the circuit for $50m (€36m) was rejected. The Capricorn offer also eclipsed that of a group called HIG Capital, which was widely expected to gain control of the venue.


LAT

The new deal saves both the Nordschleife (pictured) and the grand prix circuit

The new owner takes over in January 2015 and has pledged to continue to operate the tracks and the hotels, while it also plans to develop an automotive technology cluster at the Nürburgring.

Capricorn, which supplies high-end crankshafts, pistons, cylinder liners, connecting rods and composite materials to the motorsport industry, already has a manufacturing facility close to the famous circuits.

The administrator for the business admitted that a higher offer secured the deal, but said the promise to build up industry in the Eifel region also helped. No less than a quarter of the purchase price has been earmarked for the development work. Insolvency monitor Jens Lieser said: 'We had two excellent offers that were presented to the creditors' committee. Finally they opted for the offer that delivered the highest purchase price and good prospects for the region.'

Capricorn Nürburgring, the name given to the operating company, will be headed by Adam Osieka, a VLN racer and CEO of motorsport and tuning company Getspeed, which is based at the Nürburgring.

Dr Robertino Wild, managing partner of the Capricorn Group, said: 'As an enthusiastic motorsport fan, the Nürburgring has always been a passion of mine. We have identified the enormous potential of this unique race venue and would like to optimise the existing structures, but above all turn the vision of an automotive technology cluster into reality.'

Formula 1 teams prefer spending reductions to cost cap

Formula 1 team bosses have made it clear that they would prefer a move towards regulations that reduce expenditure in the sport rather than the cost cap, which is set to be brought in by the FIA.

The FIA cost cap is due to come into force next season, but as yet there has been no upper limit set and it seems the teams are still looking for a different approach. When asked about the progress that the teams and the FIA were making on setting a cap, Red Bull boss Christian Horner said: 'Forget the words "cost cap" for the moment – let's just focus on saving money. I think everybody wants to see all of the teams save money. The necessity to spend money in order to be competitive is what we want to reduce and I think however we achieve that as a group, it's something that we all want to see happen.


LAT

The FIA cost cap is due to come into force next season

'How to make it happen is obviously something much more complex, but you've got to look at the root causes for why costs are the way they are and then, in my opinion, address it that way.'

McLaren Group chairman and CEO Ron Dennis has also said he is against a cost cap. Eric Boullier, who is now racing director at McLaren, backed his new boss's stance, and made it clear that while many in the sport are against a cap, this does not mean they are against reducing costs.

'I think Ron has said he's not in favour of caps,' Boullier said. 'He's definitely in favour of reducing costs. Obviously trying to be competitive is the nature of any sport, and especially in Formula 1, so we just need to draw the line and make sure that technically we can't spend too much to be competitive.'

The F1 Strategy Group, which comprise six teams (Red Bull, Mercedes, Ferrari, McLaren, Williams and Lotus) plus FIA president Jean Todt and F1 boss Bernie Ecclestone met recently at FOM's base at Biggin Hill to discuss the situation. Sources suggest that budget caps discussed were around the £225m mark, which is in fact well in excess of the current outlay of most teams.

Cost caps were first mooted in 2009, when then FIA president Max Mosley tried to introduce a spending limit of £30m for 2010.

IndyCar bags new title sponsorship deal

US telecom giant Verizon has signed a multi-year deal to become the new title sponsor of the IndyCar Series.

Verizon will fill the gap left by the withdrawal of IZOD last year, and the US's premier single-seater championship will now officially be known as the Verizon IndyCar Series.

This is not the first motorsport involvement for Verizon, which is heavily involved with Penske in IndyCar, while its logos were also seen on the McLarens during the 2011 Canadian Grand Prix and the 2012 US GP. It also sponsored the IndyCar pole award and will continue to do so alongside its title sponsorship this year.

Verizon is a big hitter in the US, and last year it posted revenues of $121bn and an operating income of $32bn.

Mark Miles, CEO of IndyCar parent company Hulman & Co, said of the deal: 'Verizon is the perfect partner for us to showcase the high level of innovation and technology that is inherent in our sport. IndyCar will provide a large audience of tech-savvy consumers who are eager for the latest technology to further enhance their experience.

'Verizon's commitment to IndyCar demonstrates its belief in the direction of our sport and further corroborates our long-term goals.'

LAT

Verizon has previously been associated with the Penske team

Cosworth to create new UK manufacturing centre of excellence

Performance engineering group Cosworth is to setup a 'centre of excellence' for niche manufacturing at its new Northampton, UK, facility.

The £20m, 4645sq-m manufacturing plant was announced at the end of last year, and is expected to create 70 new jobs by the time of its opening in 2015.

'We believe that creating this centre of excellence will benefit both our automotive customers by enabling cost-effective production of more advanced engine designs in smaller quantities, and the wider manufacturing supply chain that we rely on in the UK – creating jobs and securing industry investment in the process.'

COSWORTH

Cosworth has now announced a partnership which aims to develop 'world-leading' flexible manufacturing at the plant. It has teamed up with Cranfield University, Flexeye and Axillium Research, while the innovative partnership is supported by a grant from the UK Government's Advanced Manufacturing and Supply Chain Initiative (AMSCI).

Hal Reisiger, Cosworth CEO, said: 'Our position as an independent high performance engineering and manufacturing business enables us to work with a range of automotive vehicle manufacturers and technology partners.

Professor Ashutosh Tiwari, professor of manufacturing informatics at Cranfield University, said: 'Cosworth's new engine manufacturing facility in the UK – that will house some of the most advanced technologies – will be supported by the world-leading manufacturing informatics research expertise at Cranfield University.

'We will develop novel assembly optimisation algorithms and supply chain modelling/visualisation techniques to enable flexible manufacturing at Cosworth using the latest informatics technologies.'

Goodyear scoops top NASCAR business award

Famed tyre producer Goodyear has won a prestigious award for its business activities within the NASCAR industry.

Goodyear, which has been supplying NASCAR with rubber for the past 60 years, has been given the Driving Business Award, an annual prize which is presented to the official NASCAR partner which has demonstrated 'extraordinary leadership and results through its participation in the NFFB [NASCAR Fuel for Business] Council'.

The NFFB Council, which this year celebrates its 10th anniversary, is a business-to-business platform that brings together an exclusive group of more than 50 official NASCAR partners to buy and sell products and services. NASCAR tells us that since its inception in 2004 its quarterly get-togethers have facilitated more than 1000 'speed meeting' sessions where official NASCAR partners meet and do business with one another.

NASCAR claims that where the NFFB Council really helps businesses involved in the sport is by offering an opportunity for companies to bypass the layers of corporate obstruction that might exist, and then deal directly with the decision-makers in other concerns.

LAT

NASCAR chief operating officer Brent Dewar said: 'The NASCAR Fuel for Business Council brings together partners from a wide spectrum of industries for the sole purpose of doing business with one another. What sets it apart from anything else in sports is the resolve partners like Goodyear demonstrate, as members of the Council, to drive business-to-business value.'

Goodyear has been a member of the Council since 2008, and currently conducts business with nearly half of the other companies involved in the scheme. Gary Melliere, its general manager of sponsorships, said: 'The Fuel for Business Council has helped us to build stronger business-to-business relationships and collaborate with Council members to amplify each others' marketing programmes.'

Big increase in World Touring Car TV viewing figures

WTCC raced in front of big crowds at Macau in 2013 while over half a billion watched the championship on TV

LAT

The World Touring Car Championship (WTCC) has posted an increase in its TV viewing figures for 2013, eclipsing the staggering half-billion audience it had in 2012 by close to 10 per cent.

Figures from respected German research company Repucom show a cumulated audience of 557 million viewers for 2013, up 8.9 per cent on the previous year.

In 2013, 111 TV channels broadcast at least one WTCC event, footage reaching 188 countries worldwide. This amounted to some 1176 broadcast hours, again up on the previous year (by 8.7 per cent).

Ulrich Lacher, global director enterprise services at Repucom, said that the figures were all the more remarkable because the championship was wrapped up early. 'For the second year in a row, we saw more quality in the two key factors: media impact and audiences growth,' he said. 'This despite major competition and a relatively suspense-free end of the season. The positive trend in North and Latin America is encouraging. New markets were opened and resulted in better distribution deals, which led to significant increases in audiences and media impact.

'Live and highlight coverage have been consolidated, indicating a loyal fanbase, especially in growing markets like Morocco and Hungary. 'Despite the early decision of the championship titles, that could have "poisoned" the interest of the season, the growth of 2013 was somewhat significant.'

SEEN: NEW-LOOK NASCAR RACE TRUCK

NASCAR has rolled out its next generation of pickup truck racers, which follow the philosophy embraced by both the Sprint Cup and Nationwide series in recent years in using racers that resemble their road car cousins. Robin Pemberton, NASCAR vice-president of competition and racing development, said: 'As everyone knows, it's about the product relevance nowadays, and we in 2010 kicked off the Nationwide Series car and brought the muscle cars in. That process went fairly well. Gen-6 [Sprint Cup] was a little more detailed, and it took a long period of time to get that introduced and rolling. That was about a three-year project, and this one is roughly two years, give or take.'

Pemberton added that the new truck's introduction ends a half-decade cycle for NASCAR: 'It's all about the working relationships with the OEMs and with the race teams and ourselves to create a level playing field. These projects take a lot of time, so when you're looking at all of the projects that we've brought online over the three series, you're looking at a solid five to six years of bringing up new vehicles.'

LAT

F1 teams to regret disbanding FOTA, says former boss

The man who ran the recently disbanded Formula 1 Teams' Association (FOTA) has said that the teams are sure to miss the organisation as the sport enters a possibly contentious period.

FOTA was originally formed in 2008, with the intention of fighting the teams' corners when it came to cost control regulations and to help negotiate a new Concorde Agreement. Since then, all the teams have signed bilateral agreements with the Commercial Rights Holder, tying them into the sport until 2020, while a separate body that represents just the top teams has been setup – the F1 Strategy Group. It was announced just before the start of the season that FOTA would be disbanded.

However, Oliver Weingarten, who was general secretary at FOTA, has told *Racecar* he believes the teams will miss it this year: 'I think there are inevitably going to be some crises, whether on or off the track, and the teams are now going to have to work out how to cooperate as a cohesive unit.'

Weingarten also says that the teams have decided to disband the organisation partly because of a misunderstanding as to what it actually did. 'I think there is a role for FOTA. There were a number of activities that took place that you could say were below the radar, but the teams still benefitted from a central organisation. A lot of activity that they took for granted is not being done.' Among that activity, says Weingarten, was the negotiation with the circuits for testing, talks with tyre supplier Pirelli and summer shutdown agreements.

Weingarten believes FOTA ultimately folded because of an unwillingness on the part of the teams to continue, plus a failure to persuade teams that had left (Red Bull, Ferrari, Sauber and Toro Rosso) to rejoin. 'Essentially it was the result of a consensus on a way to go forward. We tried to engage with the teams that had resigned from FOTA, and when that proved not to be possible, coupled with a lack of funds available to continue, it was the inevitable conclusion.'

Racecar has learnt that the lack of funds Weingarten refers to were unpaid fees from some teams. Each team was supposed to pay FOTA £70,000 a year.


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NASCAR signs 10-year deal with Mexican promoter

NASCAR and Mexican promoter CIE have reached a 10-year agreement for the Mexico-based Toyota Series to continue to operate under the NASCAR banner to the end of the 2023 season.

The NASCAR Mexico Toyota Series is the top motor racing series in Mexico. It traditionally runs a 15-race schedule and this season is its 11th. It has been sanctioned by NASCAR since 2007. CIE is the leading live entertainment company in Latin America and the third biggest live entertainment promoter in the world.

Steve O'Donnell, NASCAR executive vice-president of racing operations, said: 'This historic announcement represents the next step in the growth of the sport and the international impact NASCAR is making.

'The NASCAR Mexico Toyota Series continues to be a bridge that makes NASCAR more relevant to the Hispanic community in the US. Along with the NASCAR Canadian Tire Series and the NASCAR Whelen Euro Series, the NASCAR Mexico Toyota Series gives our sport a strong and unified presence across North America and Europe.'

Federico Alaman, managing director of the NASCAR Mexico Toyota Series, said: 'This extension symbolises the strength of our relationship with NASCAR. I'm very proud of how far the series has come since its inception and continuing to operate under the NASCAR banner for many years to come will reinforce the high level of competition and excitement that the NASCAR Mexico Toyota Series brings to every event.'

The impact of NASCAR on the Mexico Series is clear. Its inaugural season featured just one oval event, yet in more recent years it has run on just one or two road courses. The series is also very healthy, with average grids of 34 cars.


LAT

NASCAR Mexico Toyota Series cars in action at the Phoenix season-opener

LAT

Ford closes in on UK F4 deal

The Motor Sports Association (MSA) has selected the tender put forward by Ford to operate the new FIA Formula 4 in the United Kingdom and both parties have now entered formal negotiations.

If the deal goes ahead it could mark the end of the name 'Formula Ford' at a national level in the UK, after being an integral part of the scene for 47 years, although there has been no decision as to the title of the championship as yet.

Ford's hopes of switching its current open formula 'slicks and wings' Formula Ford to FIA Formula 4 for 2015 were given a boost late last year when the FIA decided to allow turbocharged engines.

This was something that head of Ford Racing in Europe, Gerard Quinn, had told *Racecar* was vital if Ford was to be involved in the new formula: 'Turbocharging is the way for small petrol engines for the future. One of the dispensations we have for Formula 4 is to run the turbocharged 1.6-litre EcoBoost, and that is hugely important for us.'

Ford currently promotes its FF championship through the Racing Line organisation, but there are no details as to whether this will continue with F4. It is known, however, that F4 is to be a spec formula, so part of the negotiations could revolve around choosing a manufacturer for the carbon chassis – the current FF's open formula is to FIA spaceframe regs.

The MSA has stressed that the negotiations remain subject to contract, but added that both Ford and itself are optimistic they will result in a positive conclusion.

Quinn said: 'I am delighted with the news from the MSA. Selecting Ford to go through to the next round of contract negotiations is a significant step and recognises the continued commitment of Ford Racing to junior single-seat racing.'

McLaren simulation skills to ease 'aero' flow at Heathrow

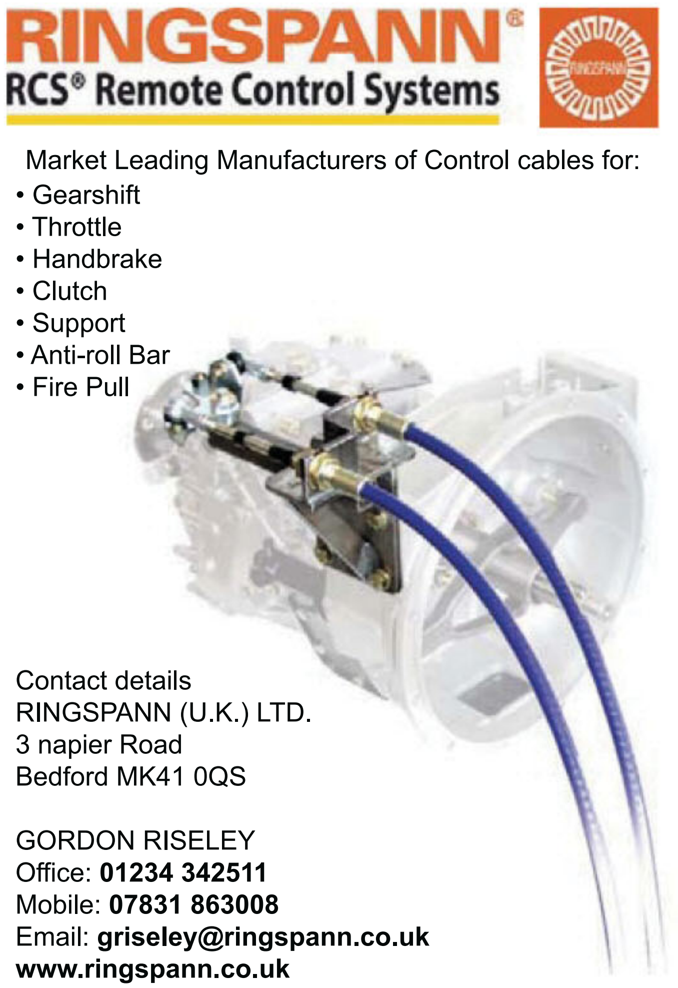
McLaren has found yet another outlet for its Formula 1 know-how with the news that it is to use its simulation technology as part of a project to increase efficiency at one of the world's busiest airports.

The company's diversification arm, McLaren Applied Technologies (MAT), will use modelling and simulation technology pioneered in F1 competition to help London's Heathrow Airport to improve its long-term planning, and also with the movement of aeroplanes. It has won a four-year contract with the airport.

The first project to be undertaken by the consortium, which is being led by NATS, the UK's leading provider of air traffic services, will involve the development of a strategic tool to enable the rapid assessment of proposed changes to airport infrastructure – for this McLaren will be contributing its expertise in data management and simulation techniques.

SEEN: LADA GRANTA WTCC

This furiously pumped up Lada is the Russian manufacturer's new WTCC contender. Built to the new-for-2014 regulations by Lada Sport in collaboration with ORECA, the Granta is an updated version of last year's challenger, which managed a fifth place finish at its home race in Moscow. Lada plans to introduce a brand new car for 2015.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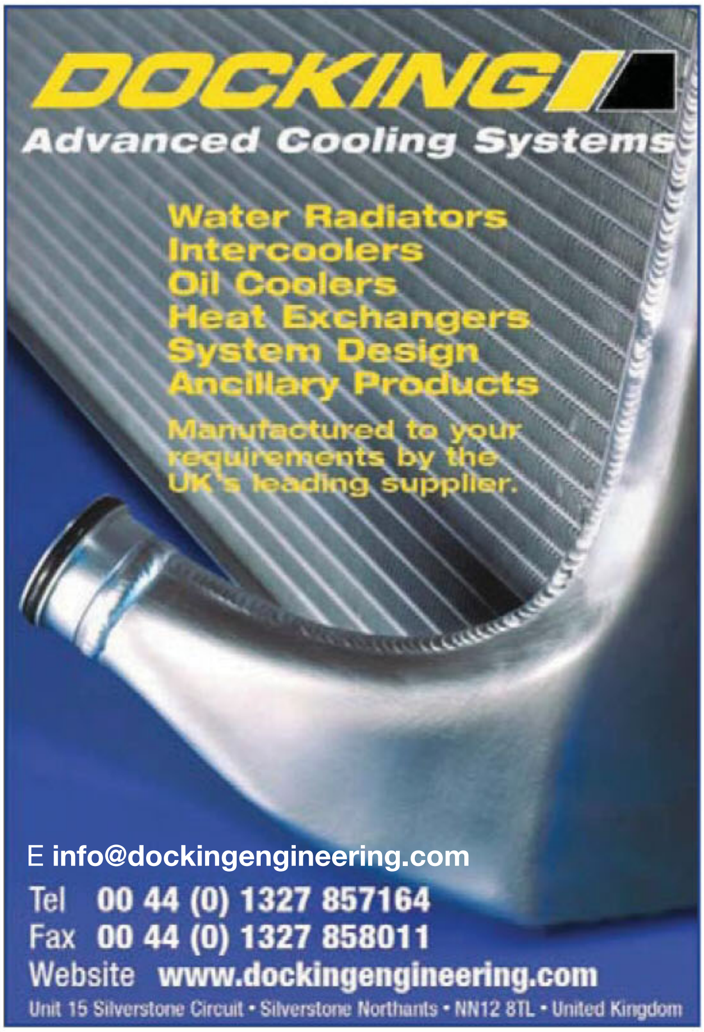
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INTERVIEW – JAMES WARBURTON

On top down under

With a massive new TV deal and three new makes on-board, V8 Supercars is on the up. We spoke to its CEO to find out what it takes to run Australia's third biggest sport

When it comes to Australian V8 Supercars they've always said you're either a Holden man or a Ford man (or woman, of course). At least they did until relatively recently, because for most of the past 20 years V8S has been a two-horse race between the GM brand and the blue oval. Now there's a different breed of fan emerging in the distinct spectator environment of the Antipodes: Volvo man, Nissan man and Mercedes man.

Clearly, with these three new makes on board, things have changed over the last year or so in V8S. But this has not been the only change, for there's also been a change at the top of the organisation that runs Australia's premier motorsport series, with James Warburton having taken up the reins at the series' Southport, Queensland base last June.

Warburton is a former TV executive who has worked for Seven Network and as the boss of Ten Network in Australia, among other business roles, but he bridles at suggestions that he does not come from a racing background. 'That is not quite correct. I've followed motorsport all of my life, ever since my dad piled me into the car as a four-year-old to go to Bathurst. We made that trip every first Sunday of October for my entire childhood. I absolutely love it.

'In my working adult life I spent many years in the automotive industry, then into media, sales and television. I was part of the team that put together the initial TV deal for Seven in Australia in 2007 and was heavily involved in the sport from that point. Before I took this position I also spent a great deal of time looking closely at the business and the sport, speaking to a lot of people to make sure I was completely across the role.'

MARK HORSBURGH

"From next year we plan to have between one and three events outside Australia"

Now he also has a year of experience as boss of V8S under his belt, so how has he been finding it? 'Like most have in recent times, the sport has endured a difficult few years due to the global economic downturn and some poor decision-making. One of the challenges has been getting the commercial side in order, which I am now glad to say has been done and we have a great future ahead.'

But just what has been done? 'As a team we have achieved a lot. The first point was consolidation and now we are in a period of innovation. We have extended relationships and events with three [state] governments, retained all of our existing sponsors and added many more new partners. Where the sport had gone backwards was the last television deal which was way under the sport's value. I am glad to say that we have just completed the largest media rights deal in the sport's history, and by the end of this year will be back at record income levels.'

This media deal was signed with Foxtel, FOX Sports and Ten Network at the end of last year and it gives the broadcasters involved all media rights including digital from 2015 until the end of 2020. It is said to be worth a whopping AUS$196m (US$177m) in cash and AUS$45m (US$41m) in advertising.

You might be forgiven for thinking close to a quarter-billion is a lot of money for what is in essence just a touring car series. But to compare V8s with the BTCC, or even the WTCC, would be to underestimate its place in the psyche of the Australian public. Because V8S is big down under. Very big. 'We are the third most attended sport in Australia,' says Warburton. 'Our major events are among the biggest television audiences in the country. It's no secret that in this country the football codes, which would be the case in most countries, have the majority audience share. V8 Supercars is the next most popular. For many fans we sit well alongside AFL [Australian Rules Football] or NRL [rugby league].'

That's an impressive achievement, suggesting parallels with NASCAR that go beyond the heavy metal V8s. There seems little sign of a drop-off in interest, either, although the activation of the interest is certainly changing. 'We increased our crowds slightly last year [about 2 million attended races in 2013], our ratings have been steady and our digital numbers have more than trebled. In Australia, free-to-air television is slowly eroding as people look to other ways to consume sport, such as through pay television for more variety and online on their portable devices. It is a landscape that is changing and evolving every day.'

It's not just popular in Australia, either – the V8S formula travels well and has enjoyed successful forays abroad in recent years, though this season it's staying in its heartland. 'From next year we plan to have between one and three events outside Australia.' But before European V8 fans get too excited, the championship's reach isn't quite as long as some might wish, admits Warburton. 'We would absolutely love to race in Europe, but under our current agreement with the FIA we are unable to race anywhere further west than roughly Turkey.'

What race fans west of the Bosporus will miss is excellent racing with spectacular cars packing, as the name on the tin suggests, big 650bhp 5-litre V8 powerplants. Yet V8 engines are hardly at the cutting edge of the automotive industry right now. Talk to most manufacturers about what they want from a race series and they will say a four-cylinder turbocharged formula with which they can best showcase their current offerings. Warburton's aware of this, and does not discount a radical change in the formula in the future. 'We are very nimble. The Car of the Future (CotF) has ensured that we are adaptable to change when and if required. Again, as proven in Adelaide [the first round in 2014, where newcomer Volvo starred], we have an amazingly successful platform right now but we will always be looking years ahead.'

Indeed, new manufacturers are entering the sport, drawn by the successful CotF concept – a silhouette formula with many control components. But what of the old guard? What of Holden and Ford? Both manufacturers have been very much in the news in Australia lately, primarily because these stalwarts of Aussie manufacturing are now pulling out of the country to make their cars elsewhere. So, is the series worried that it might be about to lose one, or two, of its major draws?

'Quite the opposite,' Warburton insists. 'I see V8 Supercars being even more relevant than ever to support their marketing and brand objectives. Don't forget that while cars may not be made in Australia, they will be sold and marketed in Australia. With the news that from 2017 no manufacturers will make cars in this country, it's fundamental for any brand to showcase their product. We do that not just through motor racing, but with the biggest sporting and entertainment events in this country, and the world. Manufacturers are looking for platforms to showcase their product and there is no better way than this. Just ask Volvo.'

Mike Breslin

LAT

Scott McLaughlin in the S60 R Valvoline Racing GRM Volvo Action

RACE MOVES


LAT

Dickie Stanford (above) is no longer team manager at the Williams F1 team, although he will remain with the wider group in an as yet undecided position. Stanford has been with the Grove outfit since 1985, when he was a race mechanic for Nigel Mansell. **Peter Vale**,formerly a technical coordinator at McLaren, will replace Stanford as team manager.

Federico Gastaldi has been appointed deputy team principal at the Lotus F1 team. Team owner **Gerard Lopez** remains chairman and team principal. Gastaldi, from Argentina, has been with the Enstone team since its Benetton days. His previous role at Lotus was business development officer.

Rob Smedley, race engineer for **Felipe Massa** at Ferrari, has now followed the Brazilian to Williams. Smedley fills a newly-created role of head of vehicle performance, and part of his work will focus on making sure the link between the track and the Grove base during a grand prix weekend works effectively.

Chinese WEC LMP2 outfit KC Motor Group (KCMG) has appointed **Maarten de Busser** as its team manager. The Belgian, who was the technical director for GP2 last year, has worked in a plethora of single-seater formulae and has also previously worked with KCMG in the China Touring Car Championship.

Rob Jones is the new chief executive of the Motor Sports Association (MSA), the governing body for motorsport in the UK. Jones, formerly the general secretary of the MSA, has been acting chief executive since October. Before joining the MSA Jones, who has competed in both rallying and racing, practised as a solicitor in Wales.

Richard Lockwood has joined the Williams Formula 1 team, where he is now head of race strategy, working with **Randeep Singh.** Lockwood was previously at Marussia, where he was a tyre/strategy engineer.

Alex Burns is now the CEO at the Milbrook test centre. Burns was previously CEO, and before that COO, at Williams F1, where he spent 11 years of his career and where he was responsible for establishing the successful Williams Advanced Engineering arm of the group. Millbrook's former chief executive, **Miguel Fragoso**, has now left the company to pursue other interests.

Michael Cannon is now Justin Wilson's race engineer at IndyCar squad Dale Coyne Racing. He replaces **Bill Pappas** in the role, the latter having left to join Rahal Letterman Lanigan Racing. Cannon was previously at Andretti Autosport.

NASCAR has announced the nominees for its 2015 Hall of Fame Class. The technical and administrative side of the sport is well represented with car owners **Richard Childress**, **Rick Hendrick**, **Raymond Parks** (the first champion car owner); engine builders-turned-owners **Ray Fox** and **Robert Yates**, and the builder of Charlotte Motor Speedway **O Bruton Smith**, making the shortlist.

Konstantin Kotitsas, a well-known figure in the Porsche Carrera Cup in the UK, has died at the age of 45. Kotitsas enjoyed great success in the one-make championship, engineering the cars that took the title between 2010 and 2013. The Greek-born race engineer also had experience in the Porsche Supercup.

NASCAR has made a raft of promotions in its Integrated Marketing Communications office. **Kurt Culbert** has been promoted to senior director, stakeholder communications; **Jayme Avrit** is now senior manager, stakeholder communications; **Matt Nordby** steps up to senior manager, broadcast and entertainment communications, and **Alex Moore** has been promoted to senior coordinator, content communications.

Bernie wins United Kingdom court case over F1 sale

Formula 1 boss Bernie Ecclestone has won a case at the High Court in the UK which was related to the sale of Formula 1 back in 2005.

Judge Guy Newey, who was presiding, threw out a claim made by Constantin Medien, which had questioned Ecclestone's role in the sale of the F1 rights to the current owner of the sport, CVC Capital Partners. The German company was trying to sue the long-time Formula 1 boss for up to $144m.

Back in 2012 BayernLB [BLB] banker Gerhard Gribkowsky was jailed for eight-and-a-half years for his part in the agreement, after being found guilty of corruption for taking a $44m payment from Ecclestone, which was construed as a bribe.

However, while the judge said that Ecclestone had paid the bribe, going as far as to say it was part of a 'corrupt agreement', he did not believe that he had tried to undervalue F1 in order to help with its sale to CVC, a central plank of Medien's case.

Judge Newey wrote in his conclusions: 'The payments were a bribe. They were made because Mr Ecclestone had entered into a corrupt agreement with Dr Gribkowsky in May 2005 under which Dr Gribkowsky was to be rewarded for facilitating the sale of BLB's shares in the Formula 1 group to a buyer acceptable to Mr Ecclestone.'

LAT

But Newey went on to add that: 'It was no part of Mr Ecclestone's purpose... [for the shares] to be sold at an undervalue.'

Ecclestone will now stand trial in Munich in April having been indicted in July last year in connection with the alleged Gribkowsky bribe. He has already stepped down from the board of Formula 1's holding company, Delta Topco Ltd, but still sees to the management of the sport on a day-to-day basis.

SPONSORSHIP

Sauber has scooped a major Middle Eastern backer in the shape of Dubai-based **Pacific Ventures**, a real estate company that specialises in high-end residential developments in the Gulf state. Pacific's logos now appear at the rear of the sidepods on the Sauber C33.

Force India announced three new partners at the start of the F1 season. Damper manufacturer Koni comes on-board as a technical partner while new sponsorship comes from two Mexican companies: **Consorcio Aristos**, which is in construction, and financial institution **FICREA**.

Ford's works team in the Australian V8 Supercars championship, **Ford Performance Racing**, has four new sponsors: **Elite Caravans** and **MightyMite** (a yeast extract spread) join as secondary backers, while both **King Gee Workwear** and **3M** logos also now appear on the team's Ford Falcons.

Formula 1 tyre supplier **Pirelli** is to broaden its exposure in the sport with title sponsorship deals with two grands prix. The Spanish Grand prix will now be officially known as the **Gran Premio de Espana Pirelli**, while the Hungarian race will be the **Formula 1 Pirelli Magyar Nagydij**.

RACE MOVES

Historic racer and preparation wizard **Mauro Pane** has died after a road accident near his home in Italy. Pane (50) founded his race team, F1 Storiche, in 1994 with his father Marcello. The team is best known for its work with 1970s era Formula 1 machinery. Pane was also the driver double behind the wheel of **Niki Lauda**'s Ferrari 312T2 in the film *Rush.*

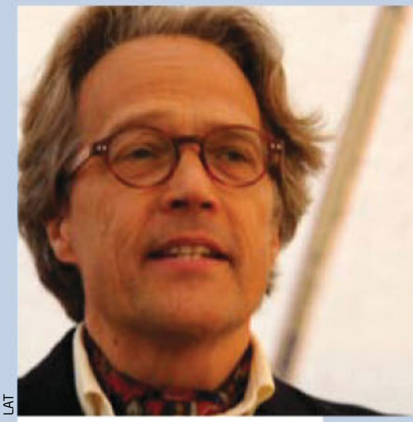
NASCAR has hired **Tom Bryant**, a 20-year veteran of the US Army, to a new position of director, touring and weekly communications. Bryant is a recently retired lieutenant colonel, who has served in the infantry and in Special Operations. He most recently served as director of public relations for the US Special Operations Command in Kabul, Afghanistan.

Former GP2 driver **Giacomo Ricci** is to return to the series on the other side of the pit wall, the 28-year-old Italian taking up a management role with the Trident team. Ricci, who started his management career last year with the MLR71 organisation in Auto GP, replaces **Luca Zerbini** as team manager across Trident's GP2 and GP3 operations.

NASCAR has hired **Ade Herbert** as a coordinator in its Fan and Media Engagement Center. Herbert is a graduate of Fordham University in New York who has served in the US Navy. Herbert participated in the NASCAR Diversity Internship Programme and worked with Rev Racing for three years in marketing and public relations.

Former CART chief executive officer **Andrew Craig** is now the representative of the FIA World Endurance Championship in North America. British-born Craig, who ran CART in the latter part of the 1990s, will now work closely with the Austin circuit, which hosts the WEC this year, and will also be looking for further opportunities to promote the championship in both the USA and Canada.

Alba Colon, the programme manager for Chevrolet Racing in the NASCAR Sprint Cup, has been recognised at the US stockcar racing governing body's Annual NASCAR Diversity Luncheon, where she was awarded the Industry Ambassador Award. Colon became the first woman to lead a racing programme for an OEM in NASCAR in 2001.



LAT

Lord Charles March (above), the driving force behind the Goodwood motorsport festivals, has been awarded the inaugural Sue Brownson award. The Institute of the Motor Industry presented Lord March with the award – named after its former president who died last year – which has been designed to recognise individuals in the sector who have demonstrated 'excellence in leadership'.

Bill Bennett, who was once a technical artist for publications such as Motoring News and Motor Sport, has died at the age of 91. Bennett was well-known for his superb cutaway racecar drawings.

NHRA Funny Car operation Don Schumacher Racing (DSR) has promoted **John Collins** to crew chief on its Make-A-Wish Dodge Charger drag team. Collins was previously assistant crew chief to **Rahn Tobler** on DSR's NAPA Auto Parts car, a position that will now be filled by **Eric Lane**, who moves to DSR from John Force Racing.

Ronnie Kaplan, who through his Ronnie Kaplan Engineering company brought the AMC Javelins to Trans-Am in the late-60s, has died. Under Kaplan's stewardship the small American car-maker scored a number of second place finishes against Chrysler, Ford and GM competition before Penske took over the Javelin programme in 1970.

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14

Rise in level of youngsters looking at engineering

According to UK Government figures, there has been a sharp rise in the number of young Brits considering a career in engineering.

A Department for Business Innovation and Skills (BIS) commissioned survey has found that the number of 11-14-year-olds thinking about working in engineering has jumped up by six per cent. The survey also showed a six per cent rise in the number of girls saying they would consider an engineering career. More parents (a rise of four per cent) also said they would encourage their children to become engineers.

The increases come in the wake of Tomorrow's Engineers Week, in November last year, when government, employers and educators came together to enthuse young people, particularly females, about the rewarding careers on offer in engineering.

Vince Cable, UK secretary of state for business, innovation & skills, welcomed the findings: 'It is encouraging to see that our efforts to highlight the importance of engineering as a career has had a positive effect, and that more women and girls are seeing it as an exciting career.

'As a country we excel in hi-tech industries, but we need the engineers to maintain our competitive advantage. Government alone cannot solve this. We need to work with industry, universities, colleges and schools to keep momentum and guarantee the pipeline of talent so that businesses are not disadvantaged.'

Government and industry launched Tomorrow's Engineers Week following the Perkins Review of Engineering Skills. Professor John Perkins found that decisions made at a young age are at the heart of the engineering skills gap problem in the UK. This is because engineers must have a strong foundation in maths and science, especially physics, but the number of young people choosing to study these subjects after the age of 16 is relatively low.

BRIEFLY

Horse brand

According to a global business review, Ferrari is the world's most powerful brand, eclipsing Google, Coca-Cola and its F1 nemesis Red Bull in the brand-power stakes. The Brand Finance Global 500, an annual study conducted by brand valuation gurus Brand Finance, pits the world's biggest business names against each other to determine which are the most powerful and most valuable, and Ferrari has come out on top. The legendary Italian car-maker and F1 entrant scores highly on a wide variety of measures on Brand Finance's Brand Strength Index, from desirability, loyalty and consumer sentiment to visual identity, online presence and employee satisfaction.

NBE back to F3

UK engine builder Neil Brown Engineering (NBE) is to return to high-level Formula 3 competition, with T-Sport packing the company's units in its European Championship Dallaras. NBE has plenty of previous experience when it comes to F3, being well-known for its Mugen powerplants in the past, but its last victory in the category was back in 2008, again with T-Sport. NBE's F3 unit was the first of the new-regulation motors – which allows for full race engines – to hit the track at the end of last year.

French connection

Well-known UK race engine builder Swindon has opened a new division in France. The expansion comes on the back of a buyout of the Cupissol Motteurs concern, which specialised in maintaining and testing rally powerplants. The French operation is based in St Marcel de Careiret, near Avignon, and is managed by Oliver Volpi, who comes to Swindon after 10 years as a project manager at Sodemo Moteurs. Volpi said: 'I'm delighted with the opportunity. We offer comprehensive engine assembly, maintenance and testing services here and joining forces with Swindon's UK head office gives us access to high technology in the fields of design, simulation and manufacturing, which will help develop our business in France.'

McLaren in no rush to find new CEO, says Dennis

McLaren Group chairman and CEO Ron Dennis has said that he is in no hurry to find a permanent CEO for the F1 team to replace Martin Whitmarsh, who left the organisation at the end of last season.

The McLaren F1 team is currently headed by Eric Boullier (racing director), with Jonathan Neale as interim chief executive officer. The position of team principal, which was Whitmarsh's title, is no longer part of the team's management structure, but a full-time CEO would fill the same role, though now in an equal partnership with Boullier.

There has been speculation that former Mercedes team principal Ross Brawn was in line for the position, but Brawn has categorically denied that he has any plans to return to F1, and Dennis has confirmed that the identity of the new CEO has yet to be decided.

'That choice of person [for CEO] is critical to the long-term future of the company and I will take my time,' Dennis said. 'And ultimately with such an important decision, it will not be mine and mine alone. I would expect to share that with the shareholders and key individuals. At the moment it is not at the top of my must-do list. I am comfortable with what we have in place.'


LAT

Dennis has also said that Neale could become the full-time CEO, if he proves successful during the early part of this season. 'Jonathan absolutely accepts that he is nominated on a day-to-day basis, but effectively not only would he love to have the job, he may well do the job.'

But Dennis also made it clear he is not worried about any perceived power vacuum at the top of the McLaren squad. 'The key thing to understand is that supplementing Jonathan's, Eric's and Sam's [Michael] capabilities with my own, for a short period of time, is adequately going to address the challenge of winning in F1.'

Dennis has also said that he has no plans to take direct control of the team at the races. 'I won't be active at the circuit. I will be there to observe,' he said.

CAUGHT

NASCAR Nationwide crew chief **Chris Gayle** has been fined $10,000 and placed on probation until the end of the year after the Joe Gibbs Racing car he tends was found to be running with a weight attached in an unapproved location at the Las Vegas round of the series. The car chief for the No 11 Toyota, **Todd Brewer**, has also been placed on NASCAR probation until the end of the year.
FINE: $10,000

Greg Ives, a crew chief on the No 9 Chevrolet in the NASCAR Nationwide Series has been placed on probation until 31 December after his JR Motorsports car was found to be over the minimum front ride height at Las Vegas. Neither Ives nor his team were fined for this infraction.

Jeremy Bullins, a crew chief on the No 22 Ford in the NASCAR Nationwide Series, has been fined $5000 and placed on probation until the end of the year after a shock absorber on the Team Penske car was found to exceed maximum gas pressure at the Las Vegas round of the championship.
FINE: $5000

SAFETY

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SEATS

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www.gprdirect.com

RACE TAPE

High quality Tesa Tape from SpeedSport

Based at Silverstone, SpeedSport are official motorsport distributors for the full range of tesa high quality tapes. Stock includes the legendary Tesa 4651 cloth race tape in all colours, double sided including 4964 and 4970, top quality helicopter tape and our own 3mm and 5mm thick single sided foam tapes.
www.speedsport.co.uk/tesatape.html

ELECTRONICS

MoTeC Toyota 86 ECU and firmware package

With limits to factory ECUs and most aftermarket systems, drivers need a more sophisticated and versatile solution. MoTeC rises above this challenge with the groundbreaking M1 ECU and the new, specially developed Toyota 86 firmware package for the FA20D engine.

Sold as a complete replacement for the factory computer, this fully programmable engine management system is designed to handle the complex demands of motorsport applications and high performance modifications with ease. It offers powerful capabilities such as turbo or supercharger control, programmable launch and traction control, and gear shift ignition cutting for flat shifts, all while maintaining factory features including power steering, ABS, stability control, air conditioning and the OE dash.

An optional plug-in wiring loom is available for quick, cost-effective installation using the car's original wiring harness, sensors and fuel system.

MoTeC's package is designed to run a standard engine straight out of the box, providing the perfect starting point for customised tuning within M1 Tune, the powerful new tuning program for M1 ECUs. It offers unique features that facilitate fast, accurate tuning, with much of the thinking done for you.

Fuel delivery within the 86 package is based on volumetric efficiency, a superior method of control that is precisely calculated from the combination of air volume into the engine, injector data and the desired air/fuel ratio (lambda). The M1 series incorporates live data logging into the tuning software, making road or dyno tuning very efficient. Areas that need attention can be pinpointed instantly without the need for separate download and analysis.
www.motec.com.au/m1package-86

ENGINE KIT

New remote filter mount from Peterson

Peterson's remote filter mount with primer allows you to prime your engine easily.

By spinning over the integral pump with a hand drill, you can have oil at all of your bearing surfaces, usually in less than 10 seconds. It's available in several filter sizes, and firewall or tube mount.
www.petersonfluidsys.com/filter_mount.html

TESTING

PowerStream reaches new level

PowerStream Industries is introducing an 8-post, 16 axis suspension and chassis diagnostic test system for the motorsport industry. Unlike any of its predecessors, the GEO has capabilities of handling many times as much data at twice the accuracy of its nearest rival.

The GEO System allows for the measuring and monitoring of all aspects of kinematic and dynamic movements of almost any racecar or truck. One of the major benefits on the 8-post 16-axis system is its ability to measure dynamic suspension as well as chassis loading and deflection, with equal effectiveness for a carbon tub, tubeframe or unitised chassis. The GEO grip/side loading wheel pads establish precision positional corner side loading, helping to access grip levelling, load direction and track motion profile for dynamic lap simulation.

This, combined with the ability to customise test inputs from RLD, track data, simulation data and racecar 'finger printing' for instant measurements of all suspension location points, means that the GEO system has more functionality than any system of its kind ever produced.
www.powerstreamindustries.com

DEALERS

The entire OMP range available from YBRACING

YBRACING are the number 1 online dealer for OMP motorsport products. They supply the entire OMP range including racewear, helmets, seats and rollcages, offering the lowest prices and same day dispatch. The new 2014 OMP range has just been launched – available to order now on the website below.
www.ybracing.com

SENSORS

New infrared sensor array from McLaren Electronics

McLaren's infrared sensor measures temperature at a distance, with no need to touch the target. The integrated infrared module senses the thermal radiation emitted by objects on a 16x4 array of sensing points, for measuring the temperature distribution across a surface. These 64 measurement pixels are transmitted via CAN to the host controller or data logging device. It is available in both 35-degree and 60-degree field of view options to suit a variety of installations. A software package is provided for viewing live data from the array.
www.mclarenelectronics.com

ALIGNMENT

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recycle

www.racecar-engineering.com

A few months ago, our free digital download of *Stockcar Engineering* involved NASCAR's switch to Generation 6 and the attitudes held within. 'The period between Generation 5 and Generation 6 took everyone – including ourselves – out of their comfort zone in terms of how much of the car we had to work with,' said Pat Suhy, NASCAR group manager for Chevrolet Racing. 'I think if we take ourselves out of our comfort zone again the way we did with the Generation 6 car, we should be able to do a great job with the Generation 7 car.' Drastically different cars were being discussed, and even V6 engines, although this has now been discounted. NASCAR EV anyone?

Taking an established brand such as NASCAR and pushing the boundaries was sure to be an eye-opener for the series. Fan backlash will almost certainly keep out the most ambitious of plans, but less outlandish plans such as the introduction of direct injection are pretty sure to make it. Lower mass, different aerodynamics and sequential gearboxes are all on the table, but the interesting point is that – having broken the established parameters – NASCAR is looking to go further.

Taking an established brand such as NASCAR and pushing its boundaries was sure to be an eye-opener

Relate that to Formula 1. The backlash against the new technology has been pretty impressive so far, and with Daniel Ricciardo being disqualified from the Australian Grand Prix amid criticism of the fuel flow meter, and the resultant drop in faith over the technology.

Criticism has been levelled at the sound, although I loved the audio from the onboard in the braking zone as the Energy Recovery Systems spooled up. An Australian website has made an audio comparison between a modern F1 car, a 2013 car, a Porsche Carrera Cup car and an Australian V8 Supercar. The sound on the straight is clearly quieter, and less dramatic, and has led to one member of the *Racecar Engineering* team to be moved almost to tears as he laments the loss of the V8 sound. He has been soundly castigated. Others on the team remember the sound of the V12s and V10s, both of which were lost to F1 years ago. The noise of the Formula 1 cars is of paramount importance to the old guard. For the new generation, is it such a big deal? It won't be long before we lose the V6 engine note. Will that invoke similar nostalgia? My only lament is the difference in sound between different engine configurations, such as you get at Le Mans.

Now that F1 has stepped away from V8, V10 and V12 engines, seemingly for good, and once the audience has got the hang of the sound, what next? Like NASCAR, Formula 1 has stepped outside its comfort zone and now relies heavily on alternative drivetrain technology. What of the future of fuels – perhaps hydrogen? This year, Cranfield University set its students a hydrogen design study. The design of the car has to include hydrogen storage, which is safely protected in a crash. The design has to optimise the spark ignition engine to run on hydrogen and quantify performance.

In order to keep costs under control, the students have to use tubular steel or aluminium in the construction of the chassis. The engine is a Radical Ecoboost 3.5 or Suzuki-based V8 and there are no rules on the use of turbos. Fuel storage must be sufficient for a 20-minute race at Silverstone.

Could hydrogen be the future of motor racing? Certainly the Green GT didn't help the cause when it tried to race at Le Mans in the Garage 56 entry in 2012. The fact that the car was considered by the opposition to be dangerous, by teams working in the pit lane to be such a risk that they asked not to be put alongside it, and by the media as a waste of time hasn't helped its cause. It was late, and didn't test well. Yet the project isn't dead. 'The project has not been abandoned,' confirms Laurent Chetrit, press officer for the project. 'It has been delayed due to the fuel cell development. The results are now satisfactory.'

With battery development accelerating through investment in Formula E, which has a 25-year exclusive contract to run electric racing, Formula 1 and the World Endurance Championship, hybrid technology will take a huge step forward in the next few years. The next stage is to focus on weight, and fuel. It is perhaps important to note that a significant percentage of Cranfield's students finish up working in sportscar racing and in Formula 1. Knowledge of hydrogen cells and hydrogen could well be relevant.

EDITOR
Andrew Cotton