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Toyota TS050

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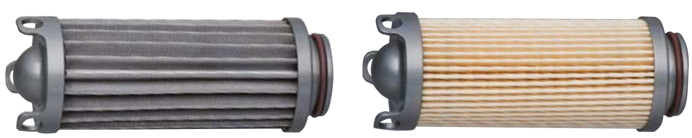

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The rise of the robots

Autonomous racecars are on their way – but what about those 'missing holes'?

If you were around Interstate 15 just before Barstow, near the California-Nevada border, on March 13, 2004, you might have remembered a quote from Hunter S Thompson's *Fear and Loathing in Las Vegas*. 'We were some place around Barstow on the edge of the desert when the drugs began to take hold. I remember saying something like: "I feel a bit light-headed; maybe you should drive . . ." And suddenly there was a terrible roar all around us and the sky was full of what looked like huge bats, all swooping and screeching and diving around the car, which was going about a hundred miles an hour with the top down to Las Vegas. And a voice was screaming: 'Holy Jesus! What are these goddamn animals?"'

But what did come out of the desert on March 13 2004 were not bats, but the competitors in the DARPA Grand Challenge, which ran from Barstow to just past the California-Nevada border in Primm.

Probably the most interesting thing in automotive engineering was out there that day. It consisted of applying IT to a mechanical platform and letting it find its own way along the route, by analysing the environment with a bunch of sensors, and using this data via artificial intelligence.

Paradigm shift

There has been an exponential improvement in other domains, such as materials, thermal efficiency, manufacturing methods. But this is a case of *more than* rather than *more of*, bringing a fundamental change of paradigm. None of the robot vehicles finished the route, but it did throw up some fundamental needs for the technology. Time being the inexorable juggernaut it is, it is not surprising that a mere 12 years on Nevada is officially the first state in the USA to approve self-driving cars, and is providing employment for lawyers to consider the legal ramifications of what is going to happen.

Google, Apple and other companies have autonomous cars running now, and this is a clear signal that advances in technology are now so exponential that milestones we once thought far away will start arriving rapidly.

But we are entirely unprepared. These exponential advances, most notably in forms of artificial intelligence, will bring more problems to what is an already chaotic job market, where the model is employment as the primary source of income. Note the probability of 83 per cent, that a worker making less than $20 an hour in 2016 will eventually lose his job to a machine. Workers making $40 an hour face better employment survival odds, of 31 per cent.

Extrapolation for car manufacture in 2020 gives two predictions: two thirds of the value will be in connectiveness, control systems, and AI in autonomous driving; and that car sales could drop by as much as 60 per cent.

This will have a major impact in an industry that has its model in volume and growing sales. By 2050 a full 50 per cent of cars will be autonomous. The knock-on effects are not solely in the car industry, which accounts for 10 per cent of the GNP in most manufacturing countries, but more directly in the whole concept of mobility, giving deep impact on the *modus vivendi*.

The initial steps of the Roborace process will be entertaining

VW raised the bar in developing the autonomous car product range. Roborace will accelerate that learning through autonomous racecars

Much in the way when the majority of the times the word *Caesar* has been used it generally preceded the word *salad*, in the near future when we say 'autonomous' the following word will be 'car', and then it will be shortened to some other, new, probably less unwieldy, word.

Mostly cloudy

Given the complexity of coordinating the flocks of autonomous cars that will descend on our roads a case can be made for the operating system to be in the cloud, to manage the interaction between the cars, coupled with V2V (vehicle-to-vehicle communication). The FCC has already allotted the 5.9GHz band for dedicated short-range communications (DSRC) among cars, other cars, and roadside transceivers. Volkswagen's Electronics Research Laboratory (which helped build the autonomous VW Touareg that won 2005's DARPA Grand Challenge race) recently fitted two Jettas and two Audi A3s with DSRC units and used V2V to successfully run them in San Francisco. Meanwhile, General Motors has gone one better than VW with a demonstration DSRC-equipped Cadillac CTS that will stop itself to avoid accidents.

All this brings us to the question of using competition to develop the systems in racing; the best way for rapid evolution. Having autonomous racing cars running fast in close proximity entails reliable sensors that can sense the environment, *see* the competition and track, and algorithms to control trajectory and aggressiveness, either totally autonomously or with V2V.

It will have to cope with track conditions, the nature of the track surface and tyre degradation. In short, do all the duties drivers do now, not always skilfully enough.

Hole-some

Roborace seems to fit the bill as far as engineers and manufacturers are concerned, the sole question being the interest of spectators in the sport if there is no driver in the loop.

True, the initial steps of this process will be entertaining if only for the inevitable effects of Murphy's Law and the issues that will slip through the programming, but eventually it will become more capable and produce well behaved robots. But will the spectators stay?

It will also determine the vision the general public will have of autonomous vehicles for general use, as the future of man-machine relations depends crucially on the economic system that engenders it, and how the observers view it.

In judging this we can be all victims of what might be called 'creeping determinism', or `abstract blindness', as illustrated by the analysis of the attrition rate in WWII bombers by examination of those that returned to base from missions.

The aircraft that returned were all shot-up and full of holes. When the question was asked, 'What can we do to protect the bombers'? A mathematician answered: 'We put extra armour where there are *no* holes.' This is not looked through the lens of abstract blindness, for it is clear that the bombers that did not return were the ones with the holes that caused them to be lost.

So, perhaps the answer to all this can just be a case of the missing holes.

Prototype possibilities

Why it might make sense for the manufacturers to supply P1 cars to privateer teams

The snow on qualifying day of Silverstone's opening round of the 2016 World Endurance Championship excused my spending more time in the garages than usual. However, it also further highlighted to me the skills of the crews that prepare and run these sophisticated LMP cars, in particular the private LMP2 teams

Such is the technology employed in these machines, even without hybrid complication, that most teams will have the benefit of engineering support from the suppliers of both their chassis and their engines. The days of operating an endurance racing car in major events with half-a-dozen people in total are long gone. Nonetheless, perhaps hearteningly, at this expensive level of international motor racing, there still remains a valued place for 'weekend warriors', the unpaid team members who assist solely for the love of being involved.

Independents' day

The key hands-on guys can truly be described as technicians rather than mechanics, because as well as the mechanical aspects they must have a good understanding of the electronics; without their correct functioning the cars wouldn't even run. Credit for a significant portion of this has to belong also to the developers and manufacturers of this complex kit. Despite CAN technology, so much wiring, boxes, sensors and relays exist that their packaging within the aero and regulation constraints is clearly a major design and servicing task.

All of which leads me on to a reconsideration of something which I had long dismissed as being impractical. Apart from acknowledging the spirit of the two teams participating in the privateer LMP1 class with their own chassis/engine combinations, one has to question their other motivation, because except in the most bizarre scenarios they are not nowadays going to beat the big guys. But just five years ago ORECA competitively ran a Peugeot 908 diesel LMP1, winning Sebring. Previously it was possible to purchase a potentially outright-winning LMP car, together with engineering assistance similar to that available as a norm now in LMP2, from Porsche (RS Spyder) and run it successfully as a race-winning private entrant (Penske for example), albeit heavily-supported. In 2004 Team Goh with its own Audi R8 car famously won Le Mans. Going further back, in one of the best periods of endurance racing prior to the introduction of 3-litre prototypes in 1994, anyone with the wherewithal and competence could purchase a Porsche 956/962 and race and win, even against the official teams.

Private eye

So could a private team now, if it was mandated by the ACO that manufacturers had to make a certain number of customer cars available each year, sufficiently cope with the technology of the hybrid power units to run a Porsche, Toyota or Audi LMP1 racecar independently? Could these privateers possibly afford them? Would this discourage manufacturers from entering the WEC? Would it improve the racing and the spectacle?

Taking these in reverse order, while it is good to see different makes competing I would argue that it is more important to increase the competition, particularly now that Porsche, Toyota and Audi entries amount to only six, out of a grid (at Silverstone) of 33. The ever-stricter chassis regulations and resulting convergence of aerodynamic solutions around these mean that it has become increasingly difficult to identify the different makes anyway, even LMP1 from LMP2. To Rebellion and Kolles, buying other manufacturers' cars might not meet their desire to do their own thing, which could continue, but to others it might provide the answer to how they compete with some opportunity of occasional outright success.

Regarding the manufacturers, certainly it would be an inconvenience to build and support more cars and set up the customer service required, but Audi and Porsche at least are very well-versed in creating such support via their healthy GT3 programmes. As long as the price cap necessary to make such a programme work were not to be set unrealistically low, given the overall budgets allocated for them to compete in the WEC it would not be such a drain on the manufacturers' resources to do this, and might be viewed as a useful back-up should their factory entries fail, for whatever reasons. Porsche and Toyota each effectively lost one of their pair of cars in the Silverstone race, and following the on-road-winning Audi's disqualification the German marque finished neither of its cars. Much-deserved encouragement for Rebellion certainly, but their third and fourth place R-One-AER machines were 11 and 13 laps down, just a few laps ahead of the LMP2 class-winning RGR Morand Ligier.

XPB

If the big teams, like Audi, had to supply smaller outfits with cars LMP1 might be more competitive. But could privateers handle the technology?

Bespoke designs

As for cost, there is no doubt that these hybrids are horridly expensive racing cars. But it cannot be inexpensive to pay for the design, development and construction of a bespoke one or two-off LMP1. If a compromise is needed, then at least it could be mandated that the manufacturers' previous year's cars should be made available, perhaps updated where practicable. Such a move would presumably increase the attractiveness to manufacturers, otherwise stuck with redundant racecars that are useful only for show and in museums.

I believe my observations from the pit garages at Silverstone answer the first question I posed, concerning the capability of privateer teams. Given the factory technician support similar to that which is available now in LMP2, but more enhanced, then why not?

Should the provision of complete cars and their spare and replacement parts not work out, then as a second attempt to encourage LMP1 privateers perhaps the power unit and drivetrain at least could be on capped offer, being the greatest performance divider of all. This could attract the likes of Rebellion and Kolles in having their own chassis, while possessing hybrid performance at least close to those of the works cars.

Dreaming? Perhaps, but then why not?

It is more important to increase the competition, particularly now that the Porsche, Toyota and Audi entries amount to only six racecars in total

Comeback kids

Toyota won the WEC title in 2014 but was well beaten by both Porsche and Audi in 2015. The 2016 TS050 signals the start of its fight back

By ANDREW COTTON

Toyota lined up for the World Endurance Championship in 2016 with an all-new car, the only one of the three manufacturers to deliver a new engine, chassis and hybrid system in a single step. It has been an extraordinary development cycle, one that saw major decisions taken as late as June last year, leaving the team with precious little time to sort out one of the most complex types of cars in motor racing today.

The TS050 is the third generation of LMP1 hybrid produced by TMG from its base in Cologne, Germany, and it is by far the most ambitious and powerful of them all. The team had a performance advantage during its title-winning season in 2014, and had made improvements for its 2015 car, but was caught by surprise by the pace of development from Audi and Porsche last year. From a performance advantage, Toyota faced a significant deficit, one that was first highlighted at Silverstone in April '15, and confirmed at Spa in May. By then it was clear that the team could no longer compete with its old 3.7-litre V8 engine and needed to switch to an all-new powertrain for this season. With all the design work already done on the

new car, the decision was taken in June to switch to an all-new twin turbo 2.4-litre V6 engine for the new season, and that had huge knock-on effects for the rest of the car.

The lateness of that decision meant that the team had to revisit the airflow through the car as the turbos, mounted low down on either side of the engine, sat directly in the area designed to feed air out through the rear of the car. New aero regulations encouraged the teams to go to a narrow front bulkhead and a high nose, to direct airflow through the car. That meant that the teams in the development cycle of producing a new car for 2016 would be able to take full advantage, and Toyota had done so before the engine layout changed significantly. However, the twin turbo layout was the fastest and easiest to design, considering the long lead-time parts for the engine and the gearbox.

For Toyota, the new chassis, new aero and new engine were the relatively straightforward elements of the car. More complicated was the switch from super capacitors to batteries for the first time since the start of its hybrid programme, and the systems then had to be integrated into this new technology, something that is not the work of a moment. The level of learning was then highlighted during qualifying at Silverstone's opening 2016 WEC round, where the team openly admitted that it did not set the nerve centre of the car up correctly.

This season Toyota makes the jump for the first time from 6MJ of storage capacity to the maximum 8MJ, as permitted by the regulations. It has achieved this despite continuing with its double KERS – one on the front axle, one on the rear. The car is capable of generating enough energy from these two systems.

Tough love

The 2015 season did not produce anything like the results that were expected in a title-defending year. Toyota carried a performance advantage from the 2014 season into the new year, and had itself made a gain of more than two seconds per lap at the Paul Ricard circuit in southern France during pre-season testing. Despite worries about the rate of development from Porsche and Audi for the 2015 season, it expected that the improved lap times should be enough. TMG was aware that both Porsche and Audi would make giant strides in performance, but no one expected them to perform quite as well they did.

'We went through a cycle of feelings and emotions last year,' says TMG technical director, Pascal Vasselon. 'We knew that we were limited in our resources and we raised our concerns. They [Toyota] said that we could have won eight races [in 2014] and we were not in a bad situation and did not need more resources. So we started with worries and concerns that we were not putting enough resources into the battle. Then the first time we put the car on the ground at Le Castellet, we were 2.5 seconds faster. Then we went to Aragon, 2.5 seconds again. It was a clear gain from the chassis. This was amazing. In F1, with stable regulations, we never saw such a clear gain. Usually you try to convince yourself that you are better but the lap times are not necessarily there. Here, it was a no-brainer. It was a big step and the drivers reported that the car was much better.

'Through to mid-March we felt that we could make it again because the step was a big one. Then the Prologue came, but we did not analyse it too much because we weren't quick in 2014. But then at Silverstone we had a clear warning

The new TS050 has had an accelerated development thanks to some late decisions last season when the manufacturer realised it was falling behind rivals Porsche and Audi. Toyota starts 2016 with a new chassis, internal combustion engine and hybrid, the only one of the three hybrid LMP1 teams to start the season with a completely new racecar package

with Audi at the time, and then at Spa we had no doubt anymore. At Spa you see everything, high speed, low speed, powertrain, and we saw that we were really behind. Where we had made 2.5 seconds, the others had made five. It was as simple as that. It was completely amazing, but that was the simple maths in front of us. Then it became obvious that we needed to develop everything in the package. Five seconds is not just bodywork. That is why, after Spa, a clear decision happened to trigger some big additional resources, bring forward the V6 turbo, and that if we wanted to stay in the WEC, we had to step up.'

Differing concepts

New regulations led to a dramatically different concept from the teams. The FIA and ACO reduced the amount of energy carried in the fuel by 10MJ, leading to a requirement for greater efficiency from the cars. But a new front wing was a much more pronounced change to the cars. Audi had used just such a flap in 2009, and carried the air flow through the car from front to back, a similar concept to this year with its R18. Toyota intended to follow a similar path.

Toyota's decision to switch engines led to a rapid development programme in Japan

'Knowing that with the new regulations with the front flap in the front element, that in the past you were not allowed, it is logical that you get more air to the front,' says Toyota's LMP1 project leader, John Litjens. 'The regulations now allow a flap, like the Audi R15. That is what it will bring. In the end the plan was to get the front of the car [sorted], which steers a lot [of aero] in the car, and it is a relatively easy way of adjusting your aero balance. There was some room for improvement in our front tyre wear. You are forced to double stint a lot, the choice of the tyres in a single stint is not an issue, but there might be circuits where it is critical.'

V6 power

Toyota's decision to switch engines led to a rapid development programme in Japan. The team produced a new engine from the ground up, but had to draw on previous experience and knowledge. As Porsche accelerated its battery development and introduced the 2016 battery in 2015, so Toyota has delivered its 2017 engine in 2016. 'The engine is completely new, but nothing is ever completely new,' says Vasselon. 'Our engine designers have background and are using everything that they know. It is an LMP1 2016 engine that was supposed to be a 2017 engine! It has been hard work for the engine designers to be ready [to] fire up before the end of the 2015; the development cycle is less than one year. They have done a good job because they had a performance target and the reliability is okay, we have done a Le Mans race distance with it.

'A twin turbo is easier to package than a single turbo because with a single turbo you have to put it somewhere in the middle, high up, you have to cool it and it is one of the decisions you have to make. The car was starting with structural elements that were not engine specific. We still had flexibility to move with that.'

Toyota's initial plan was to feed air through the nose of the car and back to the rear. However, the turbos sat right in the middle of those channels on either side. 'When we started the development of the '16 car, it was not known that we would go to the turbo engine,' says Litjens. 'It was based on the normally aspirated V8. To try to clear the front we positioned the front motor [KERS] in the chassis, so it sits higher up. It is worse for the centre of gravity, but for aero it was the way to go.

'In June the call came for a different engine, which is a bit smaller which is good, but there are much more requirements, with an intercooler, for example. The base layout of the car was done, because that is what aero needs to work on, and when the discussion came in June, the performance gap was growing and among the manufacturers it was known that the FIA would do a fuel reduction, and if this came it makes no sense to come in 2016 with the V8.

'Then there was a very busy period, in July, August and September with the Japanese colleagues. They had something planned, but they had to ramp everything up. In certain areas you have to make compromises due to lead times on the engine part on their side, and gearbox on our side. At that point you decide

The TS050s showed well at times at Silverstone's opening round of the WEC (one even finished second) but they were hindered with driveabilty issues, particularly in traffic

Silverstone was also the first time the car had seen any proper running on a wet race track so it was perhaps no surprise that the race drivers were caught out on occasion

what you know the best. We had the airflow through the entire car, like the Audi, but we had to make some changes and we had to decide what to do within a given time. There are some modifications of the flow paths that you can do, or you could go for a single turbo in the V, but then you would have a lot of other repackaging to do for heat management and we would have to have re-worked the rear suspension. In the end, we said we had to go for turbos in the conventional layout, either side and low down.'

Turbo decision

There were other reasons why the twin turbo was the way to go rather than a single turbo mounted within the V-angle of the engine, as Audi opted to do when it was considering running an MGU-H, an idea that was dropped before the car first raced in 2014. 'We had no choice,' confirms Vasselon. 'There was no possibility to improve brake specific fuel consumption. The normally aspirated engine is not bad and can achieve interesting fuel efficiency, but its peak figures, the sweet spot is very narrow, and it is not robust to altitude and temperature changes.

'At night at Le Mans we achieved very decent fuel efficiency, but in many other cases you cannot reach this sweet spot. When we saw we were so far behind last year, it was a no-brainer to go to turbo because our plan was to introduce a turbo for 2017, and come in 2016 with a battery. That was the master plan, and then we had to review that because we cannot survive another year with that engine.

When you go to a turbo, that allows you to go smaller. The base engine is lighter, but you have to add a lot of things, turbos, intercoolers, so you would not go for a downsized turbocharger for weight only. Weight distribution you can adjust to with the tyre development. In WEC we can do what we want front and rear and adjust it to what we want. You can make a WEC car work with 45-55 [per cent weight transfer], that's a 10 per cent range. Here, the tyres have some generic requirements. The WEC tyre is developed with a lot of freedom, then you can fine-tune your tyre for a given chassis,' Vasselon says.

The team has opted to stay with the Xtrac-produced aluminium gearbox casing, preferring the material to the carbon used by the other teams for weight distribution purposes. 'The gearbox is quite different, because with the turbo the load is very different, but it is the same philosophy,' Vasselon explains.

The decision to go to a twin turbo means that the drivers should enjoy greater driveability, but there is another problem on the horizon. In 2018 the plan is that the regulations will allow for 10MJ of storage in the hybrid system, and for that, a third energy recovery system will be allowed. Toyota will therefore continue with two KERS, one on each axle, and is looking carefully at its options for an exhaust driven energy recovery system. Each of the twin turbos would carry its own ERS, and the existing layout would therefore be counted as two systems. Toyota would therefore have to find another option for recovering the energy (and it admits that it doesn't know of one that would be developed enough), design another new engine which would be very costly, or re-work the turbo layout into a single turbocharger design.

For now, though, the design is new and requires development work. The team put 22,000km on to both an old and a new chassis over the winter in a bid to ensure reliability. 'Reliability is an issue, when starting late,' confirms Vasselon. 'It is a risk on this year's programme, but it is diminishing. There is no fundamental issue on the engine and the gearbox. We are on the verge of going back to a normal schedule, and the risk is reducing now. We have done a bit more than 22,000km. We are not short of mileage. We now have background on most of the components.'

Boost secrets

The team was extremely coy about revealing anything of its turbocharging technology, refusing even to admit or deny that it was using variable turbine geometry (VTG) to reduce turbo lag. 'We are working on the turbo lag, which is present, but we are finding solutions in driveability,' Vasselon admits.

The move to a twin turbocharger means the drivers should enjoy greater driveability

‘KERS energy is free of charge. If you don’t recover it, then it is wasted’

‘Each powertrain sets its own target. Porsche was running a lot of downforce last year. We focussed on what our simulation model tells us. We run simulations of the complete car with all elements at the performance target and this gives us a working parameter. From this we can do lap time simulation and we can see at which rate we need to improve aerodynamics and we can see the ratio at which we have to develop. For a given powertrain you will have a target between drag and downforce. It drives us towards less downforce than Porsche ran last year. It is easier to make a car work with higher downforce. If you manage a consistent aero platform, a car that is not sensitive, you can make it work at low downforce. At Le Mans 2014, for example, we had very low downforce, low engine power, and were very fast. The drivers were not complaining. For sure downforce helps, but it is not a total must. The Michelin tyres are not very downforce sensitive. I had a different opinion in Formula 1. The tyres were asking for it, and they were overheating and graining and they needed load to work. Michelin Le Mans tyres over the last couple of years are insensitive to graining, they don’t overheat, so they don’t ask for downforce.’

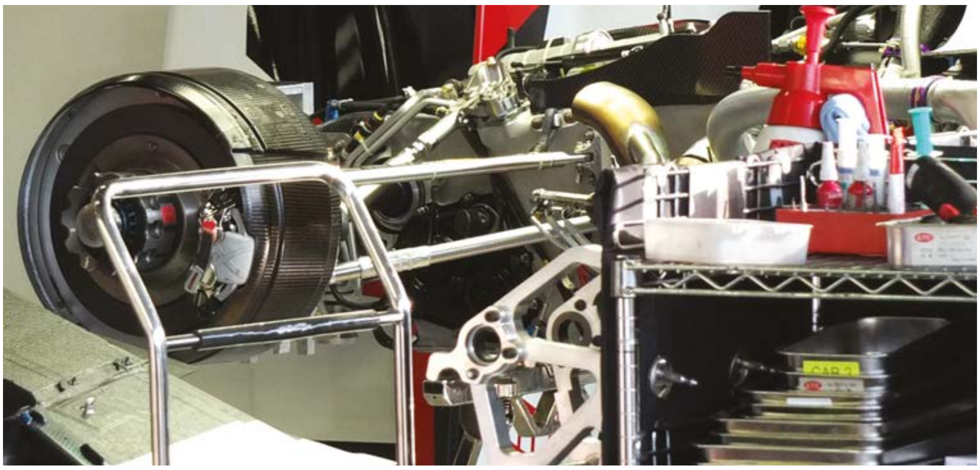
Brake system

Toyota was the first in LMP1 to introduce a complete brake-by-wire system to handle the difference between braking events including the regeneration of the hybrid system. While the front brakes do most of the work, the rears are designed to a size to work with the hybrid system. If the hybrid system fails, the brakes will quickly overheat and catch fire. Due to the pressures of low weight requirement, the team has opted for a similar braking system this season, despite such a fire at Spa in 2014. ‘It is the same principal, but the higher you go in energy class, the more difficult it is to manage the mechanical brakes because they do less and less,’ says Vasselon. ‘As a consequence, the variation of what they do is different. If they do less, there is more potential. Our braking system delayed our switch to batteries. ‘The weakness of batteries is power density and that is where the capacitor was superior. With two KERS, you need a lot of power, because you need to recover in braking, and braking events are very short. If you have low power, you don’t recover. Porsche’s system is different. It has one KERS, and the other is recovering at very low power, perhaps 50kW. When we recover, we recover at several hundreds of kW. Porsche’s system accepted the battery earlier. Our double KERS needed a lot of development on the battery side to reach the level of power required.

‘As soon as you have the power level that allows you to recover when you need to recover, you are not limited in your storage. You can do what you want with your energy. That does not make a difference at Le Mans, where you need to distribute at the start of the straight. Last year we had to recover and release as we could not keep recovering because the capacitor was full. This was a limiting factor.’

The brake-by-wire system may be the same as last year, but the integration into the whole system is not necessarily straightforward. For example, on the Saturday morning at Silverstone driver Anthony Davidson found himself on track in freezing conditions, with a full battery, no traction control and no hybrid help on his brakes either. He spun into the gravel, losing running time prior to qualifying and the team is well aware that a large performance gain is to be found with the correct programming of the heart of the racecar.

The sidepod of the TS050 contains the charge air cooler and the oil and water radiators arranged in a conventional single seater style. The packaging was a headache for TMG thanks to the late decision to switch to a turbo 2.4-litre V6 powerplant



Toyota has opted to stick with the Xtrac-produced aluminium gearbox casing it’s used previously, preferring this to the carbon casings used by the other teams for reasons of weight distribution. The gearbox is seven-speed and is mounted transversely

Hybrid switch

The switch from super capacitors to hybrid was a clear decision from Toyota in 2015, although it did briefly consider a combination of both. That concept was discounted on the grounds of weight, and as battery technology advanced quickly, both Audi and Toyota opted to follow the similar path to that of Porsche.

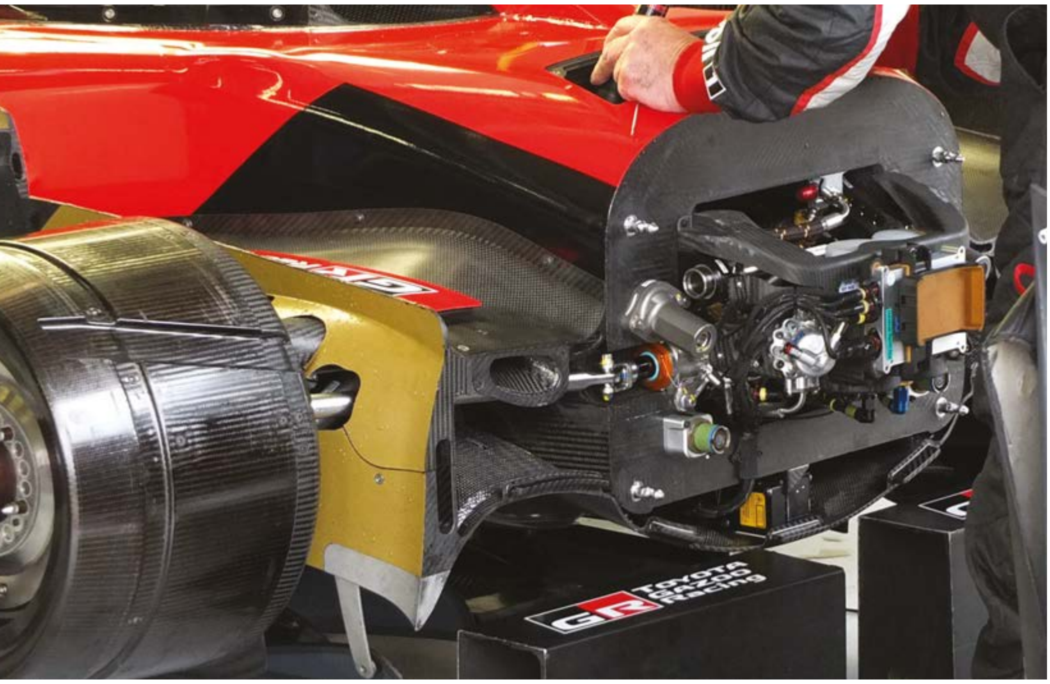
‘As soon as you can package two KERS within the weight limit you are looking good,’ says Vasselon. ‘The performance density of KERS is better than exhaust gas recovery. KERS energy is free of charge. If you don’t recover it, it is wasted. If you do recover it, you have no penalty. Heat recovery systems always have an impact on the engine. Of course, teams are working to reduce it, but it is not free of charge, even if it is lighter. If you fix the weight issue, a double KERS offers a better performance density. For Porsche it was

The suspension concept appears to be similar to that of the TS040

obvious. When you run exhaust gas recovery, you want to run only one MGU-H so you want to run only one turbo. For Audi, initially they wanted to run exhaust gas recovery, and it didn't work, and they have a variable turbine that makes the turbo lag less of an issue.'

'We wanted to change from 6MJ to 8MJ, and the hybrid system philosophy is Kinetic Energy Recovery, which is more efficient,' says Hisatake Murata, general manager, Motorsport Unit Development Division. 'There is no attack on the fuel consumption, so we have to develop the high powered lithium battery. More power volume means similar to the capacitor, or bigger. We developed it over several years, so [we started] in 2013 for the lithium capacitor or high power lithium battery.'

Of the super cap/battery hybrid system, Murata openly admits that this was a seriously considered option. 'A separate company is developing a hybrid battery system but the total weight is very big,' he says. 'I didn't like the system so I developed more storage system for high power lithium. The potential of the energy storage system [with the] high-powered lithium [is better] so I chose that one,' Murata explains.



New LMP1 regulations made the choice of a narrow front bulkhead and raised nose with flap preferable, a solution that is similar to that employed by Audi back in 2009 on its R15. The TS050's torsion bars are also visible in this photograph

Toyota was the first of the P1 manufacturers to introduce a complete brake-by-wire system to handle the difference between those braking events that included the regeneration of the hybrid system and those that did not. Calipers are from Akebono

The nature of the super capacitor was that it was very fast to charge and to discharge, while the batteries took longer to do so. For the switch between the two there was a steep learning curve, says Murata: 'Last year's characteristic was to run out of the corner very fast. This character is the same, but the storage is more huge. We can take several options when the car is running. It is very exciting for this year.'

One place where spectators will not be able to see the dramatic acceleration is at Le Mans where, for reasons of safety, the delivery of the hybrid system has been limited to 300kW, meaning a slower, more measured delivery rather than the huge dump of power at the start of the straight to get to top speed as fast as possible. It is not a decision that has gone down well at Toyota, but the team has had no option but to accept it. 'I am not satisfied with this decision, but it has been decided,' says Murata.

Suspension design

Toyota was also coy about revealing its suspension design in interviews, preferring to refer to its previous Formula 1 technology as an indicator as to what it had developed. Audi has a completely re-worked suspension system to that run in 2015, but Toyota would only say that 'it is all driven by aero requirement on one side and tyre requirement on the other,' according to Vasselon. 'Tyres are considered to be black art, but there is a lot of flexibility. You have some mistakes to avoid, but there is flexibility for a suspension designer. We make sure that we avoid the mistakes that would compromise the tyres. We did not go into this roll decoupling of Porsche. It is not worth the pain. It is a constant compromise between ride, and consistency and load of the contact patch, and the aero platform. We never completely understood what Porsche was targeting from their system. We are running the functionality that we need. Our suspension is doing what we feel it should be doing.

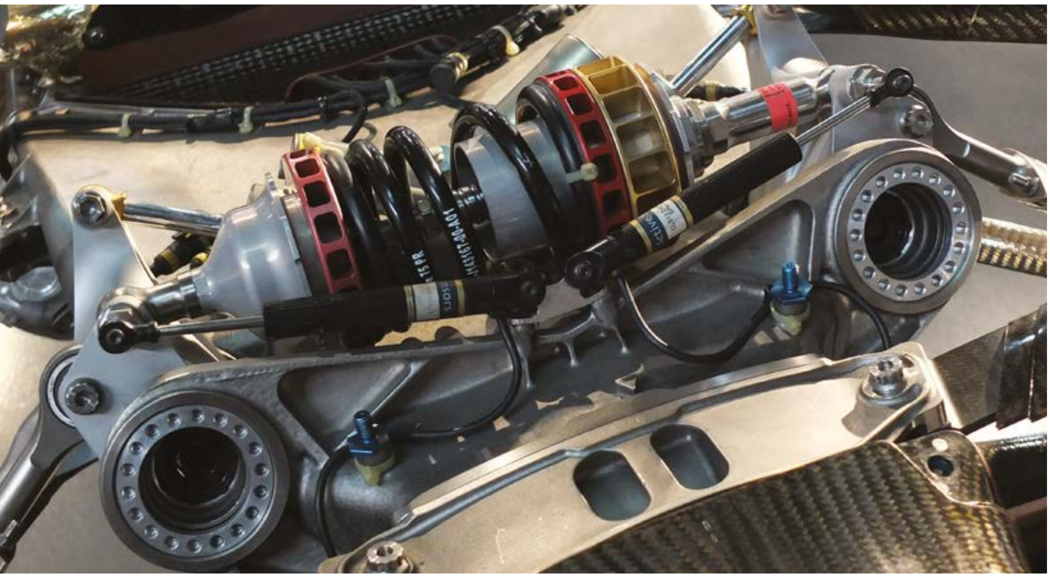
'It is a package inspired from an F1 packaging that is well suited to this kind of car.'

The concept appears to be similar to that of the TS040, with a double wishbone arrangement with pushrod actuated internal components all round. Torsion bars are used all round and there is at least a third element front and rear. Further details on the suspension will be revealed later in the year.

Managing expectations

Spa 2015 was possibly the team's lowest point, finishing three laps down on the wining Audi and with a fastest lap 2.2 seconds slower than the race-winning car. That was the point that it became clear that the season would be long and hard for the team. Finishing eight laps behind the winning Porsche at Le Mans was merely confirmation of what the team expected.


Our driving force is your performance



The TS050's rear suspension is based on the concept used on Toyota's Formula 1 car (pictured above). TMG would not be drawn on details but in essence the car's suspension is a double wishbone front and rear, pushrod system, with torsion bars

TECH SPEC

Toyota TS050 LMP1

Bodywork: Carbon fibre composite

Windscreen: Polycarbonate

Gearbox: Transversal with seven gears, sequential shift
Gearbox casing: Aluminium

Driveshafts: Constant velocity tripod plunge-joint

Clutch: ZF-supplied multidisc
Differential: Mechanical locking differential

Suspension: Independent front and rear double wishbone, pushrod system
Springs: Torsion bars
Anti roll bars: Front and rear

Steering: Hydraulically assisted

Brake calipers: Akebono mono-block light-alloy
Brake discs: Carbon ventilated
Discs: Ventilated front and rear in carbon
Rims: RAYS magnesium alloy 13x18in

Tyres: Michelin radial
Front tyres: 31/71-18
Rear tyres: 31/71-18

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

Fuel capacity: 62.5 litres

Powertrain: Toyota Hybrid System – Racing (THS-R)
Engine: V6 direct injection twin-turbo
Engine capacity: 2.4-litre
Fuel: Petrol
Lubricants: Mobil 1
Valves: four
Engine power: 368kw/500PS
Hybrid power: 368kw/500PS (front and rear combined)
Combined power: 736kw/1000PS
Battery: High-powered lithium-ion battery developed by Toyota
Front hybrid motor: AISIN AW
Rear hybrid motor: DENSO
Inverter: DENSO

High-ranking Toyota personnel were present to reassure the team that everything would be done to help it not repeat such results, and it has to be said that Toyota seems to have made good use of the resources gained.

However, with an all-new package for the 2016 season, no one could expect the car to start winning races against the likes of the Porsche 919 Hybrid, with three years of experience with the hybrid system, or with Audi, which has kept the same 4-litre V6 turbo diesel. So what would TMG consider to be a successful season this year? 'We cannot afford another season like the last one,' confirms Vasselon. 'This year, if we are competitive, it will be okay, but not for the future. We cannot say that we give up on one year. Every year is an opportunity, but it may not be realistic to say that we are going to win everything this year, but our target is to be competitive. Next year for sure we need to win several races, and be not only competitive but challenging for the championship.'

Key to the whole success of the car is the integration of systems, including the traction control which is linked to the hybrid and the ICE, the battery which is linked to the GPS positioning of the cars for power boosting and recovery options, as well as the usual systems around the car.

'We have more hybrid power, so some parameter settings are changed for sure but it is not that much,' says Litjens of the traction control system. 'There is a short preparation time, but for us we didn't think about the wet, and there is still some work to do. Powertrain control is still something to do. On one side it is sad to see it like this, the gap is shown bigger than it really is, but on the other side it is better to have this than everything fine and still have the gap. Then we would worry.'

During the opening race at Silverstone there were flashes of excellence from the Toyotas, enough to give the team hope that this could be a competitive year that it needs to show in Japan. One car finished on the podium in second place, although that was helped by its rivals falling over themselves, including Audi's exclusion for excessive wear on the underside plank. The single lap pace in clear air did indicate that the performance gap had closed. The fastest lap at Silverstone was a 1m40.303, set by the winning Porsche, while Toyota's fastest lap was a 1m40.657.

'We are still working on it, because the immediate thing that we realised is that lap times in free air were okay,' said Vasselon after the cars had run in anger for the first time. 'They were not brilliant but they were within three tenths of the quickest car. Mike Conway did a 40.6, which was three tenths off Porsche number one, but we didn't manage the traffic well. It was a combination of response time, from the drivers going on and off throttle, and the confidence of the drivers to go off line. The big gaps we had were in traffic, in free air our lap times were good.

'We are not satisfied with the result. The only positive was that the ultimate pace was in the ballpark of the other cars but the result is not good. We are leading the championship so the team effort was good! In ultimate pace, we are where we thought, although we were surprised at the pace of the Audi.

'Last year the best lap time was 40.8 by Audi, and this year they did 40.4, so a four tenth gain. Last year we did 42.2, and this year 40.6, so here we did a big gain. That is satisfying, but still we need to be closer in race stints. We cannot be happy in lap times not being far away. Last year, although we were on the podium not too far from the leaders, the pace was much worse. We were 1.4s off. Here it was closer.

'We have a few ideas where to find the time. What can hurt the drivers is a combination of things, with driveability, so we need a debrief to understand what was causing the gap between free air and in traffic.'

Toyota had a mountain to climb, and at Silverstone this year, it looked as though it had made it beyond base camp. Silverstone may not be an accurate representation of performance for the season, however. Le Mans will bring a new bodykit, and the second half of the season another kit again and Toyota will continue to improve as it learns its own technology. Can it beat Audi or Porsche? Perhaps it stands a chance at individual events this year, but the team has high expectations for 2017.

During the race at Silverstone there were flashes of excellence from the Toyotas

Up for **the Cup**

With a few simple but telling tweaks TMG has lifted its humble one-make 'Ring racer to another level. Its new Toyota GT86 CS-Cup is now set to give customer teams a fast but low cost option in the VLN

By SAM COLLINS

In recent years, racing on the Nurburgring Nordschleife has become something of a trend among manufacturer teams, which is perhaps not surprising considering how much production car testing and evaluation is undertaken on the legendary circuit.

This trend has seen a number of manufacturers building and developing 'Ring specials which tend to only run in the *Veranstaltergemeinschaft Langstreckenpokal Nurburgring* Endurance Racing Championship (VLN), or even just in the annual 24 Hour race held on the 25km course. Toyota is one brand which, in 2016, will have a significant number of new designs at the 'Ring, including a curious crossover coupe called the C-HR, which we will look at in detail in a future edition.

The Japanese firm's European motorsport research and development facility, TMG, which is located in nearby Cologne, has for some years run a one-make cup for the GT86 (CS-V3) model within the wider VLN, and for 2016 it will roll out an upgraded version of this design to run in that series. Nico Ehlert, principal engineer customer motorsports, explained why at this new racecar's launch. 'I am convinced that the CS-V3 is one of the best close-to-production customer sportscars on the market,' he said. 'But, we don't want to rest on our laurels. We want to take the GT86's performance to a new level. This project will benefit from all our know-how, and three years of cup experience. Needless to say that we also took account of our customers and drivers requests and experiences over the past few years. Their expertise was the most important gauge, as it were, and the experiences gained during the development of our R3 rally car have also been used.'

Shedding kilos

The new car is called the GT86 CS-Cup and in terms of the wider VLN it competes in a higher class, SP3, rather than its own Cup sub class. This is because the new version is significantly quicker than the old one. 'This car is much quicker than the V3,' Oliver Kroll, TMG's project leader for the Cup car, says. 'The V3 lap record with our cars is 9m38s. On the debut running of this car, when we still had a few teething problems, this car did a 9m32s, but it also encountered two sets of double waved yellows on the way to that, so I think there is a lot more to come.'

Much of this lap time improvement has come from reducing the weight of the racecar from the 1204kg of the CS-V3 in ready to run condition. 'All round, this car is 80kg lighter than the V3 car,' Kroll says. 'We took over some parts from the GT86 R3 Rally car like the doors and windows. Per door, the saving was 6kg. The original doors were really heavy so we filled them with foam on the rally car, and that has carried over.'

A lot of the development of the CS-Cup seems to have been a case of trading off weight against cost, something which can be seen when looking at the launch spec 2016 test car. It features a carbon fibre bonnet and boot lid (adorned with a large rear wing), and seemingly a composite roof, though in truth this is actually just a sticker, just for show, to highlight the lighter weight of the new car. 'The car you see here is a prototype,' Kroll says. 'So some of the parts you see may change a bit. The carbon fibre hood, for example, will not be on the final car as it is too expensive, our aluminium version weighs just 1kg more. It's just not worth the cost for a 1kg saving.

Rally crossover

With some parts, however, the increased costs are offset by a bigger performance gain. 'We have fitted a Super B lithium ion battery and that has saved 10kg,' says Kroll. 'The cost increase is worth it with the weight saving. The increased costs have to be earned. If you ask a customer for an extra €1000 for a 1kg weight saving, they will ask if we are crazy.'

Other areas of the car's development have leant heavily on other GT86 variants, especially the TMG built CS-R3 rally car, which has impressed on a number of events to date. 'It is not only the doors, the R3 and this share

The Subaru-derived boxer engine is close to production specification for reasons of reliability and cost-effectiveness. TMG has kept an eye on costs at every stage of the GT86 CS-Cup's development, mindful of its amateur racer customer base

Much of the lap time improvement has come from reducing the weight of the racecar

Don't be fooled by the faux carbon roof, that's just for show, but weight has been taken from the car in a number of areas. The CS-Cup has also been built with reliability and ease of use in mind

a lot of parts,' Kroll says. 'We took the brake calipers from the R3, the airbox carries over from that, too. Commonality of parts with the R3 is important in terms of reliability and cost with this car. Also, some of the parts come from Gazoo Racing in Japan, such as the composite bonnet and rear wing, which was originally a street tuner part. But in the early tests with the car on the 'Ring we found that it is a bit too high; it gives a bit too much drag and downforce and we didn't need sixth gear. So that had to be changed.'

Boxer tricks

The Subaru-derived boxer engine in the GT86 is present in the CS-Cup and even with a quick inspection it is clear that it is close to standard specification (unlike the CS-R3, which is rather more developed). Kroll says this is the case for two reasons: reliability and cost. 'The engines are very reliable in these cars. Actually in this car the engine is quite close to the production specification, that is deliberate. It means it is not only reliable but also cost effective. This, I think, is the cheapest option you can have to run VLN, with a proper car. The running costs are also very low as a result of this,' he says.

Customer focus

In terms of mechanical development the car has been optimised around its intended market, which is primarily made up of enthusiastic amateurs – though with a sprinkling of professional drivers and some ex-kart racers making the switch to cars. 'This is customer sport, you have to remember that there are not just professional drivers but there are guys like me who just want to jump in and race for fun,' Kroll says. 'Because of this, the driveability and vehicle stability control settings are designed around both professionals and amateurs and it has different modes you can select depending on your ability. This car is just brilliant to drive as a basic road car, it's perfectly balanced so it's really easy to develop into a competition car for the amateur. That usability is seen in a number of components throughout the car; the suspension uses dampers from Bilstein which are just two-way adjustable. The factory set-up on the cars is a good one and the scope for adjustment is really just for driver preference.

'In terms of the transmission the car has a new differential and a shorter sixth gear, it also uses an off the shelf Sachs clutch in order to be able to survive the demands of the Nurburgring. We cannot do bespoke things in this area, because this is a customer racecar,' Kroll explains.

The plan is for the prototype CS-Cup to contest the VLN races leading up to the 24 Hour race in late May. At that time a final specification will have been determined. This time-scale means that the official race debut for the completed CS-Cup will be in the 24 Hours itself, with a number of customer teams expected to use the new specification GT86 for the first time at the big event.

Super fast

The cars can lap almost as fast as Formula 1 and yet a season costs a fraction of an F1 budget. We examine the single seater success story that is Japan's Super Formula

By SAM COLLINS

Super Formula is the second fastest single seater series in the world today, and it can boast a wealth of driving and engineering talent working throughout the 11 teams now active in the series

Top-level open wheel racing has only really existed in Japan since 1973, when Formula 2000 was launched. That morphed into Formula 2 in 1978, and then Formula 3000 in 1987, and then it became Formula Nippon. Over the years this series in its various guises had produced a wide range of top drivers and engineers, including F1 World Champions and Le Mans winners.

In 2010 the Series organisers, Japan Race Promotion (JRP), appointed former Honda F1 boss Hiroshi Shirai as CEO and he set himself and the series a bold new mission to increase the performance of the cars and to raise the profile of the series internationally.

In the past Formula Nippon had been a derivation of F3000, but under the leadership of Shirai the series began to take on a new, more potent, form. The first step was to move away from F3000 based machinery to a bespoke design from Swift. Then, in 2013, the series was re-branded as 'Super Formula'.

After the re-brand Super Formula introduced a new top spec car, the Dallara SF14. Originally the stated intent of the project was to be 'faster than Force India' and in 2014 it nearly was, when you compare lap times round Suzuka, the only circuit shared by Super Formula and F1.

Today, Super Formula is the second fastest category of open wheel racing, and the 2016 grid is made up of 19 cars run by 11 teams. The series has also started to attract some serious international driving talent, and the inclusion of the reigning GP2 champion and McLaren F1 substitute driver Stoffel Vandoorne this year has certainly helping to lift the profile of the series. The young Belgian will face stiff opposition from four ex-Formula 1 drivers (including a three-time Le Mans winner), as well as a host of Super GT champions and plenty of home-grown Japanese driving talent. 'This year is such an important year for us,' Shirai says. 'With the reigning GP2 series champion racing Super Formula this year it's a great opportunity to spread our brand.' This was highlighted when Vandoorne scored McLaren's first points of the 2016 season at the Bahrain Grand Prix after making a last minute dash from a Super Formula test to the Formula 1 paddock to substitute for the injured Fernando Alonso.

Vandoorne's arrival, along with a roster of drivers including names like Andre Lotterer, Kazuki Nakajima, Kamui Kobayashi and James Rossiter, has helped Shirai to form his own

The cornering speed of the Dallara SF14 is simply phenomenal and last season some of the Super Formula racecars actually lapped the Suzuka circuit quick enough to qualify for the 2015 Japanese Grand Prix

Turbocharged 4-cylinder direct injection engines are essentially the same NRE units as found in the GT500 class of Super GT

With a switch to Yokohama tyres for this season apex speeds are now even faster. Super Formula is looking at following the lead of other single seater series by using multiple compounds for its races in the future

Hiroshi Shirai has recently stepped down as president of JRP, although he remains with the organisation as a technical advisor

vision for the future of Super Formula: 'Today in F1, many teams have a business model which requires pay drivers,' he says. 'You always have this big question of whether this guy or that guy has a real talent or a big wallet. But in Super Formula if you can fight with the top guys then it is proof that you do have the talent. I'd like to see more drivers in Europe realise this. Being a Super Formula driver should be like a badge of honour, bigger than being a midfield F1 driver or GP2 driver. In fact, I don't really want Super Formula to be a feeder category to F1, like GP2 or F2, I want it to be a top category all on its own, like Indycar. But it's also a very affordable class, perhaps just one or two per cent of an F1 budget is required by the teams, so they can sign drivers on talent, not wallet.'

But for Super Formula to become the equivalent of Indycar in Asia it will probably need to expand its horizons. Currently the seven event championship is entirely held in the Japanese home islands, but Shirai is working on this. 'My aim is to make Super Formula the top class of racing in Asia. In Europe there is F1; yes it travels globally but it has a Eurocentric concentration still, and in the Americas there is Indycar. Asia right now has no equivalent so my aim with Super Formula is to make it become that; so to do that I want to have races in Thailand and Malaysia, but at the moment there are no Asian drivers, just Europeans and Japanese [in this context the South Americans are considered European]'.

Asian expansion

'Firstly, we must highlight the Super Formula brand and concept to Asian people,' Shirai says. 'We have to promote the series in Asia, but also to the English speaking world, so we are active on social media in English and making things easier for foreigners to become involved in our series. In Japan we have strong feeder series for drivers and engineers, Japanese F3 for example, and that is beginning to get some good foreigners who then graduate to Super Formula. The door is open to the foreigners.'

The Dallara SF14 chassis used in Super Formula is built to 2010 F1 safety standards, and it has proven to be a very potent piece of kit. Its light weight (660kg including driver) and 600bhp engine, as well as the aero package, mean that while it does not have an especially fast top speed it has an extremely high apex speed, higher in fact than those seen in F1. Super Formula cars have lapped Suzuka fast enough to qualify for the 2015 Japanese Grand Prix, and faster than some F1 cars. Vandoorne described the SF14 as 'the perfect way to prepare for the 2017 F1 regulations', which will also see very high apex speeds.

The cornering speed is expected to rise further in Super Formula, too, as for 2016 the series has switched from Bridgestone tyres to

'I want Super Formula to be a top category like Indycar, not a feeder series'

The Dallara SF14 is built to 2010 F1 safety standards and this year it goes into its third season as Super Formula chassis. The series says it will not replace the car until at least 2019

a new product from Yokohama. 'Super Formula should be one of the quickest series in the world, so to achieve that we are finding ways of increasing cornering speeds,' Shirai says. 'But we are not aiming to be faster than Formula 1, they will be much faster on lap time in 2017. Recently we went to Suzuka for a test, the first time on the new Yokohama tyres, and the lap time was notably quicker. The conditions were ideal but the speed has improved again.'

New rubber

Shirai adds that the Yokohama tyres are still a new product and that he expects more will come from them in time: 'Yokohama only started to develop its new tyre last year, so the testing has only just begun on those tyres. In the first tests the cornering speeds were similar to the old Bridgestone tyres but there is a lot more potential in the Yokohama so the speeds will increase, I hope. In Sector 1 at Suzuka, the Yokohamas are already faster. Initially all the cars will use the same structure and compound but moving forward I would like to try something different, with varying specifications, as you see in some other series.'

This year will be the third season for the Dallara SF14. Its predecessors, the Lola B06/51 and the Swift 017, lasted three seasons and five seasons respectively, so the succession plan for the Dallara is beginning to be considered by some, although this is not being actively pursued by Shirai and JRP just yet. 'Right now we don't have an immediate plan to replace the Dallara. I think we will continue with this package for a while yet. We will wait and see how it develops, but maybe it has another two seasons in it [2017 and 2018], after all the GP2 Dallara is now six years [old],' Shirai says.

Whatever comes after the SF14 it could form part of an idea which Shirai is mulling over currently. This is a globalisation of the Super Formula concept, where perhaps other series such as Indycar, Formula 2 or others, could share some elements of the car concept, perhaps the chassis or even the engine rules.

As far as the current engine situation is concerned, this season around half the Super Formula field use Toyota engines, and the rest Honda. The turbocharged 4-cylinder direct injection units are essentially the same as those found in the GT500 class of Super GT (known as the NRE, Nippon Race Engine), and are similar to what the DTM was originally planning to adopt in 2017. With such commonality of engines there is perhaps one obvious omission from theSuper Formula field; Nissan, which already has a suitable unit in use in the GT500 GT-R. Indeed, during a test in 2014 Nissan works driver Jann Mardenborough proved highly competitive in a Toyota-powered SF14 run by Team Impul, a long term Nissan works team in Super GT. 'I don't really know why NISMO are not in Super Formula,' Shirai says. 'I guess they don't really have much of a history in open wheel racing. So I think it is not on the radar for that reason. We would welcome them or any new manufacturers to the series: Nissan, Volkswagen, Mercedes, of course, yes they can come. With my target of making the series bigger and bigger, then that should happen.'

Global power

The technical details of the engines are at present closely guarded secrets that the manufacturers are rarely willing to discuss, but Shirai suggests that this could change in future with the development of customer variants of the NRE engine. 'Maybe there are some series in the world that are looking for engines, and we have a good engine formula and maybe we could export it. If Audi or Cosworth or whoever wanted to build an engine to this spec and use it in a series elsewhere as well that would be good too. In future Honda and Toyota have the option of developing a customer spec NRE engine, and that could be sold globally.' While Shirai did not say as much it seemed that he might have been suggesting that Indycar could adopt the same engine rules and perhaps even one of the big European classes, F2 (though that seems to be headed toward a Mecachrome built 3.5 litre V6) or the Formula V8 3.5 series perhaps.

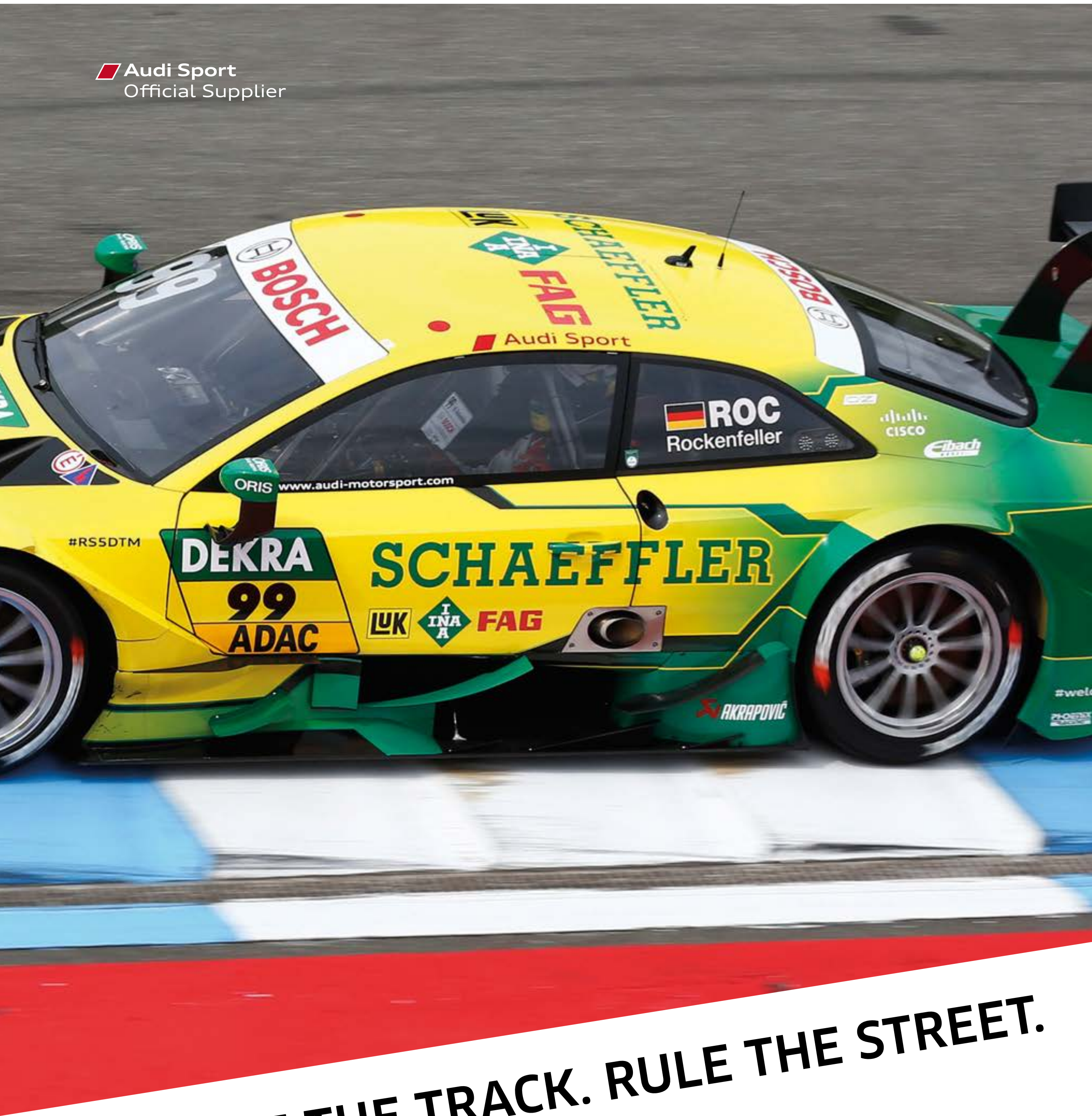
However, Shirai will not oversee his plan for the development of Super Formula. Shortly before the first race of the season he announced his retirement in order to allow another, younger, JRP board member, Akira Kurasita, to carry out the plan as the new JRP president, although Shirai will remain involved as the series technical adviser. And under the leadership of Kurasita (a former TV executive), aided by Shirai's experience, Super Formula looks set to grow substantially in the near future.

The hybrid that never was

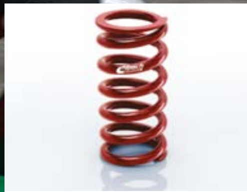
When the Dallara SF14 was first created it was designed to accommodate a hybrid power unit. Both Honda and Toyota pushed for hybrids to become part of Super Formula, Honda planning on using a system from Zytek in England, while Toyota could have used its own THR technology.

The concept had been for the motors to remain a fixed specification but for energy storage to be free, as Japan has a number of major battery and capacitor suppliers such as Panasonic who were reportedly interested in going racing. The Zytek system was tested on the old Swift chassis, but over the years the hybrid plans of Super Formula have fallen by the wayside. 'The SF14 was designed to accommodate a hybrid system but I don't think it will happen, because of the weight and the system complexity as well as the cost,' Shirai says. 'One of the mission statements of Super Formula is "quick and light", and I can't see how the hybrid system can fit into that. I ask you why today is everyone obsessed with making everything hybrid, maybe it's for road car marketing or marketing reasons? But for racing it is not always the right way.'

A footnote to the hybrid Super Formula Dallara story is the 2015 Honda RA615H prototype F1 power unit dubbed the 1X1. The engineers at HRD in Sakura City considered fitting this PU to their own SF14 chassis as a test mule, but on investigation it was felt that the battery volume was too small and that the modifications required would have been far too extensive. So instead they opted to adapt a McLaren MP4-29 F1 chassis with which to conduct the shakedown runs in England in late 2014.



IMPERIAL RANGE



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Thunder down under

By putting a 5-litre V8 lump in a modern single seater Australian venture Formula Thunder 5000 has reworked F5000 for the 21st Century. *Racecar* examines this hugely exciting 'new' category

By LEIGH O'GORMAN

Formula 5000 is a category from a bygone era. But with the advent of Formula Thunder 5000, this once famed single seater formula may be about to come to rumbling life once more.

But why? One reason is that in today's motorsport world it is not unusual to see drivers fall off of the single seater ladder and into various sportscar racing categories – particularly GTs – and one-make championships, such as the Porsche Carrera Cup. In Australia it is no different, with numerous drivers taking to V8 Supercars or its support and junior classes.

While this is a fact of life for some, Chris Lambden – a former motorsport magazine publisher and also a V8 Supercars commissioner – believes that in Australia at least, there should to be a high level single-seater destination for those who hit a roadblock after competing in the lower tiers. However, Lambden admits for many young drivers, V8 Supercars reigns supreme down under. 'Australia is very much in love with V8 Supercars,' Lambden says. Yet while he clearly understands the bigger picture of Australian motorsport, he is also clearly aware of the country's desire for single-seater action. 'About four years ago, I used to be in publishing and I sold the business. I had a bucket list and I wanted to drive a Formula 5000 car, and I ended up owning one for a couple of years. Everywhere we went, people would say "it's a shame there's nothing like it these days". Eventually I just started to think, why not?'

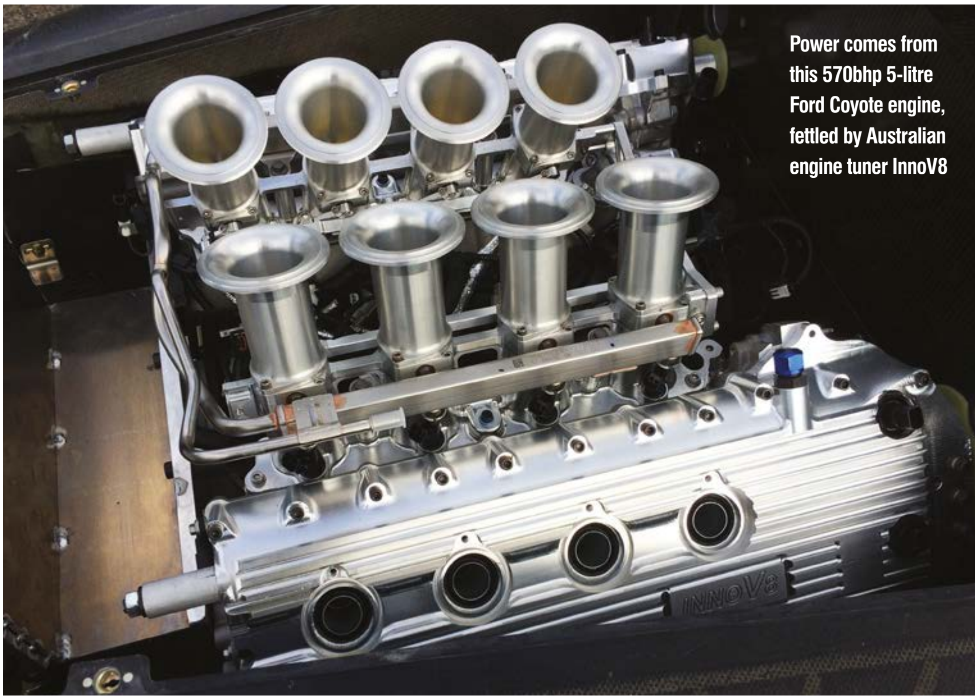
Lambden began investigating the possibility of launching a Formula 5000-style category and while defining the basic technical parameters – V8 power with low downforce and big tyres – was reasonably straightforward, developing, tooling and building the car from scratch was rather more problematic, as he quickly discovered. 'To build something from scratch here was going to be prohibitive, so we started to look around to see if there was an existing design that had possibly ceased production.'

After some investigation, Lambden began speaking to Swift Engineering and soon agreed to buy the rights to the design and tooling for the company's now defunct Formula Nippon FN09, which raced from 2009 to 2012. 'It's a brilliant car. It's a very strong car. It was a very aero car in its day, so the car as it stands –the tub, the nose, the rear crash structure and the side-intrusion stuff – we are not changing at all.'

The decision to maintain these key elements means that the FN09 retains its FIA 2009 crash test status and, according to Lambden, also creates a very controlled category making it financially viable and reasonable.

Overseeing the engineering side of the prototype and the subsequent Formula Thunder

The basic parameters are V8 power with low downforce and big tyres



Power comes from this 570bhp 5-litre Ford Coyote engine, fettled by Australian engine tuner InnoV8

The aerodynamic capability of the modern Swift chassis has been reduced by cutting the front wing down to size, though the rear wing has not been altered. Singapore-based GiTi provides rubber

It wouldn't be Formula 5000 without a mental airbox. It is still undecided whether this will remain when the car goes into service but FT5000 says the public reaction to it has been mostly positive

'We deliberately reduced the aero capability of the car, the actual cornering speed won't be as fast as it possibly could be'

5000 racecar is Borland Racing Developments, headed by Michael Borland. A veteran of Australian motorsport – Borland produced the championship winning Formula Ford 1600 Spectrum – Borland Racing Developments stands out as one of very few producers of modern racing cars in Australia.

Wizards of Oz

For Lambden, collaborating with Borland was an easy decision. 'I've known Michael for over 20 years, so he really was the first guy I spoke to when we started to put this project together. He is overseeing the basic engineering of it and the upside for us is there is a massive amount of Australia in the car.'

Maintained and tuned by the Brisbane-based company InnoV8, the engine is a Ford Coyote 5.0 litre; the gearbox will be produced by Melbourne company Holinger; while another Australian company, SupaShock, is producing the shock absorbers. Ex-F1 engineer Lee Cason is to oversee the production of carbon fibre elements from his Melbourne base, and New Zealand's Arrow Wheels is also involved.

There is plenty of understandable excitement about this project in Australia and beyond, but simultaneously it's raised questions as to the viability of running these machines on Australian circuits. But Lambden sees no issue here. 'We certainly have high enough level circuits. And we deliberately reduced the aero capability of the car. The actual cornering speed of the car won't be as fast as it could possibly be. The lesson from the past appears to be "reduce aero, so that cars can run close to each other and are based on mechanical grip rather than aero", and that's where we're headed.'

In order to reduce the aerodynamic capability of the car, the front wing has been reduced and Lambden predicts that the undercurrent tunnels have been reduced by up to 50 per cent. However, the original rear wing is still in place. 'We simply don't want to produce a modern aero car, because from the entertainment perspective and the driver input perspective, it doesn't work,' Lambden says.

The original FN09 ran with Toyota RV8K and Honda HR12E powerplants. But for it to be F5000 Lambden has taken the advice of InnoV8 boss Roger Higgins, and opted for the 5.0 litre Ford Coyote V8 stock block. Lambden is delighted with unit thus far. 'It will provide the kind of power that we are looking for, performance and durability; it is as close as you can get to bulletproof in racing.' Installation of the engine has proven to be easier than expected with the Coyote unit slotting into the engine bay with relative ease. But the fit was not completely issue free, as the team needed to add a small subframe for extra strength.

Days of Thunder

It is expected the Coyote unit will produce approximately 570bhp and that the torque will be typical of a 5.0 litre stock block engine, which naturally works well in low and mid-range. 'We are probably going to have a rev limit of about 7500rpm or maybe fractionally more than that and that's well within the capability of the engine, and will extend durability,' Lambden says. InnoV8 will also manufacturer the fuel injection system and the dry sump arrangement for the FT5000 car.

The choice of the Coyote engine also meant the weight distribution moved rearwards a little bit. The wheelbase has been increased by 50mm to accommodate the slightly larger engine and gearbox package, and Lambden feels this should prove a suitable solution. 'That helps the situation a little bit, but it is still well within the sort of distribution that a classic F5000 car currently runs.'

Other modifications are necessary to allow the package to sing in unison. Producing a 6-speed sequential gearbox most usually used in touring cars, Holinger have been required to adapt its unit to fit in with the concept of the FT5000 open wheeler. With the suspension situated beneath the gearbox casing, the height of the input shaft and the output shaft of the gearbox was lower than the existing gearbox in the FN09. Initially, Holinger and Lambden looked at two solutions, before eventually settling on a plan. Lambden: 'We could have solved it by raising the engine and gearbox and tilting it, but in fact what we have done is to make a special set of bespoke drop gears on the front of the gearbox, which allows the engine to stay at its lowest possible position.'

Thanks to a pre-existing relationship with InnoV8, MoTeC is doing the electronics for the engine and for the car. But Lambden points out that the electronics in the car will be limited anyway. 'The whole philosophy is to get back to drivers driving. There will be no high level of

‘We wanted a rear tyre that was wide, a bit retro, and something that would make grown men cry’

sophistication other than basic data and basic mechanical safety stuff.’

Oscar Fiorinotto at SupaShock has designed a bespoke suspension package for the Formula Thunder 5000. However, at the time of writing it was unknown if the car will continue to be fitted PFC brakes, as it was in Japan.

Arrow Wheels are constructing three-piece aluminium wheels that are already used in historic Formula 5000, but if finding the wheels was relatively easy, procuring tyres proved somewhat more troublesome. ‘We went to a whole lot of tyre companies; we were particularly after a rear tyre that was pretty wide, a bit retro, and something that would make grown men cry,’ says Lambden.

‘Out of the blue, we ended up talking to a Singapore-based company called GiTi. They are a global manufacturer of tyres and have manufacturing capabilities in China and America and they are starting to make waves in motor racing,’ Lambden says.

This will not be GiTi’s first single-seater effort by any stretch of the imagination. Having produced tyres for Formula Masters China, the Asian company has some knowledge and experience of single seater racing. ‘We were introduced to them and they thought this was quite an interesting project and we were able to come to an arrangement quite quickly to develop a rear tyre specifically for this car, Lambden says. ‘It will be 16.5 inches in width, which is a pretty decent sized tyre.’

Nod to the past

Like the fat tyres, there’s another rather obvious nod to F5000’s past. One of the unmissable features of the Formula Thunder 5000 has to be that simply huge airbox – a very large and wide tower that deliberately harks back to the styling of mid-1970s single seaters.

‘That was entirely emotional,’ says Lambden. ‘Without doubt, it soon became apparent that we were creating a 21st Century Formula 5000 car and so we decided to, almost as a tribute to that era, to come up with an airbox that was typical of that era.’ Lambden has not confirmed whether the airbox will remain in the final design (the car seen in the images is an 80 per cent complete prototype), but he does acknowledge that the reaction to it so far has been largely positive. ‘It is a nod to what we believe is one of the golden eras in motorsport.’

Lambden’s ambition for this category is not to be sniffed at. He sees a high quality of driver signing up for this championship, as opposed to leaving for Europe or following the V8 Supercar route that so many others have. ‘People will need to be competent because the car will have a reasonable amount of power. The Historic Formula 5000 is very strong here, but that is very much a historic category with amateur drivers. This will be a little bit more serious and will require driver input.’

With work continuing on the gearbox and other smaller elements, this project is now quite close to fruition. Lambden estimates that budgets will fall in the AUD$240,000-300,000 range per entry, for a series that will be run from December through to February.

There has been plenty of enthusiasm so far for the Formula Thunder 5000 project from both CAMS (Confederation of Australian Motor Sport) and the Historic Formula 5000 racers. ‘Warwick Brown [’70s F5000 legend] rings me every day; he’s thrilled to bits and is very supportive. Historic 5000 is about the cars, their beauty and all that stuff, and this is going to be more about the drivers.’ The first FT5000 car is expected to be ready for shakedown in June.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GT500 cars are propelled by engines built to the Nippon Race Engine (NRE) spec, which is for 4-cylinder, 2-litre, turbocharged powerplants. In Honda's case its NSX packs the HR-414E

In 2014 Super Formula and Super GT introduced a joint engine rulebook called the Nippon Race Engine, or NRE. The idea was agreed by the three main Japanese automobile manufacturers, who all wanted to focus on improving overall efficiency while following the global trend for downsized, direct-injection turbocharged engines.

Inspired by the concept of the FIA appendix engine, also known as the Global Race Engine (GRE), the new rules mandated a turbo direct-injection, 4-cylinder, 2-litre unit. But unlike the GRE concept the new Japanese regulations offered a lot more technical freedom and did not rely on air restrictors to govern performance, instead the rule-makers opted to follow the route taken in Formula 1 and LMP1 and govern fuel flow. Unlike F1 and LMP1, however, the NRE concept uses a Toyota developed fuel flow restrictor, rather than an ultrasonic flow sensor.

The additional technical freedoms allowed in the NRE regulations have resulted in each of the three engines developed and used in competition to date appearing visually different, something which can be seen by comparing the image of the Toyota design on page 21 with the pictures of the Honda unit seen here. This difference is more than just visual, however, as the engine builders are each working on different areas in order to gain a performance advantage over the other competitors.

Honda's HR-414E is the least photographed of the three NRE engines built to date, largely because it is mounted in the rear of either the Dallara SF14 or the Honda NSX Concept GT500. As such it is not readily visible from the front of the garages, and when the engine covers are removed a blanket is almost always thrown over the engine to prevent prying eyes looking at

The heart of the beast

Racecar **reveals the closely guarded secrets of Honda's rarely seen HR-414E NRE Super GT powerplant**

By SAM COLLINS

Most Super GT cars have front-mounted engines. Honda retains the mid-engine layout for its 2016 NSX, which means weight distribution is different to its rivals

'I think it's important to say that with the HR-414E and the Formula 1 V6 projects the focus for both is on combustion, especially combustion speed'

its design. The engine seen on these pages is a 2014 A or B spec version, while the version used in the opening Super GT races of 2016 is the E spec version, and has a few visual differences around the cylinder head (*RE* was not permitted to study the full D or E specification units).

F1 connection

The design and development work on the HR-414E began a relatively long time ago with, according to some inside Honda, always an eye on transferring some concepts over to the proposed F1 power unit (the RA615H/RA616H). 'In terms of R&D we started earlier with the NRE than the V6 project so we had more knowledge of turbocharging and direct injection than anyone in the company,' Masahiko Matsumoto, Honda's Super GT LPL (Large Project Leader), said. 'As a result of that the V6 started off with the NRE data in those areas.'

The two designs, HR-414E and RA616H, both utilise the same mono cylinder development engine at Honda's substantial motorsport development facility at Sakura City, 90km to the north of Tokyo, Japan. 'The mono cylinder engine is shared to study the burn and combustion speed, so we both start with that same mono cylinder then take the findings each way and develop from that, but we share all the information between us. It's important to highlight that not everything is applicable because we don't have a bespoke fuel, where the V6 has a special fuel development. I think it's important to say that with both these projects the focus is on combustion, especially combustion speed,' Matsumoto says.

This inevitably means that there is some commonality of design between the F1 engine and the NRE, an interesting scenario and one originally imagined by Ulrich Baretzky when he first proposed the GRE concept.

Compact unit

In the NRE regulations some components are single specification including much of the direct injection system, which uses many parts from Bosch. The maximum injection pressure is 200bar, notably lower than the maximum allowed in F1 (500bar), but the injector location is free as is the nozzle design. Honda has opted to offset the injector to one side of the combustion chamber (it's not clear if it has done the same with the F1 engine, but it seems likely).

Overall the HR-414E is a very compact and narrow engine, Matsumoto would not reveal design specifics but the regulations state that the maximum bore diameter is 88mm, plus or minus 2mm, with a minimum weight of 85kg. The length of the engine between front and rear mounting points is a mandatory 500mm. The overall external size and shape of the NRE engine concept is a deliberate decision due to the dual roles it must perform, in both Super Formula single seaters and a GT500 cars.

On the Honda engine the ancillaries layout can be seen from looking at the few

By design the unit is very compact. It features an unusual water pump location with drive shared with the high pressure fuel pump

images available, in addition *RE* was given the opportunity to look over a D Specification HR-414E installed in the NSX during pre-season testing. The water pump on the engine is unusually mounted near the top of the engine block, just under the intake manifold rather than low down near the sump as is more common, in addition the high pressure fuel pump shares its drive with the water pump. Mounted lower on the same side of the block is a McLaren supplied alternator. The oil filter and scavenge pump are located on the opposite side of the block under the exhaust header and the Garrett turbocharger.

'The Super Formula engine differs to the GT500 slightly in terms of its packaging, simply because the GT car is a lot bigger than the Dallara SF14,' Matsumoto reveals. 'So some components had to be relocated to be accommodated in the single seater car. The inlet chamber on the GT engine is bigger for example for that reason.'

'There is variance in the exhaust, too, for the installation but also the performance. Our car needs big torque under acceleration while the Super Formula car can sacrifice torque in favour of pure power, so the changes to inlet and exhaust also help with that, we also have different valve timing.' The intercooler solution on the two cars varies significantly, too, on the Dallara it is a single specification part shared by all cars whether they are Toyota or Honda powered, but in Super GT the development of it is permitted and the NSX has gone through a few design iterations, especially in 2014 when it suffered from a cooling issue. 'In terms of performance the two engines in Super Formula and GT start out about the same, but after the middle of the season the GT engine becomes a bit more potent. This is because in Super GT we are allowed three different specifications per season, but Super Formula is allowed only two specifications,' Matsumoto says.

Flow slowed

In one area the two engines will be somewhat closer than they were in 2015, as the fuel flow limit for GT500 has been reduced from 100kg/h to 95kg/h, now in line with the level Super Formula has run since 2015, but there will still be variance. In 2014 when both GT500 and Super Formula ran with a 100kg/h limit on the HR-414E in GT500 it was at 7500rpm, while in SF it was at 8000rpm, because of different demands.

When the NRE was introduced to GT500 along with a new chassis rulebook Honda uniquely mated the HR-414E to a Zytek derived hybrid system for use in its GT500 car, the NSX Concept GT, and then mounted this power unit in the middle of the car. This choice was something which created a significant number of challenges to overcome as the DTM chassis technical regulations which are used in the GT500 class are based on a front engine concept. Honda had to use a specially modified monocoque and also had to overcome cooling issues (see V25N12), allied to that the series promoters GTA hit the NSX with two handicap weights, one for running a hybrid power unit and the other for running a mid-engined car, this meant that the NSX was the heaviest car competing in GT500 by some margin.

Hybrid dropped

Shortly before the 2016 season began, Honda made the surprising announcement that it would not be using its hybrid system in the NSX GT500 anymore, and that the new GT3 NSX would also not run a similar system, as had been first planned. Many felt that this was to let the car run at a lower weight, but according to Matsumoto is was for much simpler reasons. 'We dropped the hybrid system because of a problem with the battery supplier. We could not continue with them so we had to either choose to abandon the system or develop a complete new battery system from scratch. The cost performance ratio of doing a new battery was just not good enough. It would cost €2m or more to do a new battery so we decided to drop the hybrid and run without it.'

The hybrid system had always been capable of having a 60kW output but the GT500 rule-makers had restricted it to just 21kW, although this was only a modest increase in power it would likely of had a notable impact on torque. However, not running the hybrid system also means that the Honda no longer has to carry some of its handicap ballast, and the internal packaging at the rear of the car has been eased slightly. 'Losing the hybrid system meant that we lost our weight handicap placed on us by the series for using a hybrid, but we still carry a weight handicap for running a midship [mid-engine] car,' Matsumoto says.

'So our total weight is now 28kg less than it was last year but also we have lost 21kW power year on year so it's a mix. I think really the performance balance is about the same when all things are compared. It's a big change losing all of the parts, the total system weight on the car was under 70kg and we could get the overall vehicle weight down more but the regulations force us to stick with the new minimum weight of 1049kg [front engine DTM type cars have a minimum weight of 1020kg]. So to meet that weight limit we had to use a fair bit of ballast, but also the regulations force us to run with

HR-414E is the least photographed of the three NRE engines built to date

Complete vehicle system simulation

Using physical modelling tools to simulate the complete vehicle leads to a better understanding of the system behaviour and interactions enabling system level optimisation.

As the complexity of today's vehicles increases due to hybridisation, more advanced driver assistance systems and many other active systems it becomes increasingly important to be able to simulate how the complete vehicle system behaves and interacts. Using simulation from the start of the project enables design decisions to be influenced and optimal system solutions to be found.

As the complete vehicle system covers many different domains including mechanics, electrical, thermal, fluid and control we need to use system level modelling and simulation tools that can create predictive models covering all of these domains.

Dymola is a multi-domain modelling and simulation tool that uses the Modelica modelling language to describe the behaviour of components, devices and systems. This capability is encapsulated into a wide range of application libraries covering engines, powertrains, batteries, electric drives, vehicle dynamics, thermal management and human comfort.

Using Dymola, Claytex has produced complete vehicle system models for studying engines, drivelines, vehicle dynamics, thermal management, hybrid technologies and body systems. These have been applied extensively in Formula 1, NASCAR and IndyCar enabling the teams to evaluate and optimise new technologies and ideas before arriving at the track. In motorsport these models are deployed in the design office, integrated into the trackside tools and telemetry systems and used for HiL and DiL testing.

'Losing the hybrid resulted in a small overall drag reduction on the NSX'

HR-414E is impossible to see with the car parked in its garage; not just because the mechanics make an effort to keep it hidden, but also because it's a tiny unit mounted low in a large car

The Honda NSX Concept GT is the only mid-engined GT500 car. Up until this season it packed a hybrid but this has been discarded because of supply issues

the exact same weight distribution as we did when we had the hybrid, so that is another potential gain which we cannot take advantage of. Once the battery and MGU was removed we had to mount the ballast in the volume left by the battery in order to meet that weight distribution, GTA check this a lot and it must remain exactly the same. I don't think the hybrid system will return now, I think that project has concluded,' Matsumoto reveals.

Despite most areas of potential gain from losing the hybrid being closed down by the rule makers there have been some minor improvements for the NSX in 2016. This year aerodynamic development in GT500 is essentially outlawed as the series prepares for the introduction of a lower downforce concept in 2017, but the NSX has found one region of improvement. 'Losing the hybrid resulted in a small overall drag reduction, because without the additional coolers there is a small benefit, but then the other cars don't have that additional drag anyway, so all that will do is put our drag level closer to theirs. Beyond that we could not change the aerodynamic package at all this year. The advantage we have gained is in terms of tyre life, it's better than it was in 2015, the weight saving allows us to run a softer compound or run the same compound for longer,' Matsumoto says

TECH SPEC

Honda HR-414E

- **Type:** In-line, 4-cylinder, gear driven DOHC
- **Capacity:** 1995cc
- **Turbocharger:** Garrett
- **Valves:** 2 exhaust, 2 inlet per cylinder
- **Injection:** Bosch GDI
- **Fuel:** Various unleaded gasoline (whatever is available in the paddock)
- **Weight:** 85kg
- **Output:** Over 600bhp

Work required

As a result of the loss of hybrid and the aerodynamic development ban, most of the Honda development between 2015 and 2016 has been on the HR-414E engine, chiefly with making it more efficient. 'With the fuel flow reduction from 100kg/h to 95kg/h, we have lost about 20kW from that and another 21kW from the hybrid, so a total loss of 41kW this year, and we have to make up for that,' Matsumoto says

In the first outing for the hybrid-free NSX powered by the HR-414E/E , a 250km race at the Okayama circuit, things did not go well at all. The Honda NSX Concept GTs could not live with the pace of the GT500 cars from either Lexus or Nissan and Matsumoto was clearly unhappy with the result. 'It was clear that the engine output was not good enough compared to the others, in addition we suffered from stability issues under braking and an overall lack of tyre grip, it is something we must work hard to understand,' he admitted following the race. 'Next year we expect to introduce an all new NRE unit called the HR-417E. This is because the regulations are changing a little bit so we will have to do a new engine to fully optimise those new rules. But for the final year of this engine, HR-414E, we must look to increase the output, it is almost pure performance work, but for HR-417E the focus is all about reliability at the moment. We need some more horsepower on the HR-414E so it's about continuing that combustion work, we are looking at the combustion shape and looking at the ignition and trying to have a faster combustion. It is the same way that the F1 engineers are going too.'

Global relevance

Despite its recent troubles the HR-414E is clearly a very advanced engine and while it may seem that it is a Japanese oddity (as with all NRE designs) its relevance may be wider than is first apparent. Although the engine is called the 'Nippon Race Engine' that does not mean that its usage was ever planned to be restricted to Japan or Asia, and elsewhere in this edition a customer variant of the concept is discussed (see page 22). In addition to that, the three manufacturers in the DTM all started work on their own versions of the NRE before abandoning the projects for quoted reasons of difficulty and expense. Both the proposed customer variant and the German version are likely to differ from the cutting edge specifications used in Super GT and Super Formula with a lot less development allowed, but the core concept will carry over.

It has also been rumoured in Japan that the HR-414E will form the basis of Honda's customer specification 'Global Race Engine'. Time will tell if that is the case, but perhaps this Japanese engine could find its way on to the circuits of Europe or the ovals of the USA sooner than you might expect.

Nordic invasion

First Sweden, then Australia, now the world … How Volvo's Polestar performance division has prepared its S60 for combat in the World Touring Car Championship

By ANDREW COTTON

'Our commercial needs required us to have an international programme as soon as possible to support the international brand'

Volvo's full works entry in to the World Touring Car Championship has been on the cards for some time. The Swedish manufacturer has contested the European Touring Car Championship and flirted with the WTCC for a while, even running a season-long programme in 2011 with its C30 model. However, it has now committed itself to a full assault with a two-car entry for this season, having developed its S60 saloon for the series.

The route to the WTCC has been a convoluted one for Volvo, starting with it buying the Polestar brand and turning it into its high performance division. Polestar will now also be responsible for motorsport, and will mediate between the car manufacturer and series organisers and regulators, and the racing team, now called Polestar Cyan Racing.

The WTCC programme continues the growth of the racing team, which also has Australian and Swedish touring car programmes. Polestar was founded in 1996 by Jan 'Flash' Nilsson to contest the Swedish Touring Car Championship with the Volvo 850. It won the title during the team's first two seasons, 1996 and 1997.

The team then campaigned the S60 in the 2003 STCC season, the first for the new FIA S2000 regulations and a year later Christian Dahl took over as sole owner of the company, signing Robert Dahlgren as its lead driver. Along with Tommy Rustad, the team scored pole at every race, won each event, and Rustad the title.

In-race development

Dahlgren was then part of the team that entered the C30 in the WTCC in 2011. This was a critical programme, as for the first time Polestar had one of the 25 prototype engines for the next Volvo production car, the new S60, and it used the racing programme to develop it, as Mattias Evensson, head of engine development at Cyan Racing explains: 'We have been trying to get this together for quite a long time, with just a few occasional races during the years, and then in 2011 we did the full season with the C30. The engine that we did in 2011 was based on a pre-production 4-cylinder Volvo engine that was going into production two years later, and that is still the base for what we run now. We took what we learned in 2011, and all the experience that we gained during the season, and we put it into this engine. This engine is new from the ground up, although it is still based on the production engine.

'It was one of the first 25 blocks that Volvo did in the first pre-production development programme, so we were quite early,' Evensson adds. 'Then it was difficult to get hold of prototype parts, and now it is much easier as we get the production parts. Volvo has made quite a big step forwards compared to what we had in 2011, both in the size of the block and the cylinder heads, and material choices for the castings. At the same time as we have developed the race engine, they have pushed the production engine. Their first performance

Volvo's entry into the WTCC was delayed while it made sure all the right pieces were in place. This mainly involved buying Polestar to create a performance arm of the company, and developing the S60 racecar campaigned by Cyan Racing

If the car's not enough there's a big sign to show you just what Volvo wants from the involvement of its Polestar performance brand in the WTCC; but this is not just show and the links between Volvo and its race team are strong

target was quite a bit lower than it is now. I was based at Volvo working on the production engine when they shut the WTCC project down after 2011. I was based there and was trying to feed our knowledge into the production engine. In that sense it is quite unique to have a close association with the production engine.'

The turbo used in the 1.6-litre unit is standard to the WTCC, and there have been certain restrictions placed on the development of the production car powerplant. 'The air restrictor is smaller, the power has increased quite significantly from [2011], but we started with the new production blocks and new production cylinder heads, new crankshafts, new rods, pistons, valve train, everything compared to the old engine,' says Evensson. 'The oil system is different, and it was quite nice to get a chance to develop. You get the chance to do something over again with what you have learned. To get a second chance you have a lot of knowledge you can put into it.

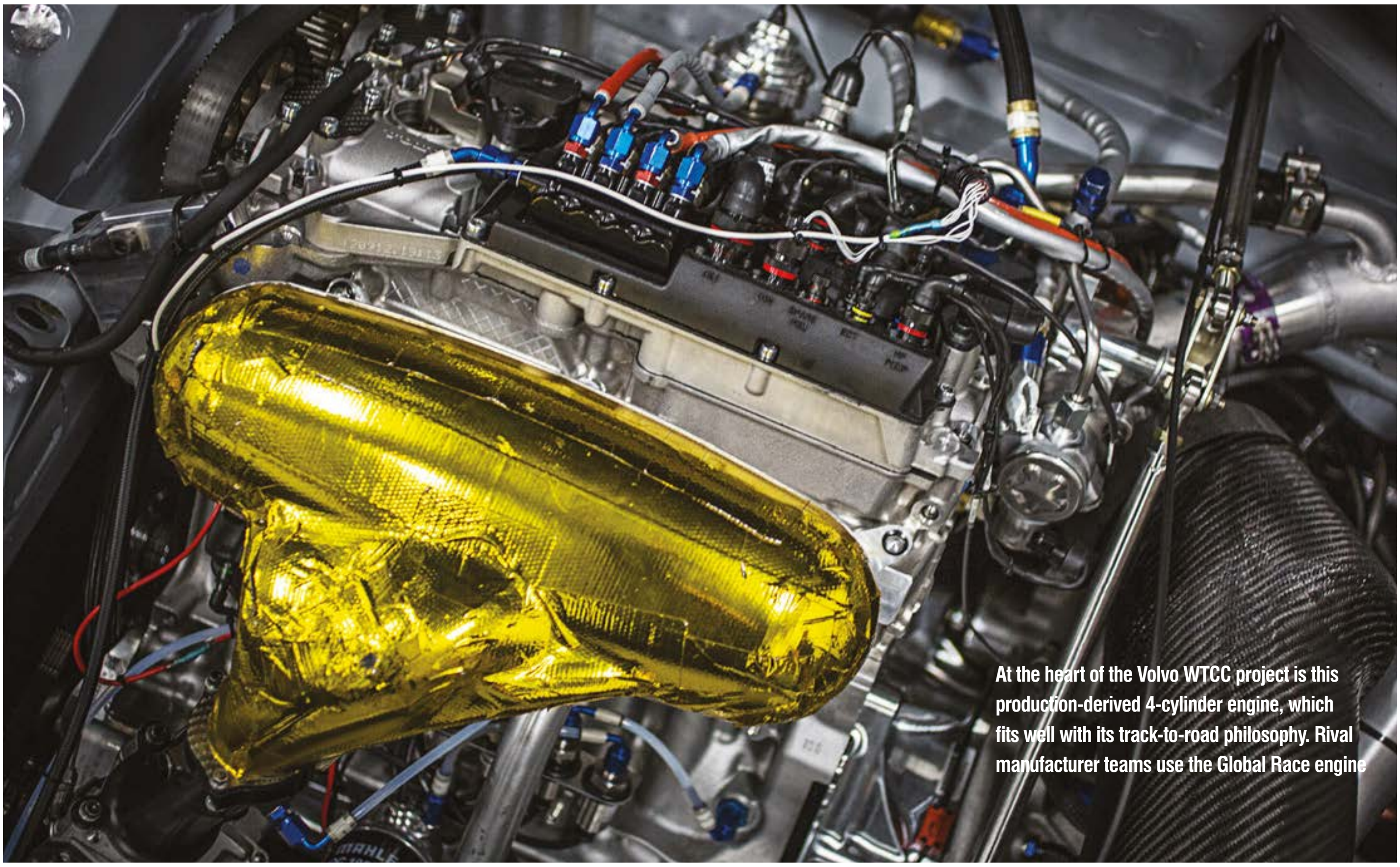
'The change in the crank was for weight and we are revving it a lot more, the stroke is much shorter, as the production car is 2-litre and this is a 1.6. The bore is similar to the production unit. We had to modify the block because it is a dry sump on the engine, so we don't have the big oil sump, so we can drop the engine in the chassis, and we tilted it 25 degrees, so we tilted it as far as we can by the regulations.'

The rivals from Citroen, Honda (Mugen) and Lada (ORECA) all have bespoke Global Race engines, and run with a standard valve size which is bigger than the production-based engine regulation, which allows the valve size to be increased by a maximum of 1mm. 'There are other things; you can't change the bearing dimensions compared to the production engine,' says Evensson. 'It has not been a big limiting factor, and the benefit of using a production engine is marketing. You are actually racing with the production engine. It is great what Polestar has done.

'The mechanical part of the engine is not limiting. We don't have to limit the torque because the mechanical element is not up to it, [it is] more [about] the job that you can do extracting what you can from those regulations.'

Delayed action

The link between Volvo road cars and the race team is strong, and part of the reason that its entry into the WTCC was delayed for so long. Volvo decided not to continue racing the C30, which killed off that programme, and meant that Volvo could not join the WTCC when it introduced new regulations in 2014. Volvo was due to contest the WTCC in 2015, but that debut was again delayed, this time due to the purchasing process of buying Polestar and developing it into its performance arm. 'The optimum is to enter when they change the regulations,' explains Alexander Murdsevski Schedvin, head of motorsport at Polestar. 'We were planning for an entry in 2012 with



At the heart of the Volvo WTCC project is this production-derived 4-cylinder engine, which fits well with its track-to-road philosophy. Rival manufacturer teams use the Global Race engine

Polestar has made full use of Volvo's huge resources to build its TC1 racecar and its chassis has benefited from the employment of the manufacturer's shaker rig, wind tunnel and its CFD capability

The WTCC could switch from current Yokohama tyres next season, while there are to be technical regulation changes for 2017, too – which means the S60 will need to be modified for its second year

the V40, but then we decided not to use the V40, so we pushed the whole programme back and started from a clean sheet of paper again. From November 2013 onwards we have been actively developing this programme. Our commercial needs required us to have an international programme as soon as possible, to support as soon as we can the international brand. We would have entered in 2015, but the acquisition of Polestar takes time so we decided to take that time and enter in 2016.'

That leeway has meant that the team has been able to develop the car away from the racing environment for a year, testing mainly in Sweden. 'We took the decision early that we didn't need to rush into it, to build a car in half a year and go racing last year,' says Evensson. 'We decided to do proper work and development, build a test car and use that. There were quite a few changes from the test car that we ran last year to the racecars now. It was not so much a performance change, more reliability and making it more durable. We have done so much testing before we have gone to the racecar from the test car. We started running on the dyno in April last year, so we had more or less three or four months on the dyno.'

Chassis and suspension development was also key, with the team finding fatigue in the subframes and needing to make changes. It's a similar story to that experienced by Honda in the first year, possibly due to underestimating the aero efficiency of the racecar.

Volvo entered the WTCC this year with only two cars, rather than the three required for the new MAC3 qualifying initiative, where three cars complete two laps and the time of the slowest car counts as the qualifying time. Volvo's goal is to enter a third car as a factory team, before considering supplying customer cars.

This as the third of a three-year rules cycle, and a development of the regulations designed to reduce the cost of racing for privateers is under discussion. Options include reducing the amount of carbon used for the bodywork, as well as reducing engine leasing costs, and a decision is expected by June of this year.

TCR conundrum

Despite the likes of Kia and Alfa Romeo building cars for the TCR series, a burgeoning low-cost touring car category built along the same lines as the S2000 regulations with national series around the world, Volvo ruled it out for that very reason. 'TCR is not a World Championship and Polestar [is now] an increasingly global product for the Volvo group,' says Schedvin. 'It is extremely difficult to leverage your motorsport heritage by trying to persuade a customer or journalist in the US what STCC, or what the V8 Supercars in Australia is. It is difficult to communicate that.

'But everyone understands the concept of a world champion, or of an Olympic gold medallist. This is the global, official world

The team has been able to develop the racecar away from the racing environment for a year

Volvo has no intention of offering customer cars next year but it could run as many as five works machines, which clearly shows its intent. At the first round of the WTCC at Paul Ricard in France Volvos finished in the top 10 in both of the races

championship, which is [the] number one [reason]. Number two, obviously: the hardware, software optimisation on the powertrain, and also the complete S60 [racing] car has a perfect alignment to the S60 [road] model. The powertrain which its uses is essentially the same that we use in the WTCC.'

TCR is also less of a good fit for Volvo in other ways: 'The TCR is a small hatchback, which you have in the WTCC as well, but the technical regulation allows us a very good car in the WTCC which is the priority for us,' Schedvin says. 'We have decided to have all activities on the S60, the B-segment car. A world championship, plus the fact that we can use our own technology right down to using the base engine block, the only one in the world championship [to do so].'

Works support

The S60 is a completely clean sheet of paper design and the Volvo marque was heavily involved in the development of the chassis and the aero. As the performance arm of the group, Polestar had full access to Volvo's facilities, including the full-scale rolling road wind tunnel, as well as being able to tap into the manufacturer's CFD capability and test the chassis on the company's shaker rig. 'We did both CFD and wind tunnel work,' says Evensson. 'We have not done the CFD in-house before, but the regulations are so aero dominant that we hired someone who was with Red Bull before, and he has been working on the CFD and aero, together with Volvo because they have good capacity with CFD and correlating that to the wind tunnel.

'We have everything in the technical area in the car developed in-house and in the same building; the aero, chassis, body, all sitting in the same room. You know what the others are doing, and you always have interactions between everyone – to have it all in-house is a big development,' Evensson says.

'We used the Volvo wind tunnel, which is very good, full scale, rolling floor and you can run at 250kmh, so it is a good facility for us. That is also an area that you need to be able to loop. You need to build the kit, test it and then go back and make tweaks on it, and you need time to do it. Rapid prototyping is very efficient for the body parts. While the old S2000 regulations demanded a change to a production car, the new car had to be created from scratch and it was the first time the team had undergone the FIA's homologation process, which was a learning experience in itself.

'The chassis is the first time that we have built such an extreme touring car,' admits Evensson. 'With the old S2000 regulations, it was a lot to tweak the production car, you had to use production uprights and sub-frames. With the TC1 regulations you are free to do what you want. You can build your own suspension, packaging, sub-frames and the cars are quite aero intensive compared to the old regulations. It is a brilliant regulation in terms of engineering freedom.'

But it is precisely this freedom that the series is looking to reduce in order to bring running costs down for the privateers. The stated aim is to reduce the annual budget by €200,000 for the customers through a system of restricting the amount that a manufacturer can charge for engine lease deals, plus increasing the base weight of the car, to allow them to run with fewer carbon body panels.

These regulations are yet to be ratified, while Volvo has no plans to sell customer cars anyway, it prefers instead to run as a manufacturer only. Series organisers expect that Volvo will bring up to five cars in 2017, so it is set to become a major player against Honda and Lada.

Polestar had access to Volvo's facilities, including the shaker rig and the rolling road wind tunnel

The 1913 Coupe de l'Auto Peugeot that finished second in that year's Indianapolis 500

Indy **cinq cent**

In the early years of the Indianapolis 500 Peugeot brought innovative twin-cam engines to the Brickyard – technology that would go on to feature in the race right through to the 1970s

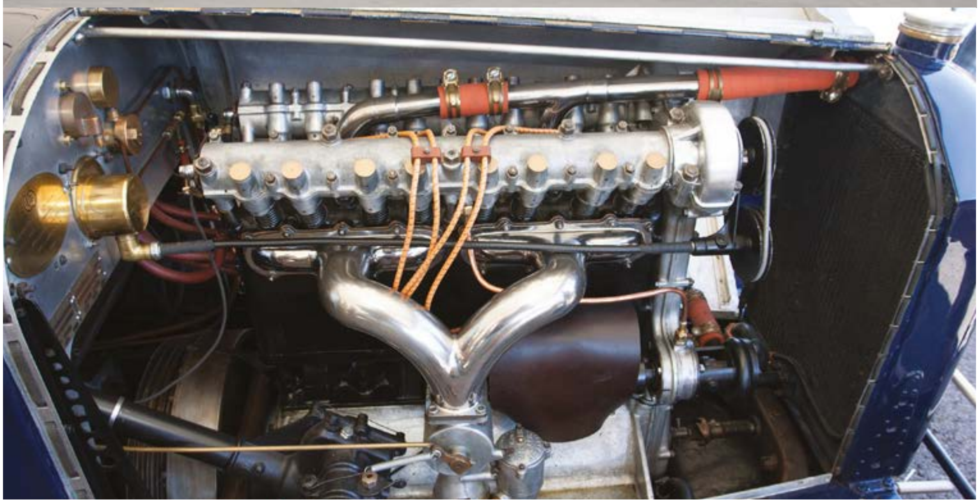
By WOUTER MELISSEN

Jules Goux won the 1913 Indianapolis 500 with a 13-minute margin over his closest rival, Spencer Wishart. In terms of technology the Peugeot racecar used by the young Frenchman, and particularly its engine, was also miles ahead of its competition – and it would set the standards for engine design for decades to come.

Originally developed for the 1912 French Grand Prix, the large Peugeot 'four' featured twin overhead camshafts, actuating four valves per cylinder. Following the debut victory in the all-important French Grand Prix, the 1912 vintage factory-owned car was subtly modified to comply with the regulations and then shipped to the United States, chasing the lucrative $20,000 price for a first place finish. Goux was one of a total of six European drivers that had travelled across the Atlantic for what was the third, and first truly international, Indy 500.

Four-valve heads had actually previously been used with the valves actuated by using lateral camshafts mounted on either side of the engine or a single overhead camshaft. It is even believed that Delahaye produced a prototype engine with twin overhead camshafts, but that unit never appeared in public, and the Peugeot engine was definitely the first to use the principle successfully.

The driving forces behind the development of the engine were Goux himself, Georges Boillot and Paul Zuccarelli. Nicknamed *Les Charlatans*, the trio had raced Peugeots with



Top: A 1916-specification Peugeot similar to that year's Indy 500 winner; this is the very car that failed to qualify in 1949
Above: With its twin-cam engines and four valves per cylinder Peugeot was well ahead of the game at Indy 100 years ago

great verve, but also had more than a grasp of the engineering element. Having raced against the four-valve engines of rival manufacturers, they were convinced that Peugeot could do better and they persuaded Robert Peugeot to back the development of the twin-cam engine. The actual design of the engine is often attributed to the young Swiss draughtsman Ernest Henry but the three Charlatans are understood to have also been instrumental in its inception. Some even believe that all Henry did was transfer their ideas on to paper, but his subsequent, independent, designs suggest that he too was a talented engineer in his own right.

Originally slated for the 1911 French GP, the Henry engine did not appear until the following year. Displacing just under 7.6 litres, it featured a head and block that were created in a single iron casting. The crankshaft ran five main bearings and drove the camshafts through bevel gears and a vertical shaft. A remnant of the traditional engine design was the partly exposed valve-train. The camshafts were enclosed but the valve-stems and springs were not covered.

On the original design, lobes on the camshaft both opened and closed the valves, with assistance from return springs. This early desmodromic style valve actuation was not used again for the second-generation twin-cam engines, which debuted in 1913 and were raced at Indianapolis in 1914. These engines also used gears to drive the camshafts.

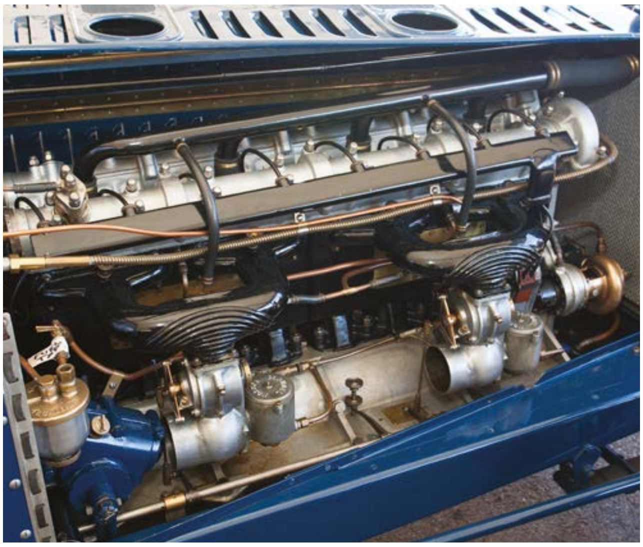
Among the immediate advantages of the four-valve, twin-cam layout were that it allowed for compact, hemispherical combustion chambers, cross-flow porting and the use of a single, centrally mounted spark plug. While there were no actual displacement restrictions in the regulations yet, it's interesting to note that the 130bhp produced at 2250rpm compared well to the 140bhp produced by the 1911-winning Fiat, which had an engine nearly twice the size. The engine was not bolted directly into the steel ladder frame but instead was first fitted to a U-shaped steel subframe.

Whereas most contemporary grand prix cars still used a chain drive, the new-for-1912 Peugeot used a propshaft to connect the separate four-speed gearbox with the rear axle. The actual design of the axle followed the Hotchkiss live-axle principle. The suspension was wholly conventional with semi-elliptic springs on all four corners. To slow the car down, drum brakes were fitted to the rear axle only. Another development was the use of Rudge-Whitworth wire wheels with a single lock nut. In 1913, ears were added to this nut to create the first 'knock-off' wheel nuts.

In the 1912 French Grand Prix, one L76 Peugeot was entered for each of the three Charlatans. After Goux was disqualified and Zuccarelli retired with ignition issues, it was up to Boillot to defend Peugeot's honour. He fought closely with the much larger engined Fiats but after the leading Fiat dropped out, Boillot snatched the prestigious victory, averaging close to 70mph. Louis Wagner in the sole surviving Fiat was second, but he was a full 13 minutes behind Boillot.

Before travelling to the United States, Peugeots also won the Mont Ventoux Hillclimb and the Sarthe Cup at Le Mans, while a special streamlined version of the car raised the Brooklands lap record to 106.22mph.

To meet the 450cu.in displacement limit imposed for the Indy 500, the Peugeot engine was de-stroked to 184mm from 200mm, bringing the swept volume down to just under



The 1919 Ballot (above) with the Ernest Henry designed twin-cam straight engine (above right). In many ways this was the forerunner of the legendary Offenhauser Indy engine

The 1921 Peugeot with fully enclosed valve-train (above right) failed to recapture the glory of Peugeot's earlier Indianapolis wins, as other manufacturers developed the technology

7.4 litres. The slightly revised Peugeot faced opposition from familiar manufacturers like Mercedes, Sunbeam and Isotta, but also from the likes of Mercer, Marmon and Stutz.

Goux did not hide his heritage during the race, as he consumed the champagne he brought with him from France to cool down during the pit stops. But this did not slow him down one bit on his way to score the first Indy 500 win for a European car and driver. In front of a 90,000-strong crowd, he averaged 76.59mph.

For the 1913 French Grand Prix, the organisers had imposed a fuel restriction, which suited the relatively efficient Peugeot engines very well indeed. For their victory defence, a 5.6-litre version of the Henry engine with a gear-driven valve-train was developed to power the grand prix machines.

Bound to a displacement limit, a 3-litre version was also readied for the smaller Coupe de l'Auto cars. Again, three cars were entered in the grand prix and Boillot scored a repeat win, ahead of Goux, who placed second. The closest rival was a Sunbeam, which finished 12 minutes in arrears. Owing to the efficient twin-cam engine, Boillot's Peugeot still managed to average 72.1mph during the 570-mile race, a frugal run of 16 miles to the gallon.

No major victories were scored by Peugeot in 1914, but Leon Duray did come very close to winning the Indy 500. Driving a considerably smaller Coupe de l'Auto specification Peugeot, he led 77 laps and was ultimately beaten only by a much larger engined Delage.

One of the 1913 vintage grand prix Peugeots, with Dario Resta at the wheel, placed second again at the 500 in 1915. Resta returned the following year to claim Peugeot's second victory with a machine based on those 1913 grand prix cars. It featured a slightly smaller version of the engine with a displacement of just under 4.5 litres. Such had been the rate of development that despite running an engine two-thirds the size, Resta had managed to average 84mph compared to the 76.59mph clocked by Goux just three years earlier.

When racing resumed after the Great War, Peugeot claimed yet another Indy 500 victory in 1919. Again using a car based on 1913/14 technology. That year, one of the rivals was an even more sophisticated Ballot, which used a twin-cam straight-eight that had the valve-train fully enclosed. Not surprisingly perhaps, the Ballot engine had been designed by the newly recruited Ernest Henry. This was the final step in the evolution of the twin-cam engine and it would form the inspiration for many of the great Indy engines, including the legendary Offenhauser. Peugeot also created a similar, fully enclosed engine, but the Americans had caught on and a European manufacturer would not win the Indy 500 again until 1939. Peugeots were last raced at the Indy 500 in 1921, but in their few outings they had certainly made a lasting impression at the Brickyard. But it should be noted that one owner did try to qualify his 1916-type Peugeot for the 1949 Indy 500, but he failed to make the grid.

For bringing twin-cam, four-valve engines to the Brickyard, Peugeot was awarded with three Indianapolis 500 victories, which complemented its pair of victories in the French Grand Prix. Since then the French manufacturer has had to content itself with wins in World Rallying and endurance racing.

The 130bhp produced at 2250rpm compared well to the 140bhp produced by the 1911-winning Fiat, which had an engine nearly twice the size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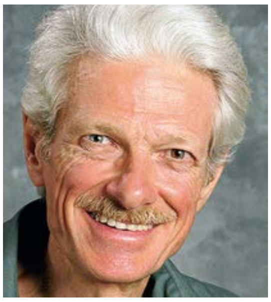


Autonomous cars: are we losing control?

The rise of 'robot' technology and the dangers it might present

QUESTION

What do you think about self-driving cars or drone cars? Do you think this is the future? Do you think it's good or bad?

THE CONSULTANT

This subject is huge. The situation will evolve, and my views on it may evolve too. But as of right now, here's my opinion: in a controlled environment like a race track, as an engineering exercise, unmanned vehicles offer fascinating possibilities. On the street, they absolutely must be prohibited, for reasons that I don't see anybody else talking about, but absolutely must be talked about.

First, let's define what we're talking about. We now have remotely piloted aerial vehicles, commonly called drones, which are used for military purposes, hobby activity, and surveillance. To an increasing degree, the control technologies used for unmanned aircraft are being applied to land vehicles and water craft. The control technologies have now evolved to the point where some vehicles can operate with no human pilot at all. Some can operate without even an identifiable remote human operator anywhere in the loop. The technologies at issue break down into the following categories: partially automated control of manned or unmanned vehicles; remote control of manned or unmanned vehicles; fully automated control (autonomy) of manned or unmanned vehicles.

These categories are useful as an intellectual framework. However, in real life, we will not necessarily see clear demarcation between them. With inanimate entities, as with animate ones, autonomy is a matter of degree.

What is being planned is not simply individual vehicles that can operate with no driver intervention and safely navigate themselves and their human and/or other cargo to a destination. The idea is to integrate both autonomous and human piloted vehicles into an intelligent vehicle and highway system (IVHS). This means these automated control systems will be subject to extensive wireless monitoring and intervention, which will modify the behaviour of the vehicles, both as individual entities and as group systems.

Some of the prospective benefits of this are very appealing. It's likely that both roads and vehicles can be used more efficiently. Traffic can be routed around choke points. Vehicles can be operated in closer proximity to each other. Vehicles on the highway can be formed into nose-to-tail drafting packs, saving both space and fuel. A queue of cars at a red light can accelerate almost simultaneously when the light turns green. People in the cars can read, work, message each other, make all sorts of pleasurable and productive use of their travel time, much as they can now in a bus or airplane, without having to worry about causing a crash. If the system can be made sufficiently reliable, many deaths and injuries might be prevented – not only for motorists but for pedestrians and cyclists as well.

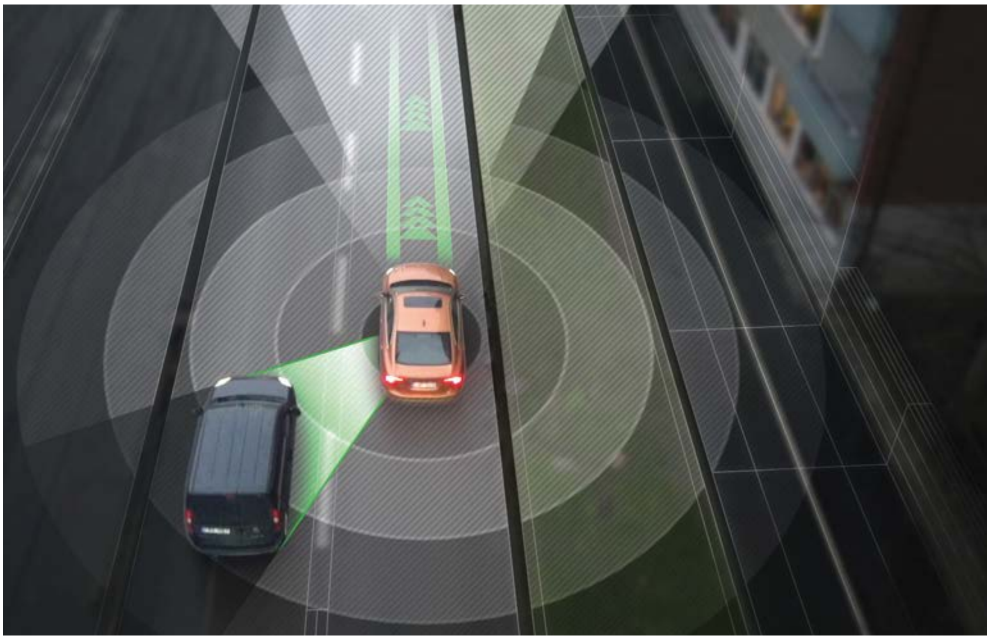
There are serious prospective problems as well, which I will address shortly. First, though, what about the possibilities for motorsport? What happens when we can replace the 'flawed component', the driver, with some electromechanical system? Before examining this, we should note that the driver *is* an electromechanical system, and really a pretty good one; superbly versatile and adaptable, unusually reliable and long-lived, self-repairing, capable of very complex interaction with other such systems, and already available in inexhaustible supply. Moreover, at all but the top levels of motorsport, the driver is available free, because finding drivers is never a problem, because driving is fun. So why would you want to build a self-driving race car? You do all the work, the car has all the fun.

Showbots

But when racing is not done for pleasure, it is done as a business. Economically, professional racing is viable because it attracts eyeballs, which can then be charged admission and/or sold to advertisers. Why do people like to watch racing? I think it's because they vicariously experience some of the pleasure and thrill the driver gets. The buzz from driving a racing car is so good that people not only pay really big money to have the experience themselves but will also pay fairly serious money just for a little contact high. So will

Why would you build a self-driving racecar? You do all the work, the car has all the fun

Could the road cars of the near future be herded in to drafting packs, just like in NASCAR, thanks to autonomous tech? This would help by creating more space on the road while it could also go some way towards reducing fuel consumption



The technology involved in autonomous cars is now very advanced, but can we trust that its power will not be abused?

people want to watch driverless cars race? I guess we'll find out pretty soon.

From the standpoint of making the cars go fast, there is definitely a case for eliminating the driver. Many of the advantages are similar to those in pilotless aircraft. The automatic control doesn't even need to be fully as good as a live driver. It just needs to be almost as good. There are other advantages that can outweigh a small disadvantage in quality of driving. The driver doesn't have to be packaged. There is no need for windows. The controller can manage a huge variety of devices at once. The vehicle can undergo acceleration and jerk of far greater magnitudes than the human body can sustain.

Gobots

I think that even with existing control technology, it should be possible to create driverless cars that will lap existing tracks at much higher speeds than existing manned cars, if the advantages described above are exploited. However, the forthcoming Roborace series is really intended primarily to further control system development. There appears to be a good chance that robotic car racing will be promoted not as a spectator sport but as a laboratory to develop control systems for use in road cars

This could be seen as a good thing. It could be a chance to have racing that truly justifies its existence as a means of improving the breed, and is therefore morally justified and socially useful, rather than just a way to have fun or make money.

You have as much chance of being killed by a human-piloted car as you have of deliberately killing yourself

But the broader question of whether we want computers to control cars and other devices that can kill is much like the question of whether we want them to count votes. Computers can count votes much more conveniently and potentially somewhat more accurately than live humans. However, they can also be programmed to rig the count in any number of ways, and there is no way to tell whether the programming is honest or not.

Similarly, computer controlled cars, even partially computer controlled, can be made to save lives or to take them. And there lies the big problem, the major fly in the ointment that leads me to insist that computer controlled cars, wirelessly connected to the 'internet of things' must be prohibited, despite all the potential advantages I have described.

As some recent controversies have shown, computerised car controls can possibly be hacked, or can malfunction, and this can cause crashes that can seem extraordinarily convenient for some parties, and which cannot be definitively proven to be anything but an accident. Even if they can be proven to be non-accidental, it cannot be determined who was responsible. We might thus have the domestic civilian equivalent of drone strikes.

Oh, but we must do something about the terrible death toll caused by fallible humans in cars, must we not? In the US, we lose between 30,000 and 40,000 lives to motor vehicle crashes every year. How can anyone be so callous as to suggest that anything outweighs the lives that could be saved if we replace fallible human drivers with electronics?

First of all, computers and other electronics are anything but infallible themselves. They are subject to crashes, intermittent faults, glitches, hacking, viruses, and on and on. I sometimes see people insist that electronics are the most reliable part of a car. I strongly suspect that most of these people get a new car every year, probably from the car company they work for.

Second, 30,000 to 40,000 deaths sounds horrendous, but we need to put that in context. We have about 2.6 to 2.7 million deaths per year in the US. The vast preponderance of them are from disease. Heart disease and cancer alone account for more than half. Accidents of all types are about 4.4 per cent. Motorist deaths in car crashes are about 1.3 per cent. That's about the same percentage as suicides. Add in non-motorist deaths from collisions with motor vehicles, and the number is still under two per cent. You have about as much chance of being killed by a human-piloted car as you have of deliberately killing yourself.

Yet we are being asked to share the road with cars that are controlled by nobody can really know what or whom, and are subject to the caprices of complex electronics. Coming at the same time are ubiquitous RFID chips and biometric recognition. These cars will be able to detect not merely your presence, but your identity as well. This all can easily be combined with the massive electronic surveillance that we all know is already operating, and software like that recently introduced in China, which assigns you a 'social credit' score similar to a financial credit score, based on almost everything you do and say.

Nobots

Taken as a whole, such a system provides its rulers with the means to identify anybody who might challenge their power and wealth, erase such persons from the face of the earth with the click of a mouse, and have the whole event indistinguishable from an accident.

Show me somebody who has the means to kill with impunity, and I'll show you somebody who will be sorely tempted to use it. A society run by an elite with such capabilities can only be an authoritarian dystopia. Robot cars are not the totality of this system, but is it wise to accept them in exchange for gains in efficiency or convenience, or the hope of reducing a hazard that is only about as likely to kill you as you are to kill yourself?

CONTACT

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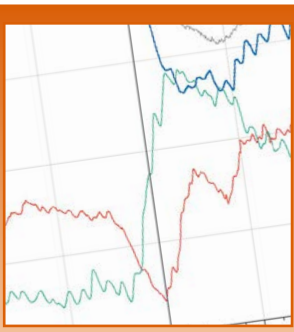


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

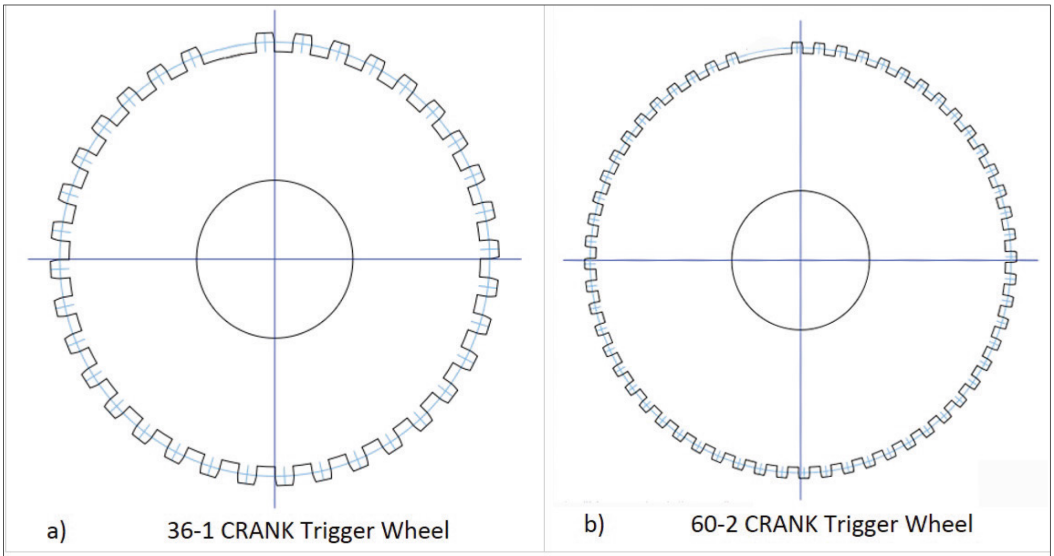
Engine sensors: crank and cam

Crankshaft and camshaft sensors are crucial components for engine performance. But just what do these devices actually measure?

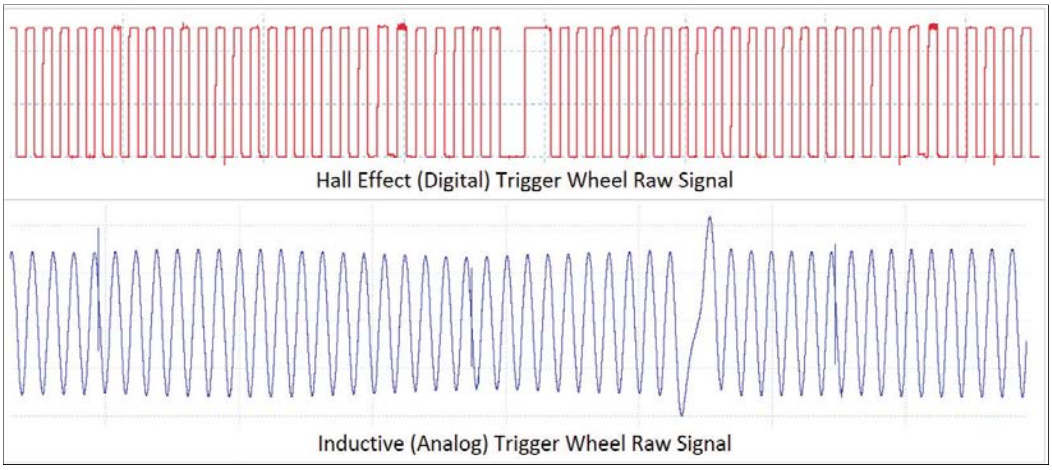
Crankshaft position and camshaft position sensors are arguably two of the most important sensors on a four-stroke internal combustion engine. Fundamentally, the function of these sensors allows the ECU to tell at what point it is in the engine cycle; more specifically, the exact position of each cylinder's piston through induction, compression, detonation and exhaust strokes. This in turn is used to determine the instance when the fuel system should begin injecting fuel into each cylinder and when the ignition system produces a spark.

So what do these sensors actually measure? All modern engines (almost) feature a toothed trigger wheel which rotates with the engine. The wheel is made from a ferrous material which, as the teeth pass by the sensor, triggers an electrical signal. Standard trigger wheel patterns used in motorsport are *N minus M,* which denotes the total of teeth and number of missing teeth on the wheel, the most common being 36-1 and 60-2.

As engine control becomes more advanced and with the introduction of new technologies such as Variable Valve Timing (VVT or VCAM), complex strategies can be used to advance and retard the ignition timing in real time to increase both engine power and efficiency.



This engine trigger wheel has 36 teeth and one missing tooth **This is 60 teeth, two missing. Both are common in motorsport**



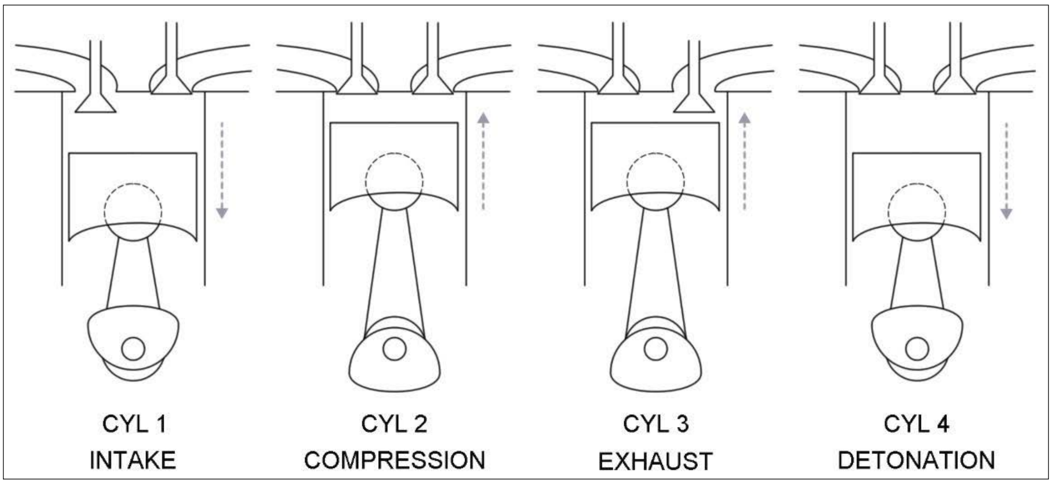
Scope traces showing read-outs produced by the two different types of sensor for the same standard 36-1 trigger wheel pattern

Hall and inductive

There are two main types of sensor technology used to measure the crank and cam positions: hall effect (digital) and inductive (analogue). The two sensors can usually be identified by the number of pins, an inductive sensor usually has two wires (polarity is important and will be explained in more detail in a later article), whilst the digital hall effect sensor has three pins (a dedicated power, ground and signal output).

The scope traces (left) show the difference between the two outputs produced by the two different types for the same standard 36-1 trigger wheel pattern. As can be seen the hall effect signal is characterised by a square wave and the inductive,

Complex strategies can be used to advance and retard the ignition timing in real time to increase both engine power and efficiency



Inner workings of a basic 4-cylinder engine showing how the cylinders relate to each other during the internal combustion cycle

Table 1

0°	180°	360°	540°
1. Detonation	1. Exhaust	1. Induction	1. Compression
2. Exhaust	2. Induction	2. Compression	2. Detonation
3. Compression	3. Detonation	3. Exhaust	3. Induction
4. Induction	4. Compression	4. Detonation	4. Exhaust

XPB

Crankshaft position and camshaft position sensors are arguably two of the most important sensors on a four-stroke internal combustion engine. These sensors allows the ECU to recognise at what point is the engine cycle

Knowing the position of the cam enables the ECU to determine which phase the engine is in, giving 720-degree synchronisation

an oscillating wave. The ECU then reproduces a digital signal where it calculates the speed at which the engine is turning.

As the engine speed (RPM) increases, the frequency for both outputs also increases. However, with an inductive sensor the amplitude will also increase. This is an important factor when calibrating the voltage thresholds for crank signal recognition in the ECU.

Engine synchronisation

In order to perform a complete cycle of the engine, the crankshaft must rotate through two full revolutions. Consider that in a standard four-stroke, 4-cylinder engine, cylinders one and three are mechanically 180 degrees out of phase with cylinders two and four. However, in terms of engine phase, cylinders one and two are 360 degrees out of phase with cylinders three and four respectively (see diagram above left).

At this point it should become clear that the crankshaft position sensor is used to determine where the engine is within a 360-degree revolution. This is where the camshaft position sensor comes in. Knowing the position of the cam enables the ECU to determine which phase the engine is in, giving its 720-degree synchronisation.

Table 1 shows the phase of each cylinder during a complete engine cycle whilst in 720-degree synchronisation. In this case the engine is set up to run in a 1-3-4-2 firing order with 0-degree corresponding to cylinder one being at top dead centre (TDC).

In next month's instalment we will take a look at how the ECU uses the signals received to gain 720-degree synchronisation, what happens when there is a sensor failure, how injection and ignition timing relate to the crank and cam signal inputs, and how to diagnose some simple set-up problems if your engine stops running.

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Spire sportscars aero examination

Successful bike-engined club racers get the wind tunnel treatment

For our latest mini-series we have tested a brace of cars representing an immensely popular worldwide phenomenon – motorbike-engined sports racing cars. Spire Sports Cars has enjoyed much success in the UK in the 750MC's championships and other categories that cater for this type of car, marque owner Paul Nightingale and driver Tim Gray grafting in harmony to achieve outstanding results. Gray won the 2015 750MC Bikesports title with 12 wins and 12 fastest laps from 12 races, netting lap records at each circuit visited. He also scored wins in other series. And in the 750MC's Road Going Bike (RGB) sports category (won in 2012 by Gray in his first season with Spire), John Cutmore finished runner up in 2015 with Al Boulton third in their Spire 'GT-3's. So the on-track pedigree of these diminutive sports racers is self-evident. But how would they perform in the MIRA full-scale wind tunnel?

The rules in RGB Sports mandate two-seater chassis and prohibit wings, place a 50mm limit on forward splitter protrusion, allow floors which must be flat laterally and, in the centre, flat longitudinally too, but save for the minimum ground clearance of 75mm, the height of the front and rear floor is free. Fences, strakes, vortex generators and so on are prohibited. With the scope for downforce generation thus limited, the data from the wind tunnel was going to be very interesting.

The Bikesports rules allow much greater aerodynamic freedom. Two-seater or single seater configurations are permitted, as are wings to the width of the car, splitters, front diffusers, dive planes and so forth. The only rule that references the floor is the minimum ground clearance of 40mm. Thus, downforce generation under these rules was relatively free.

Balance comparison

Table 1 compares the cars in the best balanced configurations found in our wind tunnel session. In the case of the RGB car this was a few configurations into the session, but the Bikesports car was well balanced as it had arrived from a recent race. With the static weight distribution on both cars in the region of 47-48 per cent including driver, the downforce split, as shown by the %front values, of approximately 44 per cent on both cars in **Table 1** would provide a confidence-inspiring balance with mild understeer at 'aero speeds' on track. It's very interesting to note that the drag coefficients were almost identical yet the negative lift or downforce coefficients were very different. This is reflected in the much higher efficiency figure of the Bikesports car, as given by the –L/D value.

It's interesting to compare the data with other cars we have tested in the tunnel, and although there are a number of cars that bracketed similar aerodynamic performance ranges, those shown in **Table 2** perhaps put the Spire data into a useful perspective. Again the values used were at notionally balanced set-ups. We can see that the Spire RGB car had roughly similar efficiency to the Mallock Mk 28B we tested in Summer 2015, and produced slightly more downforce and drag. The Mallock generated its downforce with a wide nose/ splitter and a single element full width rear

The Spire GT-3 RGB car has an aerodynamic package that is heavily restricted by the technical regulations and wings and most other aero appendages are not permitted

Table 1 – Balanced aerodynamic configurations on the Spire RGB and the Spire Bikesports cars

	CD	-CL	%front	-L/D
Spire RGB	0.568	0.886	44.24%	1.560
Spire Bikesports	0.565	1.399	43.85%	2.476

Table 2 – Further racecar comparisons

	CD	-CL	%front	-L/D
Spire RGB	0.568	0.886	44.24%	1.560
Mallock Mk 28B	0.508	0.806	42.2%	1.585
Spire Bikesports	0.565	1.399	43.85%	2.476
Ligier JS49	From 0.564	From 1.413	38%	From 2.466

The rules in RGB Sports mandate two-seater chassis and prohibit wings

Bikeports car is much more advanced aerodynamically, with pronounced forward body concavity, splitter with diffuser, rear wing and rear diffuser. Single seat chassis also allowed

Tim Gray (left) and Paul Nightingale blur into action to fit a 60mm rear deck Gurney to the Spire GT-3 RGB car. This device added significant rear downforce

Table 3 – The first two runs on the Spire RGB car

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.505	0.651	0.377	0.247	57.9%	1.289
+60mm rear body Gurney	0.611	0.987	0.333	0.654	33.7%	1.615

It's interesting to note that the drag coefficients were almost identical yet the negative lift or downforce coefficients were very different

wing. Meanwhile, the Spire Bikesports car compared well with the lower end of the scale seen on the Ligier JS49 CN car we tested in the winter of 2008.

The Ligier had undergone some fairly serious aerodynamic development by the manufacturer and also its then owner, and featured an extended front splitter with profiled diffuser, large areas behind the front wheels for the extraction of splitter exit airflow, a secondary splitter, a wide flat floor and large diffuser, plus a full width dual element wing. So the configurations of the Ligier and the Spire Bikesports cars were quite similar, and led to similar aerodynamic performance, as expressed by the coefficients (note that the Ligier's slightly greater dimensions actually saw it generate slightly more drag and downforce in absolute terms). Higher downforce levels than those shown in **Table 2** were obtained on the Ligier with rake and wing changes, but the same should also be possible on the Spire.

Balancing act

Both of the Spire cars had recently been raced and were notionally in an aerodynamically balanced state for dry conditions at the track visited, Oulton Park in north-west England. Sometimes the results from the first run on a car in the wind tunnel session can dictate that the session simply proceeds as planned. But seemingly more often than not, the plan is immediately changed to looking for an aerodynamic balance (mindful as always of the wind tunnel's fixed floor, which tends to underestimate the downforce from devices near the ground). And so it was with the Spire RGB, which ran first in this session, because the first run showed quite a marked forward bias to the downforce. The plan was always to examine the effects of rear body Gurneys for the first few runs, but this was changed to a bolder move to fit the biggest body Gurney available for the second run, as part of a quest to maximise balanced downforce. The data from the first two runs are shown in **Table 3.**

Rear deck Gurney

The baseline configuration produced around 58 per cent of the downforce on the front, which with a static weight split of around 48 per cent front would produce more front grip than rear at higher speeds.

To put this into context, at wind tunnel test speed (35m/s or about 78mph) the total downforce in baseline set-up was around 590N, roughly 10-11 per cent of car plus driver weight, which would rise to around 17 per cent at 100mph, so although this was reasonably significant, the disparity between unbalanced and balanced was clearly less than for a high downforce car. Hence, the car may have felt slightly 'loose' at higher speeds, but was not a lethal high speed oversteerer. The 60mm rear deck Gurney added significant rear downforce and put the %front value on the 'understeer' side of aerodynamic balance.

We shall continue with the tale of balancing the RGB car in our next issue.

Racecar's thanks to Paul Nightingale, Tim Gray, Sam Johnson and James Kmieciak

CONTACT

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

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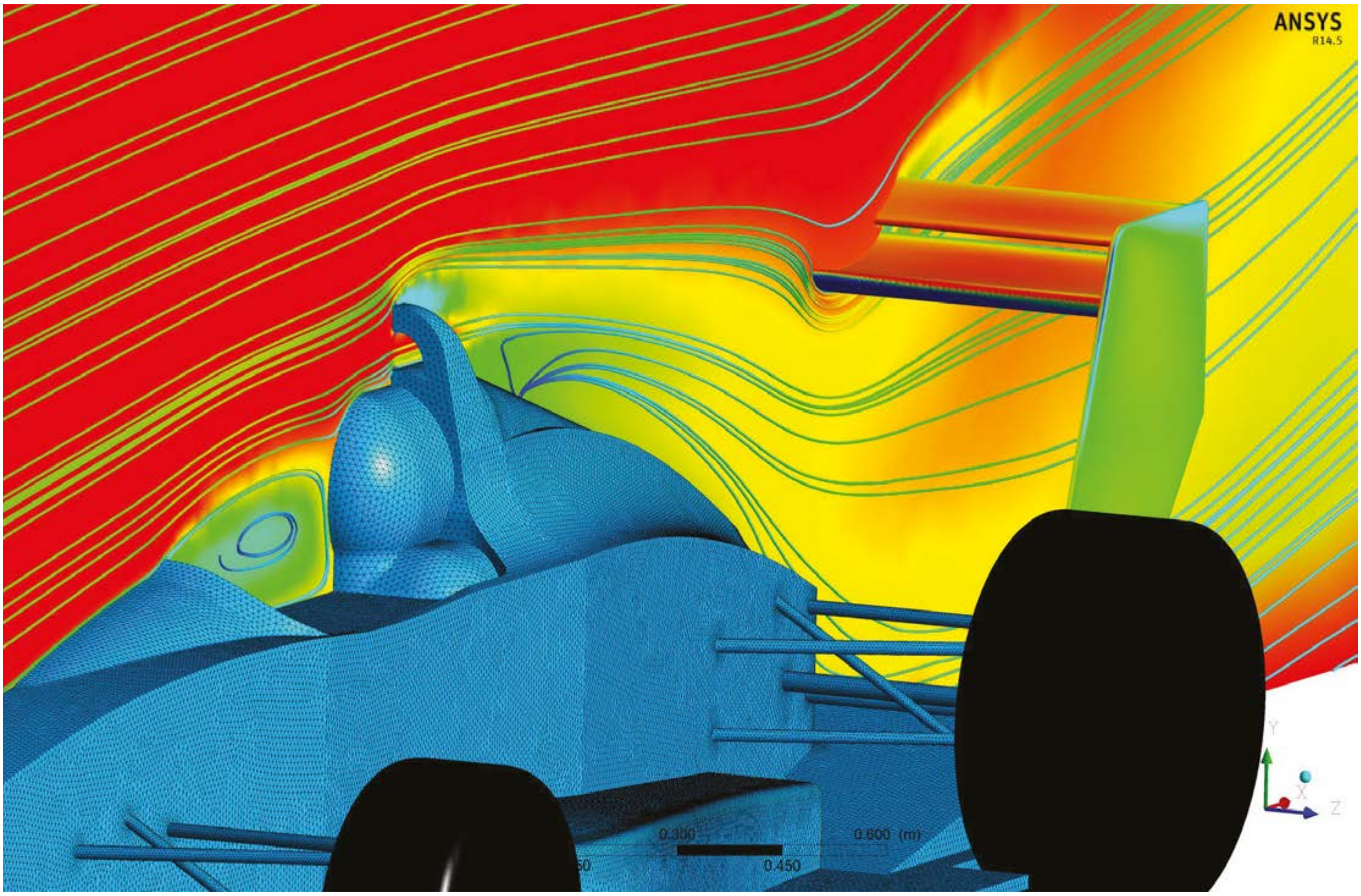
A tail of two elements

In the second part of our CFD study on the aerodynamic basics of single seater rear wings we take a look at how the addition of a dual-element device will affect our model's aero performance

By SIMON McBEATH



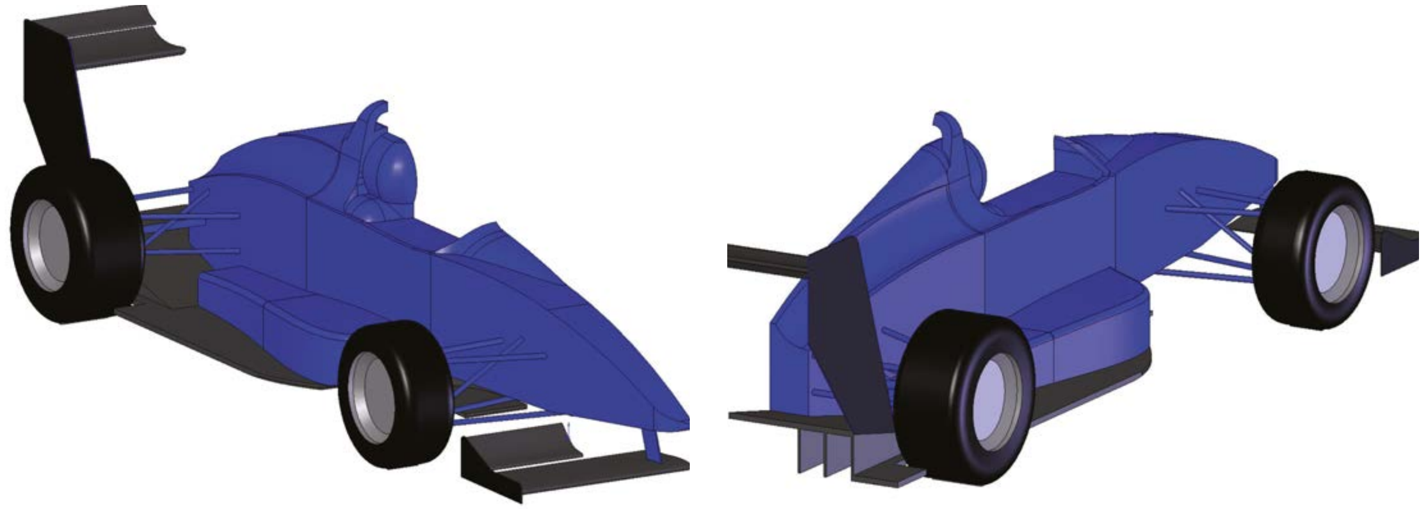
Whether or not there are regulatory constraints on aspects of rear wings such as configuration, dimensions or location in a given competition category, there are often still freedoms that enable optimisation of a wing. Even if the wing profile(s) are stipulated, it may be that how the wing is deployed can be explored to advantage.

We examined a range of parameters on a 300mm chord high downforce single-element rear wing on a single seater model in our December 2015 issue (V25N12), including angles, spans, fore/aft location, height and the number of tiers. In this article we have again used ANSYS CFD-Flo to look at a dual-element wing that utilised the same profile as that single-element wing for its main element, with a cambered flap, all scaled to the same 300mm overall chord again for direct comparisons with the data in that earlier feature. Here we will see the results of some variables that have not received much attention – as well as some of the obvious ones.

Our model

The single seater model on which our wings were tested was unchanged from the previous article, and once more featured a flat underside between the wheels, a V-divider and 'tea-tray' splitter at the front of the underbody and a rear diffuser that started in line with the front of the rear wheels. The front wing was again 1400mm span with a part span flap either side of the raised nose, but as we shall see very shortly, the front wing not surprisingly required uprating for this project. Rear wing span was nominally 1000mm in all 'off-car' cases examined, and was 960mm to fit between end plate mountings that conveniently attached to the outer faces of the diffuser (this being the most aerodynamically effective mounting found during the previous project) for on-car evaluations. The fore/aft or *x*-location was fixed in all on-car cases, again to the most effective overall position found previously, and height was also fixed so that the top edge of the end plate was at 900mm from the ground plane – see **CAD 1** and **CAD 2**.

Your erratic writer once again mixed his SI and Imperial units so that air (and ground, where relevant) speed was set at 100mph while forces are reported in Newtons, N (divide by 4.459 to obtain pounds, lb). The CFD simulations included mesh



CAD 1 and 2: The single seater model used to evaluate 1000mm span, 300mm chord dual-element wing. The front wing needed uprating to achieve an aero balance

CAD 3: Dual-element and single-element wings were first compared in isolation

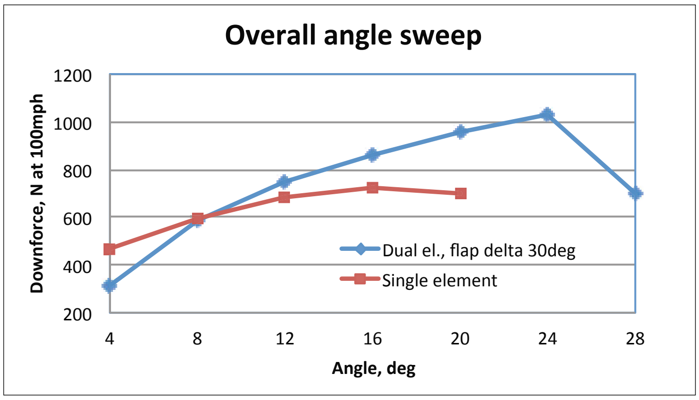


Figure 1: Downforce versus angle on the dual-element and single-element wings in isolation. It's clear here that the dual-element wing's angle range is much extended

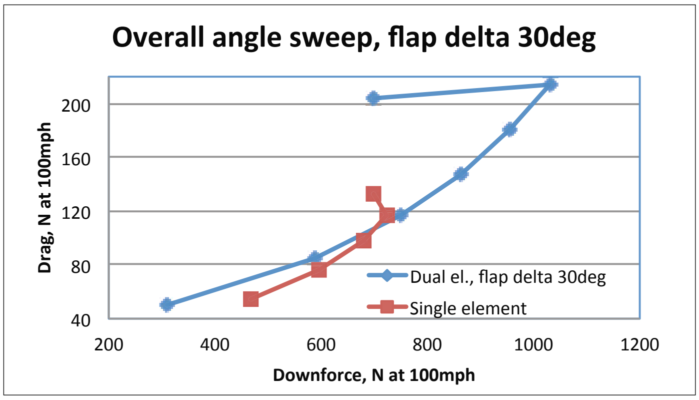


Figure 2: Downforce versus drag for the two types of wings when tested in isolation

refinements around the wings and wheels to improve flow separation capture, the K-epsilon turbulence model was used, and moving ground and rotating wheels were applied. Simulations were run until the calculated forces were satisfactorily steady.

Single versus dual

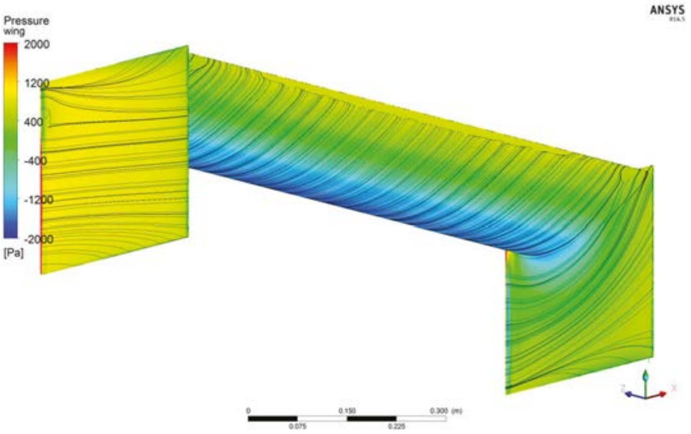
The first step was to compare the 300mm chord single element wing with the same chord dual-element sibling off the car, and in glorious isolation. While this would not indicate what the on-car performance of the wings would be, it's a common way of comparing one wing with another, whether using a wind tunnel or a numerical method such as CFD, and providing the comparisons use the same methodology and conditions then they are valid assessments of relative performance – see **CAD 3**.

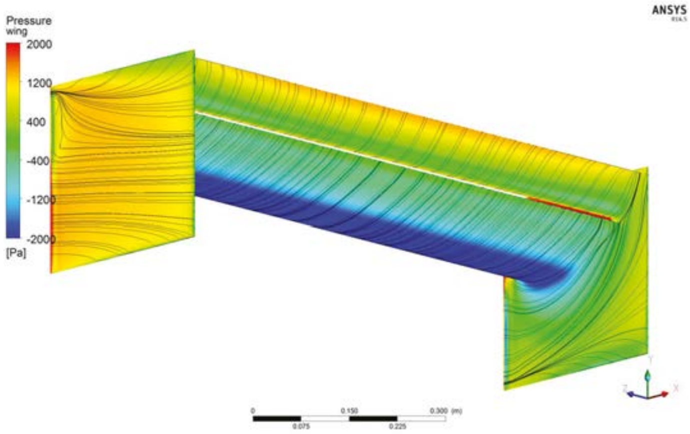
One of the potential variables with a dual element wing is the angle of the flap relative to the main element, and that will be examined during this article. However, for this first comparison the flap angle was fixed at 30 degrees relative to the main element, with a notional 10mm vertical slot gap and 20mm horizontal overlap (more on this aspect in due course, too). The whole wing was then rotated about the flap's trailing edge so that the position of the trailing edge remained fixed relative to the simple end plates (as can be seen the CFD model comprised half the wing and one end plate only, or half the car in the case of on-car evaluations, as is common practice with symmetrical models, to reduce the required computational resources and accelerate solving time).

Downforce versus angle of attack data are shown in **Figure 1**, with the data from the single element wing plotted for comparison. Keep in mind that the two wings were of identical overall dimensions, 1000mm span by 300mm overall chord, and it becomes very clear that the dual-element wing's angle range was much extended, with considerably greater peak downforce as a result. Note that at the lowest angle tested the dual-element wing actually generated less downforce than the single-element wing. This is because the main element was sufficiently 'nose up' at this low overall angle that flow separation occurred over the upper surface of the main element which effectively starved the slot gap, and hence the flap's suction (lower) surface of air. In fact this well-cambered dual-element wing didn't really start to work efficiently until 8-deg overall angle or so, but then it's supposed to be a high downforce wing so it would be unlikely to be deployed at angles that low, and the data here is included for comparison only.

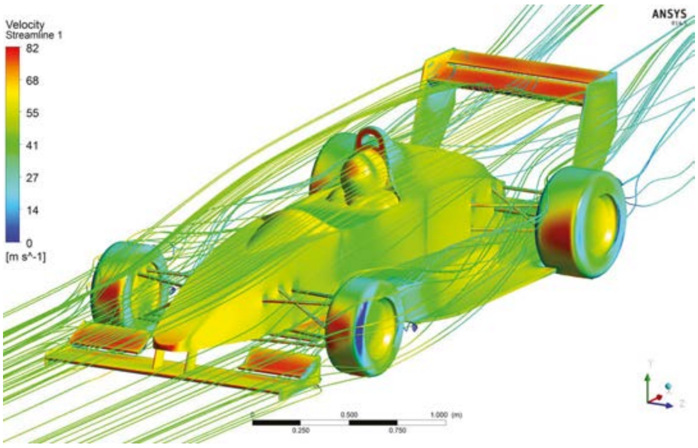
Figure 2 plots downforce versus drag to enable analysis of the efficiency of the wings. From this it was clear that there was a crossover at around 12-deg, the single-element wing being the most efficient at lower angles and downforce levels, but obviously unable to match the dual-element wing's performance at higher angles and downforce levels. Explanations of the mechanisms by which dual-element wings can function at higher angles to generate much higher

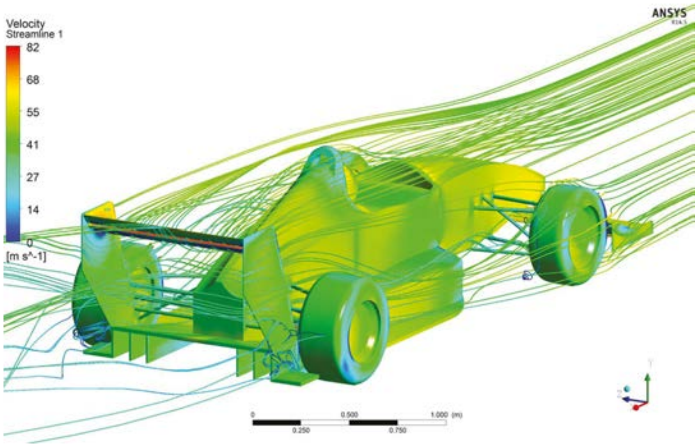
At the lowest angle the dual-element wing generated less downforce





CFD 1 and 2: Lower pressures were achieved on the dual-element wing's suction surface. It is also interesting to note here the beginnings of flow separation at the trailing edge of the single-element wing, this is absent on the dual-element example at double the angle





CFD 3 and 4: The dual-element wing enabled our single seater to generate significantly higher total downforce (33 per cent with 16 per cent more drag), with the car aero balanced

Table 1 – Basic aerodynamic data on the single seater with single- and dual-element wings, forces in N at 100mph

	Drag, N	Downforce, N	%front	L/D
Single-element, 12deg	821.53	1868.22	37.5%	2.274
Dual-element, 20deg	954.48	2484.30	38.4%	2.603
Difference, %	+16.2%	+33.0%	+0.9%	+14.5%

downforce levels may be found in good aerodynamics text books (such as D McLean's *Understanding Aerodynamics, Arguing from the real physics*, Wiley, 2013).

But in essence the slot gap between the two components enables the wing to function with greater camber and at a much steeper overall angle before stall occurs. This provides beneficial modifications to the boundary layers on each component and also the lessening of the adverse pressure gradients on the suction surfaces of each component. Stall is delayed to a greater angle, and this particular dual-element wing stalled at just over 24-deg, 8-deg more than the single-element wing, with over 40 per cent more peak downforce being generated from the same wing area **[CFD 1** and **2].**

On-car baseline data

From the data in **Figures 1** and **2** the dual element wing with an overall angle of 20-deg was selected and then 'plugged in to' the car model. After modifications to the front wing (bigger flap chord and span, and the whole wing moved 100mm further forwards) a set of data at an approximately equivalent balance level to the baseline single element set up was obtained, and the basic parameters are shown in **Table 1**.

So with the dual-element rear wing in this baseline configuration, and with the front wing uprated and moved to enable a balanced set-up, the car produced 33 per cent more overall downforce with 16 per cent more drag compared to the single element wing **(CFD 3** and **4)**.

It's interesting to compare the sources of the forces, too, something that CFD enables very simply, and **Tables 2** and **3** show the contributions of each major component to drag and downforce for each wing case. Looking particularly at the rear wing it is apparent that its drag was greater, but so too was its downforce contribution in absolute as well as relative terms. Notice too that the chassis/body/floor contribution to downforce increased when the dual-element wing was fitted (see **CFD 5**), an indication of the strengthened interaction between the more potent rear wing and the underbody. Also of interest in passing is the combined drag of the front wing and front wheels; the more powerful front wing on the dual-element rear wing car contributed more drag, but also appeared to reduce the drag on the front wheels so that the combined drag of the front wing and front wheels was a very similar proportion of the total in each case. Clearly the drag and lift contributions of the front (and rear) wheels were also modified by the altered wing set-ups, too.

To get an idea of the response to a lower rear wing angle a run was performed with the wing at 12-deg overall, and the data compared to the 20-deg angle baseline run, as shown in **Table 4**. Total drag reduced by 8.9 per cent and total downforce by 8.2 per cent, and, not shown in table 4, front% went from 38.4 per cent to 44.2 per cent, so balancing adjustments at the front would obviously be required to bring this figure back to the desired level.

Note in **Table 4** that chassis/body/floor drag and downforce decreased, implying again a weakened wing-underbody interaction at the lower wing angle, but front wing drag and downforce (and front wheel drag and lift) remained essentially unchanged.

Having obtained some baseline comparisons it was time to investigate

Its drag was greater, but so too was its downforce in absolute terms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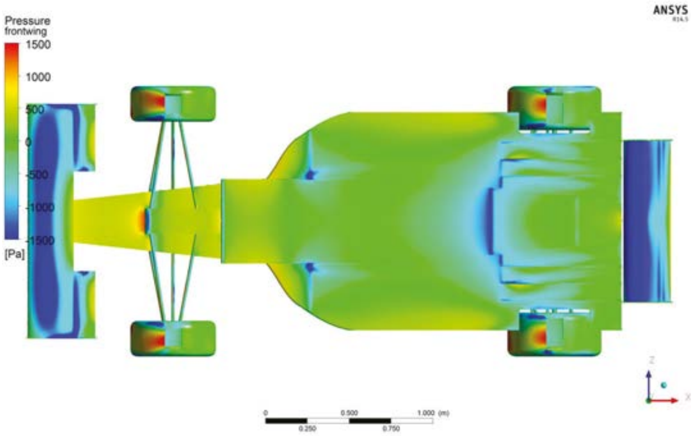


CFD 5: The suction in the underbody fore and aft of the diffuser transition was greater with the dual-element wing, and with the more potent versions of it

Table 2 – Drag and downforce contributions (negative downforce = positive lift)

Configuration	Single-element wing		Dual-element wing	
Component group	Drag, N	Downforce, N	Drag, N	Downforce, N
Chassis/body/floor	403.40	773.24	414.98	903.00
Front wing	74.81	650.70	128.43	891.52
Front wheels	118.75	-41.73	101.42	-56.27
Rear wing	100.00	494.06	164.97	767.16
Rear wheels	124.57	-8.05	144.68	-21.11
Total	821.53	1868.22	954.48	2484.30

Table 3 – Drag and downforce relative contributions

Configuration	Single-element wing		Dual-element wing	
Component group	Drag	Downforce	Drag	Downforce
Chassis/body/floor	49.1%	41.4%	43.5%	36.3%
Front wing	9.1%	34.8%	13.5%	35.9%
Front wheels	14.5%	-2.2%	10.6%	-2.3%
Rear wing	12.2%	26.4%	17.3%	30.9%
Rear wheels	15.2%	-0.4%	15.2%	-0.8%
Total	100.0%	100.0%	100.0%	100.0%

Table 4 – Different dual-element wing angles

Configuration	12deg dual-element wing		20deg dual-element wing	
Component group	Drag, N	Downforce, N	Drag, N	Downforce, N
Chassis/body/floor	396.44	844.50	414.98	903.00
Front wing	128.51	889.90	128.43	891.52
Front wheels	100.24	-52.97	101.42	-56.27
Rear wing	112.15	613.48	164.97	767.16
Rear wheels	132.05	-13.94	144.68	-21.11
Total	869.39	2280.98	954.48	2484.30

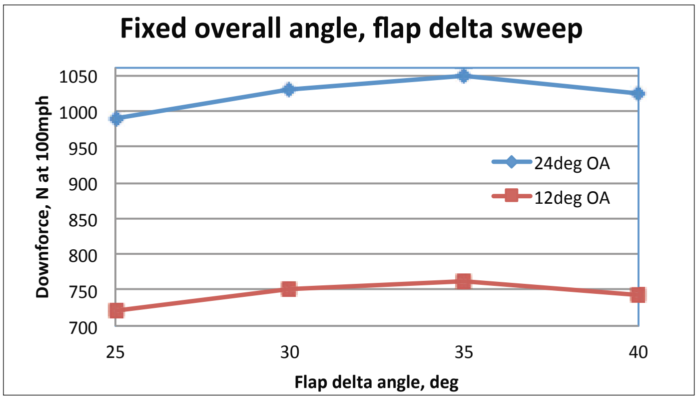


Figure 3: Peak flap delta angle versus downforce at two different overall angles

CAD 4: Minimum and maximum flap delta angles at the same overall angle

Table 5 – The effects of different flap delta angles

	Drag, N	Downforce, N	%front	L/D
Flap delta 25-deg	929.10	2455.46	41.4%	2.643
Flap delta 30-deg	954.48	2484.30	38.4%	2.603
Flap delta 35-deg	955.24	2487.52	39.2%	2.604

other variables on the dual-element rear wing. The first of these was 'flap delta', that is, the angle of the flap relative to the main element. For any given overall wing angle, there is theoretically an infinite range of relative angles between the main element and the flap, and these obviously dictate the overall camber of the assemblage. It is well known that greater wing camber generates higher downforce, so greater flap deltas should have the same effect; as always, up to a point. **Figure 3** shows downforce data at four different flap delta angles on our dual-element wing in isolation at two different overall angles. Note that the wing's downforce peaked at the same flap delta angle of 35-deg at both overall angles. However, the peak flap delta is likely to vary somewhat according to the design of the main element and the flap profiles **(CAD 4).**

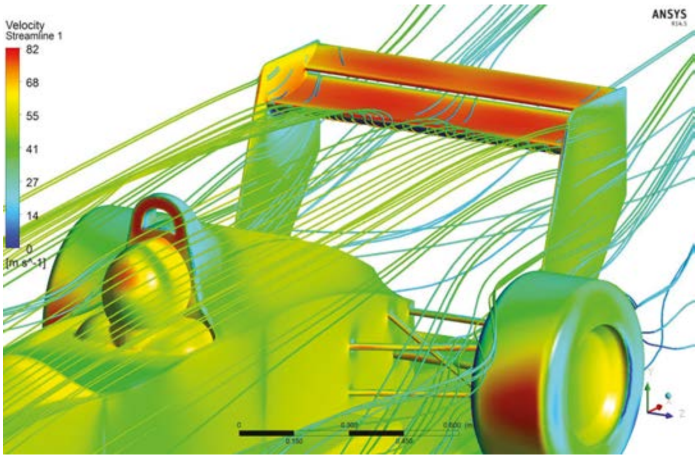
The wings with flap deltas 25-deg and 35-deg were then plugged into the car in turn so the performance of the whole package could be assessed with different flap delta angles compared to the baseline 30-deg flap delta angle. **Table 5** summarises the data, and it looks as though the wing actually peaked at flap delta 30-deg on the car, as opposed to 35-deg in isolation. This perhaps should not be surprising, since the angle of the onset airflow to at least the centre portion of the wing is greater on the car than in isolation, making the effective angle of the wing somewhat steeper **(CFD 6).**

Flap chord ratio

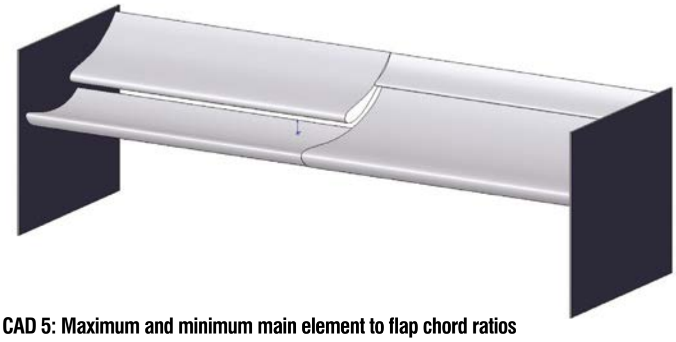
The relative sizes of the main element and the flap is another variable with a theoretically infinite range of possibilities, so can we narrow down the practical range of values to use? In this trial the wing had a fixed overall angle at 20-deg, 300mm chord, and the relative angles of the two elements were adjusted to give approximately equal camber in each case. The ratio of the flap and main element was altered by scaling the overall dimensions of each element. This process clearly affected element thickness too, which may have had some influence on the results. The downforce data from runs on the rear wing in isolation (**CAD 5**) are shown in our **Figure 4**. Our baseline wing had a main element to flap chord ratio of just under 2.5:1, which appeared to give somewhat higher downforce than the ratios either side. What was striking, though, was the drop off in downforce at the 1:1 ratio, where main element and flap had equal chord dimensions. However, drag was also lower at this ratio, giving rise to the –L/D plot in **Figure 5**.

So would this improved wing –L/D be noticeable on the car model? The short answer appeared to be *No*. **Table 6** provides the summary data for the baseline wing and the 1:1 chord ratio wing on the car and shows that –L/D barely changed and if anything slightly reduced with

What was striking was the drop off in the downforce at the 1:1 ratio



CFD 6: The onset flow angle was steeper in the centre of the wing than at the outer ends



CAD 5: Maximum and minimum main element to flap chord ratios

Table 6 – Comparing main element to flap chord ratios on the car

MP flap chord ratio	Drag, N	Downforce, N	%front	L/D
2.445	954.48	2484.30	38.41%	2.603
1:1	911.09	2353.28	41.47%	2.583
Difference %	-4.5%	-5.3%	+3.1%	-0.8%

the 1:1 ratio wing. The reason for this appeared to be that although the wing's downforce (and drag) reduced, so too had the downforce from the chassis/body/floor but, because underbody downforce is 'efficient downforce', this only produced a small decrease in drag. Thus, overall the downforce losses were slightly greater than the drag reductions. This point demonstrates the importance of optimising a wing on the car it is intended to be used on. It is also possible that more refined models and CFD processes would find different results, but within the resolution available from these simple simulations, a smaller main element to flap chord ratio didn't yield a measurable efficiency benefit.

Slot gaps

We looked at this aspect of dual element wings in some detail in our March 2000 (V10N2) issue, putting theory into practice in one of our first sessions in the MIRA full-scale wind tunnel. In that instance we evaluated a 15-point matrix of vertical spacings and horizontal overlaps on a dual element wing (mounted on a DJ Racecars hillclimb single seater) and came up with optimum values that were somewhat larger than aeronautical text books had suggested, but which seemed to better match common practice in high-end motorsport categories.

Optimum vertical gap was five per cent of main element chord and optimum overlap was 6.7 per cent of main element chord. So for our 300mm overall chord dual element wing in this CFD exercise, with ~230mm main element chord, this suggested a starting point of 11.5mm vertical gap and 15.4mm horizontal overlap. In practice the profiles were inspected by eye in CAD and judged to look closer to optimal with a 10mm vertical gap and a 20mm horizontal overlap (the flap nose shape 'fitted' the aft-cambered section of the main element better), so this was how our baseline wing was configured as our starting point for adjustments.

Once again our wing was evaluated in isolation **(CAD 6),** and the first part of the trial saw the horizontal overlap fixed and the vertical gap adjusted to three more spacings. Then the vertical gap was fixed at the optimum found in the first part, and the horizontal overlap was adjusted to three more values. While much less thorough than a full matrix of data points, this expedient approach enabled the response to changes in gap and overlap to be illustrated. Overall angle was 20-deg and overall chord was 300mm at the baseline setting of 10mm vertical gap and 20mm horizontal overlap, but clearly overall angle and chord altered slightly with each change in the slot gap, so the data incorporates these changes too. **Figure 6** shows the downforce data for the vertical gap adjustments and **Figure 7** for the horizontal overlap adjustments.

Figure 6 shows that downforce peaked at 10mm vertical slot gap, although it might have been possible to squeeze a little more downforce by testing finer increments either side of 10mm. And although **Figure 7** shows that, of the overlaps tested, 20mm did produce the peak downforce, again it could well be that more downforce could be obtained with an overlap between 10mm and 20mm. The range of downforce levels achieved

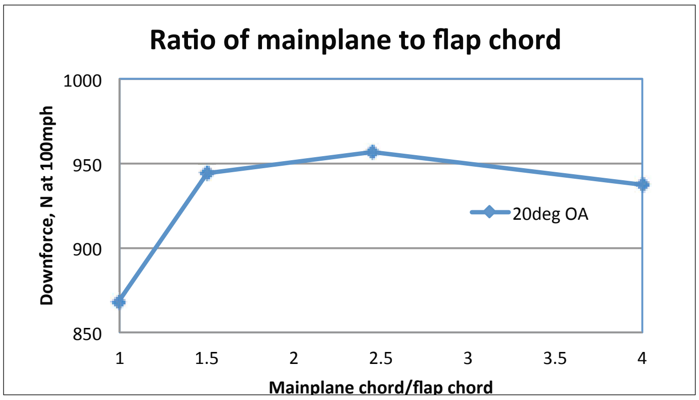


Figure 4: This shows the main element to flap chord ratio versus the downforce

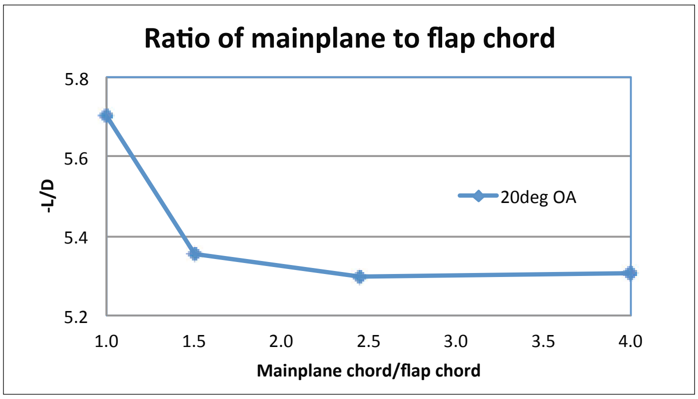


Figure 5: This shows the main element to flap chord ratio versus wing efficiency

CAD 6: Slot gap variations; at the same vertical gap with the wing in isolation. The 20mm difference in horizontal overlap in this image significantly affected the results

It's important to optimise a wing on the car it's intended to be used on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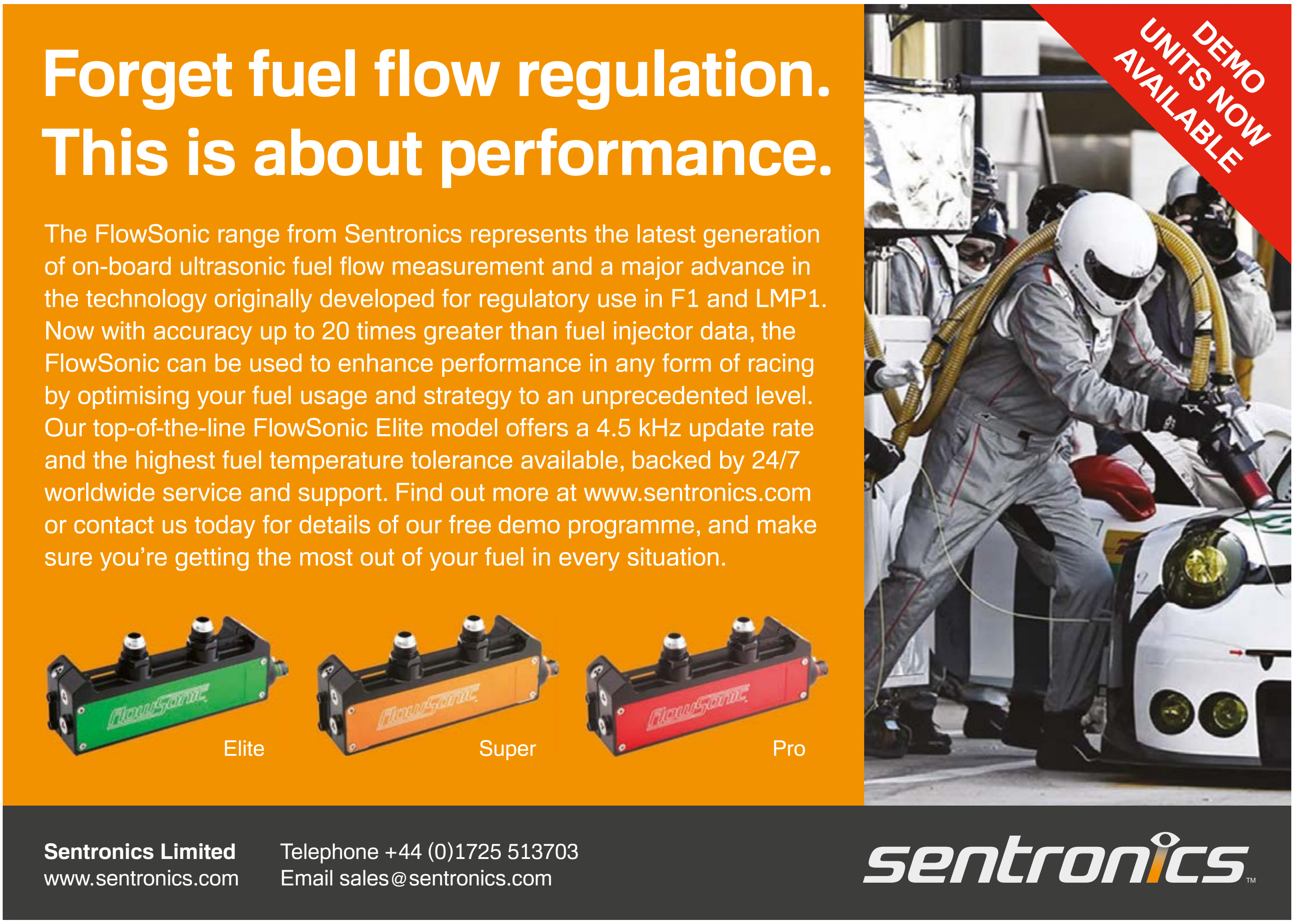
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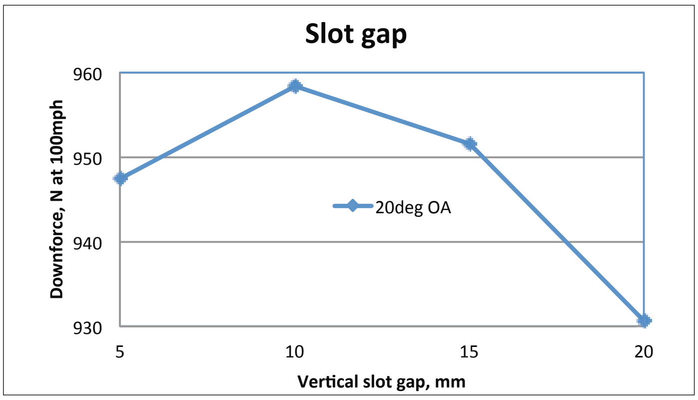


Figure 6: This shows the vertical slot gap at fixed horizontal overlap versus downforce

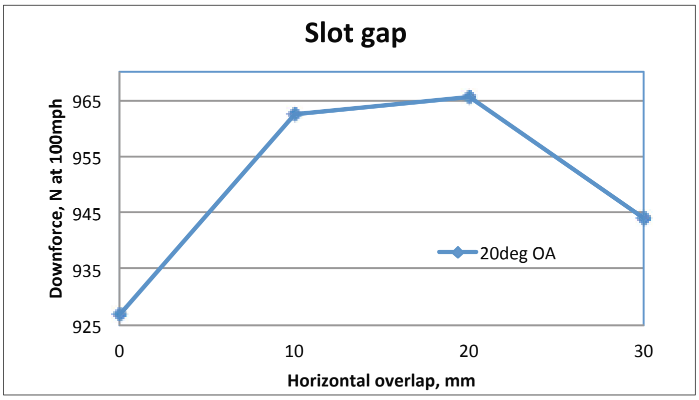


Figure 7: This shows the horizontal overlap at fixed vertical gap versus downforce

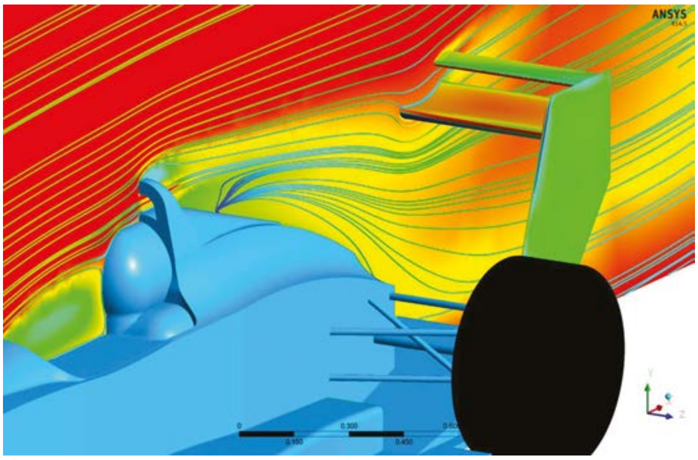
Table 7 – Comparing the best and worst rear wing slot gaps

	Drag, N	Downforce, N	%front	L/D
Best SG (10-20)	948.96	2465.39	39.05%	2.598
Worst SG (10-0)	939.70	2396.40	39.82%	2.550
Difference %	-1.0%	-2.8%	+0.77%	-1.8%

Table 8 – DRS data

	Drag, N	Downforce, N	%front	L/D
No DRS	948.96	2465.39	39.05%	2.598
Med DRS	869.83	2264.97	44.76%	2.604
Max DRS	797.88	1985.58	53.09%	2.489

CAD 7: A clear illustration of running no DRS (left) and maximum DRS



CFD 7: With the DRS at 'max' the wing could be seen to turn the streamlines less

was reasonably significant and suggested that it most certainly is worthwhile getting this aspect right.

But if we look at the best (10mm vertical gap, 20mm horizontal overlap) and worst (10mm vertical gap, 0mm horizontal overlap) of these wing configurations on the car model, then what differences do we see overall? **Table 7** summarises; note the data on the 'Best SG' model differs from the baseline model slightly because the rear wing end plate was extended 20mm rearwards to accommodate all the slot gap models, with up to 20mm greater plan view chord.

Once more it was apparent that optimising the wing off the car only told part of the story, because whereas the wing in isolation produced 3.9 per cent less downforce in the 'worst SG' case, on the car the 'worst SG' rear wing produced 2.6 per cent less downforce. But because the rear wing was performing less strongly the chassis/body/floor also produced less downforce, so the whole car generated 2.8 per cent less downforce overall with the worst rear wing slot gap configuration.

Looking at DRS

It was inevitable really; the temptation to try out the equivalent of DRS while performing this type of rear wing analysis exercise was bound to be irresistible. In this case it was only going to be of any interest to examine the effect on the whole car's aerodynamic performance, so two different DRS configurations were carried out and compared to the results with the baseline wing set up. The baseline configuration was referred to as 'No DRS'. The flap was then rotated about its upper trailing edge line by 15-deg for the 'medium DRS' position, and rotated by a further 15-deg for 'maximum DRS', **(CAD 7)** which put the flap at an actual angle of just 8-deg, the same angle as the main element in the 20-deg overall angle model. The overall results are shown above in **Table 8.**

So this DRS device did what it said on the label; total drag reduction from No DRS to Max DRS was 15.9 per cent, with a virtually linear increment at Med DRS. Thus at any given speed the car would absorb 15.9 per cent less power with the wing in the Max DRS position. For example, 47.5bhp compared to 56.5bhp at 100mph in this instance. Looked at from the viewpoint of the theoretical maximum speed, say the car had 250bhp at the wheels and its frontal area was 1m2, then using the formula that equates power absorbed to speed:

BHPabs = (CD.A.v^3) / 1225

we can calculate theoretical maximum speeds of 73.38m/s (264.2kmh or 164.2mph) with No DRS and 77.73m/s (279.8km/h or 174.1mph) with maximum DRS.

Clearly there were other consequences from deploying this DRS system, too, the summary data that is shown in **Table 7** showing the significant loss of total downforce and the marked forward shift in aerodynamic balance.

Summary

This further examination of rear wing rudiments has shown that a dual-element wing enabled 33 per cent more total downforce on a single seater model than a single element wing of the same dimensions. Through the revelations of CFD we could see a stronger interaction with the car's floor that contributed to that downforce boost; that the relative angle between the two wing elements can be used as a tuning tool; and that the main element to flap chord ratio and the slot gap need to be kept within a certain range for optimum performance. We also found that DRS really does make quite a difference!

Many thanks to ANSYS UK for providing the CFD software.

The dual-element wing enabled 33 per cent more total downforce

Loop the loop

Simulators and test pilots were used in aviation long before motorsport, but these days when both are combined, dedicated driver-in-the-loop pilots become a vital racecar development tool

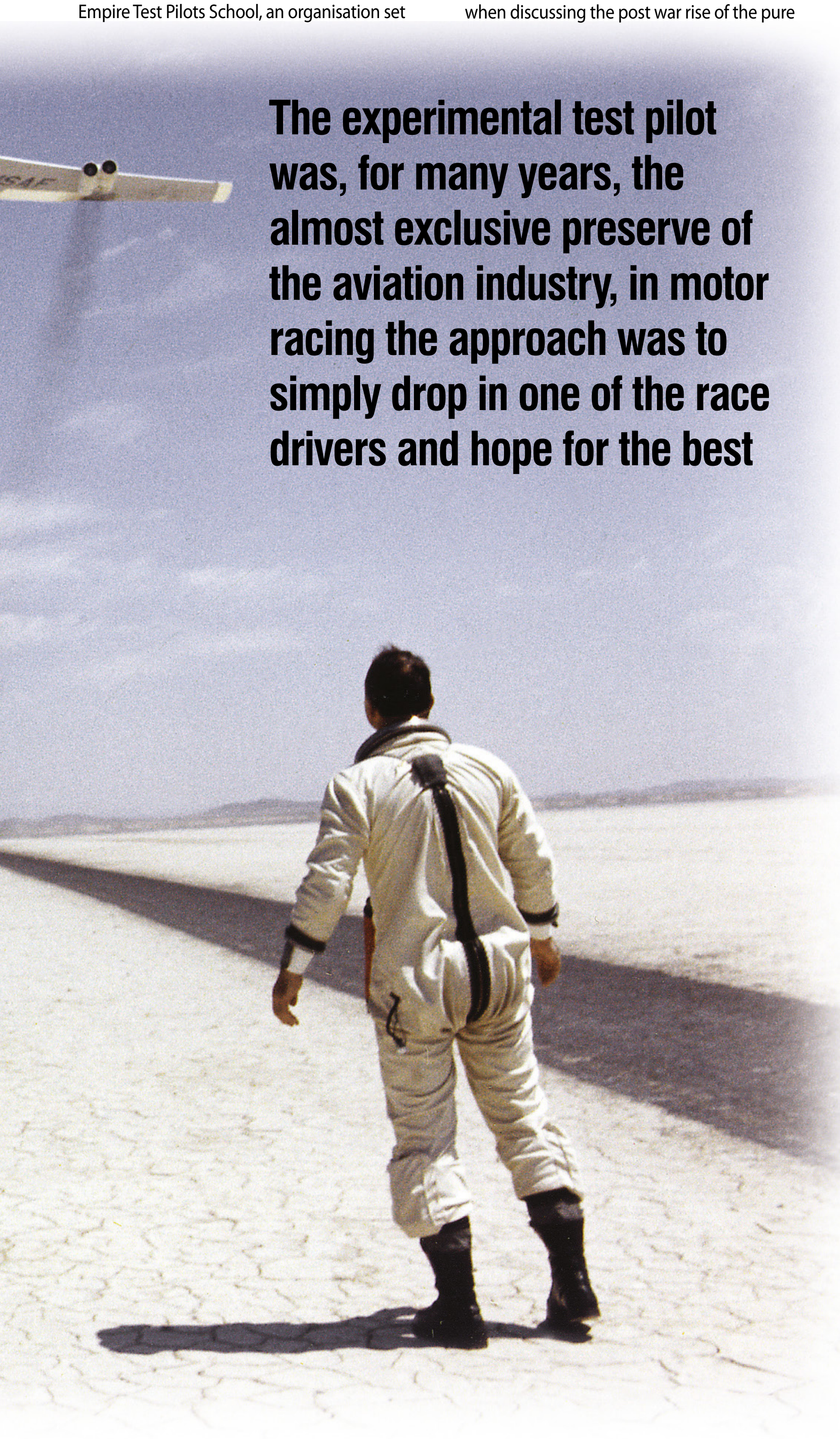
By SAM COLLINS

In the 1950s the test pilot, like the racing driver, was a glamorous figure living in a world of speed and danger. These days, for both the skies and the race tracks, much of the testing is done on simulators

Motor racing has a long history of following in the footsteps of aviation, from the obvious carry-overs like wings, wind tunnels and monocoque construction, to perhaps less apparent tools. It is a process which is ongoing as the industry finds new things used initially in the development of aircraft that are now core to competition car design; CFD is a very good examples of this.

At the dawn of the Cold War, a hut at Cranfield Aerodrome, then a Royal Air Force base, bore the words *Learn to Test – Test to Learn*. This was the motto of the relatively new Empire Test Pilots School, an organisation set up during the Second World War. Prior to the establishment of the school, the British test pilot had the 'take her up and put her through her paces' mentality. Test pilots such as Geoffery De Havilland were seen as heroes of post war *derring-do*. They would take huge risks and push the limits without fully understanding what they were, or understanding the machine in which they took those risks. But things were beginning to change, and it was realised that a more reasoned approach was needed.

'The old-fashioned version of the test pilot wrapped up in its hazy aura of glamorous high adventure is gone,' wrote one USAF officer when discussing the post war rise of the pure experimental test pilot. 'No more do they judge a test pilot's flying skill by his ability to tear the wings off the aircraft in a screaming terminal velocity dive. This has been replaced by flying abilities capable of holding very close tolerances to airspeed, altitude, and rate of climb while engaged in reading data, adjusting power, and writing down observations. It is an exact science requiring precision flying of the highest calibre.'



The experimental test pilot was, for many years, the almost exclusive preserve of the aviation industry, in motor racing the approach was to simply drop in one of the race drivers and hope for the best

Test pilots

The experimental test pilot was for many years the almost exclusive preserve of the aviation industry. In motor racing the typical approach was to simply drop in one of the race drivers and hope for the best, the logic being that, after all, these were the people who would drive the cars in competition. The engineers would get what feedback they could and then work from that. Indeed, right up until the late 1980s there were very few examples of pure experimental test drivers valued by the teams for their ability to develop a racecar just as much as they were for their racing ability, despite the fact that in the automotive industry, experimental test drivers were commonplace.

There were, of course, some notable exceptions to this over the years, such as Mark Donohue with Penske in the 1960s and '70s, for example. As was the case with experimental test pilots, the skill set of Donohue was quite different to that of the traditional top flight racing driver. He had more understanding of engineering and could perhaps feel and grasp more of what the car was doing during tests, giving not only him but the whole team what he called an 'unfair advantage.'

Aces low

But by the 1990s, test drivers were becoming commonplace in F1 and top level racing, with the likes of Allan McNish, Alex Wurz, and Pedro de la Rosa all going on to become known for their ability to understand the machine and aid its development. Racing had finally caught up with aviation once again.

However, in the 21st century the rise of another aviation technology in motor racing has seen a new breed of experimental test driver begin to emerge, and for some young racers they are beginning to make a lucrative career out it. The driver-in-the-loop simulator has still not reached full maturity in motorsport and many in the business are still learning the technology's full capabilities, but they are also rapidly discovering that the driver who drives in the races is often not the best one to do the bulk of running in the simulator.

'I think that the skill set they need on the simulator is not exactly the same as it is to win world championships, and in some ways it is harder to find a good simulator driver than it is to find a good race driver,' a simulation specialist at a leading F1 team says. 'The skill sets are very similar, but they are distinct. Much

Simulators have transformed racecar development, but they have also changed the lives of the drivers, making practice easier and creating a lucrative new income stream for some

like that of being a test driver, they need the technical knowledge and to be able to feed back in a good way, to articulate the feelings they get. But on the simulator they need more patience perhaps, better analytical skills, and to understand and separate the different systems like the platform and the vehicle. One thing that is very important is repeatability, just like it is with a test pilot or a test driver.'

This range of skills has become even more pronounced with the rise of so called 'engineering class simulators' and hardware-in-the-loop techniques. Allied to the reduction of on-track testing in many top level championships the simulator drivers are now not only becoming a crucial part of the car development team, but also one of the least talked about. Many are capable of driving faster lap times on the simulator than the race drivers, even though some of them rarely, if ever, get behind the wheel of the real thing.

'When people hear about drivers on simulators they think of big games,' says Porsche's LMP1 driver Brendon Hartley. 'Some people think of it as a driver tool, but when you are immersed in a big project it is more a tool for the team and engineers.' The Kiwi is a works Porsche LMP1 driver in the World Endurance Championship, but he also has substantial experience as a simulator driver with Formula 1 teams, including Mercedes. 'The way the simulators are used is hard to get your head around initially, but there are millions of calculations going on, everything is calculated on it,' Hartley adds. 'I remember doing tests of the different compliances of a suspension component, just a little bit softer or stiffer, it's amazing we can pick that up on the simulator. It speeds up development time and reduces costs.'

Sick note

Because of the very different and still evolving environment of the technology it might seem logical to assume that the older generation of drivers would be more useful in the role of simulator pilot, as they are able to call on their experience in a variety of car types on a variety of tracks. But actually it is younger drivers like 26-year-old Hartley who typically are better suited to this role, though this may change with time. Indeed, it may be that some of the older drivers are not physically able to cope with this strange new virtual world. Famously this included Michael Schumacher who would feel 'sim-sick' when driving the Mercedes simulator.

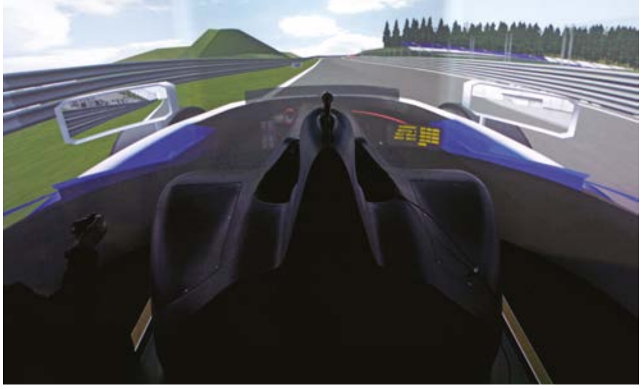
'With the onset of nausea it depends who you are,' explains Toyota LMP1 driver Anthony Davidson, who has also played a key part in the Mercedes simulator programme alongside Hartley. 'Generally the older drivers tend to struggle more with it over the younger ones who have grown up with similar technologies, the so called Playstation generation. I'm just young enough to be part of that generation, my mum would have been much happier if I had come home and sat down and done my homework. Looking back I'm quite happy that I sat in front of the Playstation instead as it's given me a job! It's all about how your mind can slip into a different world, and while not believing that it is real, not getting confused that it isn't real at the same time. When your eyes are seeing something that your inner ears cannot work out, that is when you start to feel sick. The only thing that makes me feel queasy on the sim is when you spin and the car goes backwards for a while then comes to a stop. There is something that goes on in my brain which does not like that. It's a good thing really as I try to avoid spinning!'

Many in the industry have still fully to understand the true value of the simulator to racecar development, and are reliant more on what off-line simulation tells them about this. It is not unknown for an engineer to trust what the computer tells them more than perhaps they should, forgetting at times the old adage that 'the perfect set-up is undriveable.'

'Once the driver is feeling it and responding properly then that is the driver-in-the-loop,' Hartley say. 'The computer alone can create results but it can't give that feeling that we have as drivers. I still think it's a long time until you

The driver who drives in the races is often not the best one to do the bulk of running in the simulator

A simulator test driver needs excellent analytical skills and has to understand and separate the different systems like the platform and the vehicle, while repeatability is also very important



With a reduction in on-track testing in many championships the simulator drivers are now a crucial, if largely unsung, part of a racecar's development process

Kiwi racer Brendon Hartley has worked as a simulator test driver for F1 team Mercedes in the past and is typical of the young drivers often chosen for this work

One of the problems sometimes experienced by drivers in a simulator is motion sickness. Younger drivers tend to be less susceptible to this, perhaps because they're used to video games

'The only thing that makes me feel queasy on the simulator is when you spin and the car goes backwards for a while, then comes to a stop'

can get a computer to drive quicker than I can on a race track. Maybe I'll be proven wrong by Roborace, but I think it's a long, long way away. Even with a simulated lap they still need to use a racing line created by a human driver. The off-line sims can tell you one thing, the computer can tell you what is quicker, 60 per cent weight forward or whatever, but as a driver you will not be able to deal with that for lots of different reasons that a computer cannot work out.'

The human touch

It seems that the consensus is that the computers are no substitute for human feeling and indeed they cannot quantify what makes a car driveable or not. This goes beyond simple car set-up and has major implications on car design. Putting the driver in the loop will allow the engineer to push the limit to an extent not possible with pure off-line simulation and too risky to try with real world on track testing.

'It plays a role in development,' Davidson says. 'Say the team has a new aerodynamic direction, they can be fairly confident of how it will perform through the off-line calculations but the final say will rest with the driver. If the driver has no confidence in the simulator then there is a high chance that he will lose confidence in the real car and that is quite often the case. Using the simulator allows you to inject a bit of reality by adding the human in the loop. Off-line simulation has been used for years to determine basic set-ups, like gear ratios, ride heights, springs and damper settings, but the AI [artificial intelligence] driver will always struggle to find a balance in the car. It's like the Eurofighter which cannot be flown without the computer aids. An AI driver will create an unstable or impossible to drive car.'

So, according to Davidson and others, it is the imperfect component which is essential in developing the car towards perfection, and to achieve performance in areas previously unattainable without the DIL simulator. 'The human will push beyond the impossible envelope of grip where the AI will always know the limit of the grip and will never exceed it,' Davidson says. 'That becomes a problem when it comes to finding a balance. The human in the loop, his mistakes and imperfections, allows things to go beyond the limit of grip and that is the region where you find a good balance. The AI driver cannot do that, it will always give you a too pointy car, so it will always kick the arse of a human around a high speed corner, but that is not reality, it will drive in ways a human cannot.'

Understanding the human is, then, key to getting the best out of the simulator and advances in this area can bring on-track performance gains. This is where motorsport is beginning to explore new ground in R&D terms and is now going in very different directions to aviation. What the experimental test driver responds to is very different to what the experimental test pilot responds to and the simulator hardware is developing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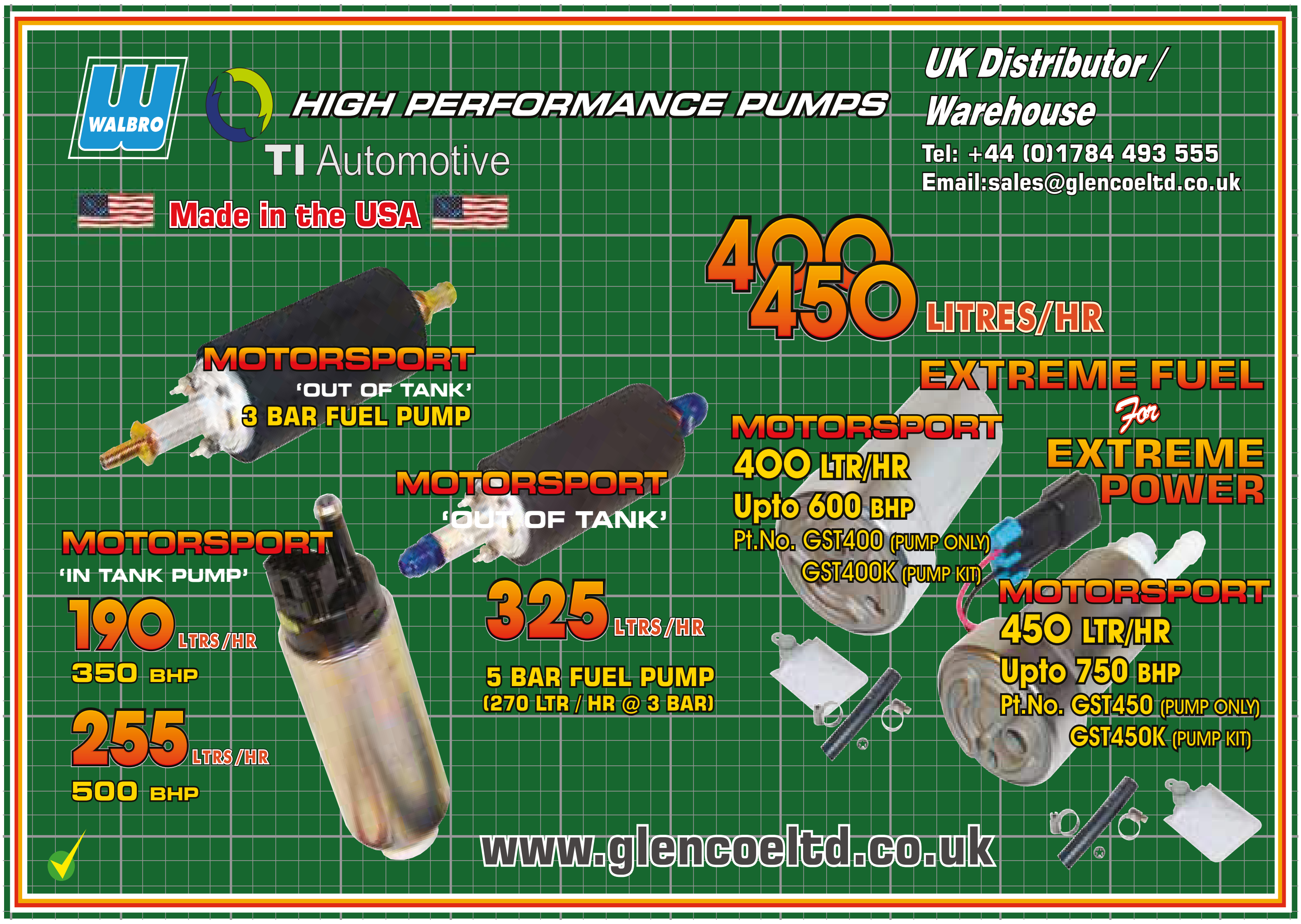
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The black art

Modelling the tyres is a challenge, especially when it comes to their thermal properties, while the track surface also needs to be replicated

Tyres are everything in motor racing, and nowhere is that more true than with driver-in-the-loop simulators. Getting a decent model of the rubber used on any given car is crucial to the simulator delivering decent results, and for most this is still an area of significant research.

'Tyres is the tricky thing,' Hartley says. 'Understanding the rubber on the road is something of a dark art, that is always a bit of work to get right. The technology to model tyres is getting there but still needs time. Things like the thermal model, the track surface and so on, that is all getting better but it's a process.'

Tyre war

In some series where there is still a tyre war, such as Super GT, understanding that tyre performance can have a major impact on on-track pace then getting hold of the best data is essential. 'As it is a tyre development class, that complicates things a bit because there is a lot of secrecy from the tyre makers, so we have to keep all of that data seperate,' Honda's Super GT project leader Masahiko Matsumoto says. 'I think in future we could do a lot more on the simulator to help develop the tyres. We have different tyres on our cars, two types in GT500. So we have to look at the different ways to set up the cars. We use the simulator for that with the drivers working on those set-ups for the respective car and tyres they use in the races,' Matsumoto says.

The Super GT series is one of the few championships in the world where there is a tyre war, which means that understanding tyre performance can be critical

'Before the simulator came on line we just had to check things at the track. We use the same drivers in the simulator as we do in the car. The reason that we do not have a dedicated simulator driver at the moment is that we are still developing the simulator, the data and how we use it, so we need real driver feedback.

'I don't see it going the route of the dedicated test driver yet. It is perhaps easier with a smaller team though where you only have one car and one team to work with, that makes it easier to correlate data. But we need the race drivers to try things on track in reality, too, just so we can compare the feedback,' Matsumoto says.

Simulators also play a role in ensuring that drivers get the most out of their rubber once a decent model is found. This has become especially relevant in Formula 1 in recent years. 'You can use the simulator for driver training in different ways, Davidson says. 'You can highlight regions where peak loads are and train them to avoid that. That is useful in a series like Formula 1, for example, where the Pirelli tyres are susceptible to overheating and going off. You can teach a driver not to overheat or stress a tyre, and to drive in the best way for the tyre.'

differently as a result of this. And it seems that ultimate realism is not the end objective.

'I have been driving simulators for about six years, they have improved a lot in that time,' Davidson says. 'But at the end of the day it's only ever going to be another simulation tool, and for a driver it's quite limited, what you can learn from it, they are no longer just driver development tools. The tool is mainly there for the engineers. They would not build a simulator just to make the drivers more happy now.'

Driving sensation

As detailed in the last two editions simulator hardware is now being developed specifically for ground vehicle use and the targets of that development are not those of either the driver or the test pilot. 'The cueing and the sensation you get as a driver has got better and better,' Hartley says. 'It's got to the point now where that while you don't have the exact same sensations as in a racecar, it is good enough in many ways, all the engineers need is you to feel something. Whether it's the vibration, or you need to feel the little bit of oversteer, or the little bit of understeer, they need you to feel it enough that you can interpret half a per cent on weight distribution or half a per cent on aero balance. Once you have got that it's got to the point in the racing world where you don't need to develop the simulator further. You could keep spending money to make it more and more realistic for the driver, but as we can already feel the small changes we can still develop the car. Every little detail is simulated.'

Future development

It is those hard to quantify 'feelings' that are the focus of development. But the exact direction simulator technology is taking is equally hard to understand, as it is not simply a case of increasing the realism for the driver. 'We can feel so many small things already,' Hartley says. 'Of course, I would like to be able to feel more sustained *g* but the room needs to be bigger for that and the budget gets exponentially higher as you go. Already the data from the sim is pretty much as good as the data from the real car and that can be fed to hardware test rigs. From me driving on the sim the engineers on the rigs see the exact loads the car goes through, it's as good as real track data and that is ultimately what they want.'

Motor racing has now caught up completely with aviation in this area of simulation and has seemingly set off on its own path of technological exploration. It is easy to forget that a decade ago many of the techniques and technologies which are now commonplace had never even been applied in the motorsport industry before. It will be fascinating to see how the world of simulation develops over the next decade and beyond until it reaches its full maturity. And, it will be fascinating to see how an AI racing series functions.


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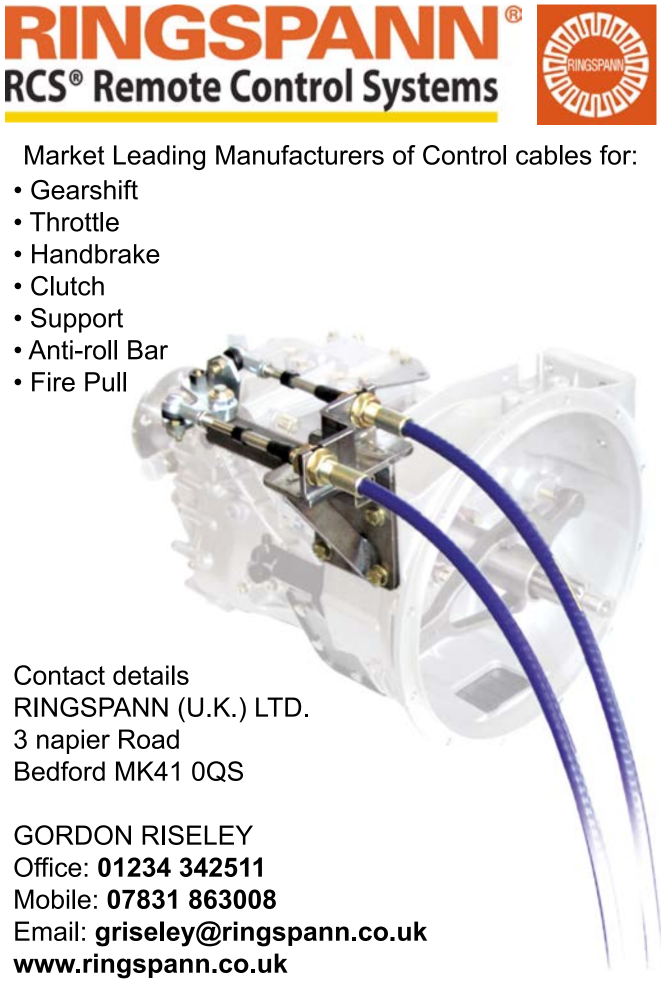
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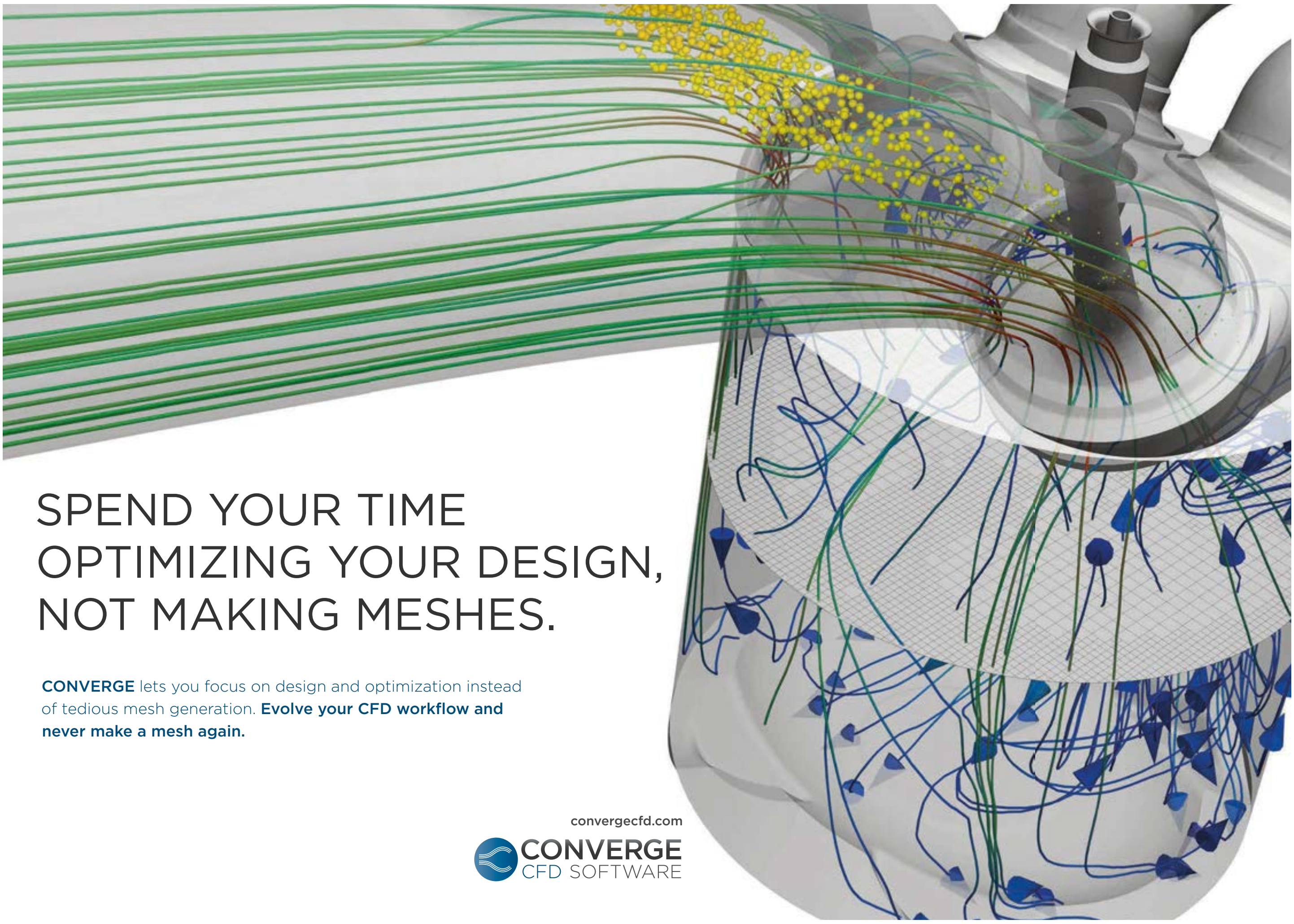
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False economy

Racecar's numbers man argues that it's madness that data logging is limited in some entry level single seater categories – and then does the sums to prove his point

By DANNY NOWLAN

MSA Formula is the name under which FIA Formula 4 is promoted in the UK. While this championship runs with data logging, some of the other Formula 4 series around the world have optional or limited logging

Recently I was having a discussion with a colleague of mine who is involved with Formula 4. After talking over some quick metrics on the car I casually asked what logging they were running. When he told me it was limited to driver inputs and no damper pots, a torrent of short and sharp four letter words ensued describing the utter insanity of what I had just learnt. However, it did get me thinking.

One of the biggest misconceptions in this business is that data logging is expensive. This is total nonsense, and we are going to outline the channels you need to log and show you what you can do with them right here.

Data protection

Before we begin, though, I need to address the utter insanity of the limited logging in F4. I have a simple question for the regulatory bodies here (if you are a regulatory body that allows damper pots to be logged the following does not apply to you). Are you completely mad? Formula 4 has been created as the new nursery for drivers and engineers and mechanics learning their craft. As they progress up the ranks, if they are not data literate they don't stand a chance. As said, this doesn't just apply to drivers. It applies to teaching young engineers and mechanics what to look for in the data, so they can engineer the car.

As someone who has been in the trenches as a race and data engineer, I believe this is one of the first skills you must learn. Also, any driver worth their salt must have the ability to review data and understand it. This is why F4 cars must

Table 1 – The core channels you need to log

Channel	Role	Freq
Engine RPM	Engine/Chassis	50Hz
Engine temp	Engine	10Hz
Oil pressure	Engine	10Hz
Lateral acceleration	Chassis	200Hz
Vehicle speed	Chassis	50Hz
In-line acceleration	Chassis	200Hz
Vertical acceleration	Chassis	200Hz
Steering	Chassis	50Hz
Throttle	Engine/Chassis	50Hz
Damper position FL	Chassis	200Hz
Damper position FR	Chassis	200Hz
Damper position RL	Chassis	200Hz
Damper position RR	Chassis	200Hz
GPS altitude	Chassis	10Hz

EQUATIONS

EQUATION 1

$$F_S = \left(k(x_s) + c(\dot{x}_s)\right)\cdot MR$$

EQUATION 2

$$w_m = \frac{F_S}{k_t}$$

EQUATION 3

$$d_i = \frac{x_{s_i}}{MR} + w_{m_i}$$

EQUATION 4

$$rh_f = rh_{f0} - \frac{d_1 + d_2}{2}$$

$$rh_r = rh_{r0} - \frac{d_3 + d_4}{2}$$

EQUATION 5

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

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

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

EQUATION 6

$$iR = \frac{1}{R} = cv\_sign\cdot 127.008\cdot\frac{a_y}{V^2}$$

run data logging with the right senosrs and to not do so will have terrible consequences for the drivers, engineers and mechanics as they progress through the ranks. It will also look completely ridiculous when club racecars and even games like *iRacing*, *rFactor* and *Project Cars* have more data logging than a professional formula car! But the great news is the core of what you need to log on a racecar can be distilled down to just 14 channels. And these channels are presented in **Table 1**.

Core channels

Table 1 isn't just based on text book theory. What you see here is the basis of the ChassisSim monster file, and the engine channels that are the first port of call of any engine diagnostic you should be looking at when the car is initially downloaded. I've also added the vertical *g* sensor and GPS channel because recently I have found this invaluable for completing circuit models that take into account camber and track undulation. As we will discuss in further detail, this is not going to be a channel list that will break the bank.

The first point to be raised is that this information can be used to reverse engineer the aerodynamics of the car. I have discussed this on many occasions but allow me to present a quick recap. Every damper pot on the car is a load cell. That spring force is given by **Equation 1**, where F_s is the force of the spring damper unit at the wheel, x_s and [dot] x_s is the movement and velocity of the spring, *k* is the spring rate or function and *c* is the damper rate or damper function specified at the damper, and *MR* is the motion ratio of the spring expressed as damper/wheel movement. It is assumed the zero of the spring function is when the car is on the ground. In most cases the spring function *k* is a spring rate. If bump rubbers are used the spring function *k* can be easily deduced by a look-up table. If you are fortunate enough to have strain gauges fitted to the car, then all the hard work in **Equation1** has been done for you.

Tyre deflection

Now the spring force has been determined we need to determine tyre deflection. In the absence of laser ride height sensors; the tyre deflection is given by **Equation 2**, where k_t is the spring rate of the tyre. This is where things can get a bit tricky. As we know tyre spring rate is a function of wheel speed, tyre pressure and camber. However, to get started I would suggest you use a single approximate figure to get you going. While not strictly accurate, it will form a basis on which to get started and you can add a more complex analysis later on. Also, in my experience, if the appropriate value of k_t is chosen this can actually get you very close.

Once the deflection of the tyre is known the user can deduce how much the corner of the car compresses under this load. This deflection can be deduced by **Equation 3**, where d_i is the compression of the corner of the car for corner *i*; x_s is the spring deflection for corner *i*, and w_{m_i} is the wheel movement for corner *i*. The convention for the car corners is at the discretion of the user. The convention that I use is *1* is the left front, *2* is the right front, *3* is the left rear and *4* is the right rear.

Once the user has deduced the corner deflections the ride heights can be calculated. The front and rear ride heights are given by **Equation 4**, where rh_{f0} and rh_{r0} are the initial ride heights. These can be either drop heights or ride heights from the floor. The choice here is really up to the end user and whether they want to clarify the aero-map by either drop or floor heights.

F4 has been created as the nursery for drivers, engineers and mechanics learning their craft. As they progress, if they are not data literate, then they don't stand a chance

Now that we have clarified the ride heights and forces for this particular point the aerodynamic forces associated with this point is given by **Equation 5**, where C_LA (sometimes referred to as C_Z) C_DA (sometimes referred to as C_x) are the lift and drag coefficients, *awf* is the factor of downforce on the front, *ax* is the in-line acceleration, *T*(rpm) is the engine torque in Nm, *gr* is the gear ratio (in terms of torque multiplication from engine to gearbox) and r_t is the rolling radius of the tyre. I have presented on multiple occasions an F3 hand calculation example. What I have just shown here is the basis of the ChassisSim aero modelling toolbox.

Model toolbox

The other thing you can do with the data presented in **Table 1** is to use it to reverse engineer the tyre model of the car. You can do this by doing a whole bunch of track replays and changing the tyre model to minimise the differences between actual and simulated *g*. What I have just described is the basis of the ChassisSim tyre force modelling toolbox and the results of this are presented in **Figure 1**. As always actual data is coloured and simulated

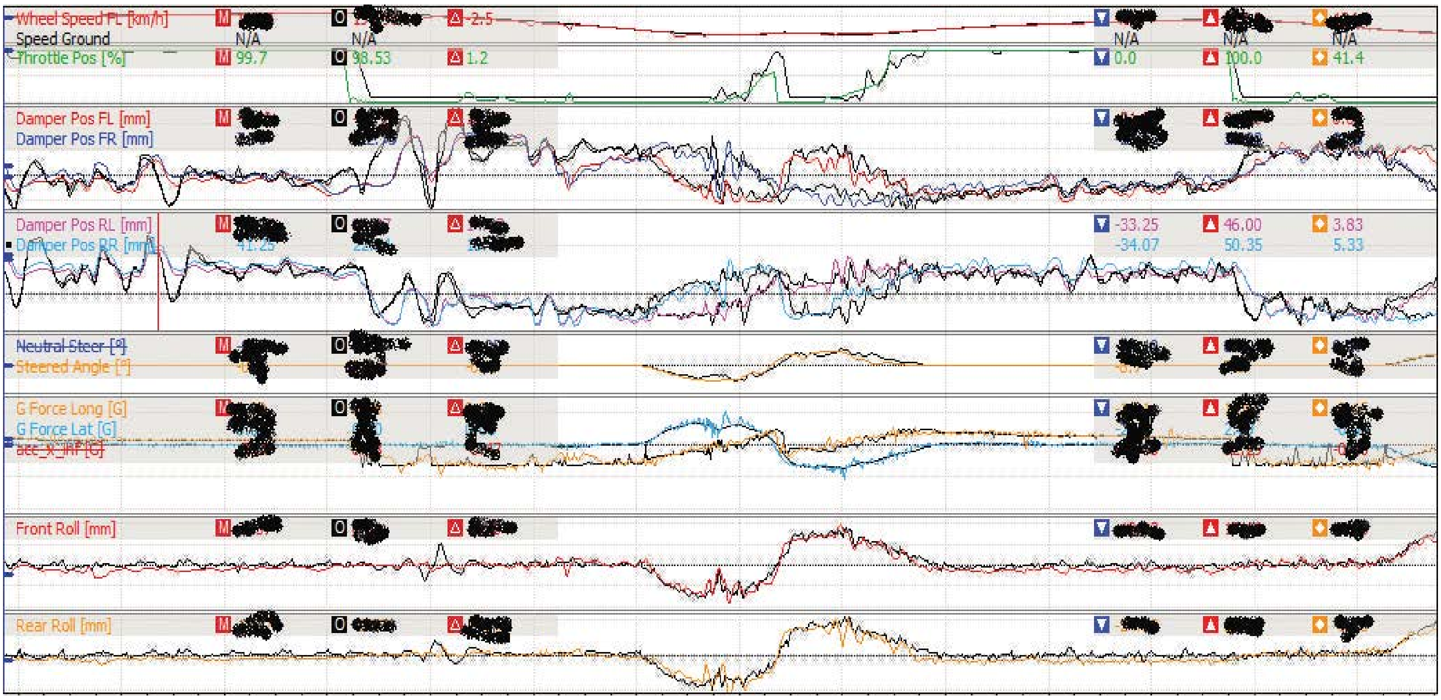

Figure 1: Example of correlation for a V8 Supercar on a street circuit: first channel is speed, second trace is throttle, third and fourth are dampers, and the fifth trace is the steering

Table 2a – Breakdown of prices for data logging, Motec option

Item	Price
Motec ADL 3	$5000
Three axis accelerometer	$1200
Damper pots	$400
Steering sensor	$200
Throttle sensor	$200
Temp sensor	$200
Pressure sensor	$400
Brake pressure sensor	$197
GPS package	$400

Table 2b – Magneti Marelli option (courtesy Competition Systems Australia)

Item	Price
Magneti Marelli DDU310 Dash Logger	$5350
Three axis accelerometer	$395
Damper pots	$450
Steering sensor	$225
Throttle sensor	$127
Temp sensor	$65
Pressure sensor	$185
Brake pressure sensor	$197
GPS Package	$1150

is black. The first channel is speed, the second trace is throttle, the third and fourth traces are dampers and the fifth trace is steering. The moral of this story is that all this was generated using only the information provided in **Table 1**. This did not require a $100,000 data logging suite to create.

Also, you can readily create a circuit model with a car fitted with the channels outlined in **Table 1.** Firstly, with the lateral acceleration you can deduce the curvature file, which describes the path the vehicle takes. The working out for this is shown in **Equation 6**.

Top secret

This is one of the best kept secrets in data analysis. The road surface profile can be reverse engineered from the dampers (the ChassisSim bump profile modelling is an excellent case in point). Lastly, you can reverse engineer the road camber from the vertical *g* accelerometer and GPS data. It is actually a spin-off of **Equation 6**. Here we just sub a_z for a_y and look at the vertical curvature from the road surface provided by the GPS altitude. We simply compare this to the normal curvature calculated from a_z and the difference is the road camber. It's that straightforward.

However, the real question to answer is; what is the price? The answer to this is; not as exorbitant as you would think. Let me present two options you can go with as examples. One will be Motec, the other Magneti Marelli. The break down of prices in Australian Dollars is presented in **Tables 2**. Whichever road you take the investment will come to less then $10,000 (Australian). This is inclusive of taxes and will also equip you with everything you will need. These are also the Rolls Royce options, and there are other systems, like AIM, that can get you going for lower prices.

Bottom line, CAMS (the Confederation of Australian Motor Sport) is capping the cost of Formula 4 at $170,000 (Australian), and a rolling chassis will cost you in the order of $60,000, give or take. So, in the grand scheme of things this is not going to break the bank.

Think of this another way. A cost of $10,000 would cover you for a couple of days of testing. Now before you all chime in and say this is too high, add in flights, accommodation and food for driver, engineer and two mechanics, as well as the cost of running the car. But you pay this expense just the once and all your testing becomes much more valuable, too.

Essential skills

Not only is data logging essential, you only need a handful of channels, and it is not as expensive as you think. The reason it is essential is it will educate you in the skills you need throughout your career. Also, the combination of channels you need will allow you to reverse engineer parameters, while it is a perfect complement to tools such as ChassisSim. The combination of these tools will allow you to not just understand the car, but extract its maximum performance. This combined with the competitive pricing makes the use of data logging simply a no-brainer.

The moral of the story is all this was generated using only the information provided in Table 1. It did not require a $100,000 data logging suite


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New or deja vu?

A concept for a racecar of the future sparks memories of the past

When I saw the McLaren MP-4X concept car images I had a strong feeling of deja vu.

One feature of the MP-4X reminded me of the use of saw-tooth vortex generators in CART many decades ago. Ferrari picked this up, and vortices generated ahead of the diffusers found use for some time. Then, they disappeared for a time. McLaren then added vortex generators at the lip of their radiator intakes. Vortices do not know up from down, just high and low pressure, so the generators on the top of the intakes actually help decrease the pressure under the rear wing. The first time I noticed the paths of vortices occurred during a landing in a Boeing 737 many decades ago. Since then, I've watched the *extremely* slow growth in the use of these tiny generators on aircraft, until the addition of eight generators on the engine nacelles of the Boeing C-17 military transport aircraft.

The McLaren MP-4X also illustrates a slow convergence of designs of F1 cars and prototype sportscars. The Adrian Newey-designed Red Bull concept F1 car and the MP-4X, when compared to the latest Sports prototypes, show a great deal of similarity.

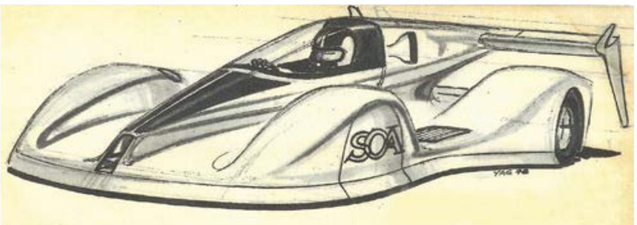
On the subject of sportscars, I've had a thought. The designers could be allowed any width (span) rear wing, with the limit being that the span must be the width of the windscreen. Thus if a designer wants a rear wing the full width of the car, the windscreen would have to be the full width of the car.

I've also made a sketch of my take on the safety hoops for F1 cars, using the upper lip extension of the radiator intakes, much like leading edge extension strakes, which act as supports for the front legs of the hoop.

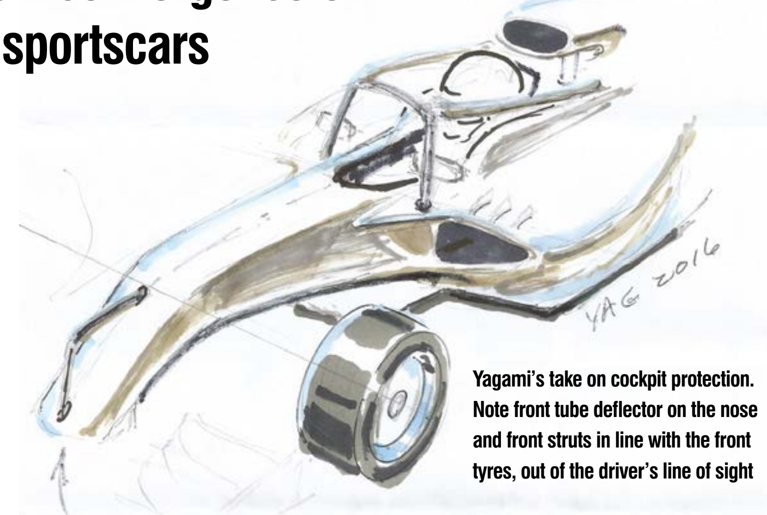
The challenges for the future are great, which means there are great opportunities as well. Oh, and I have also found a sketch I made in 1978 of a racing car of the future – it seems very pertinent now, doesn't it?

Richard H Yagami

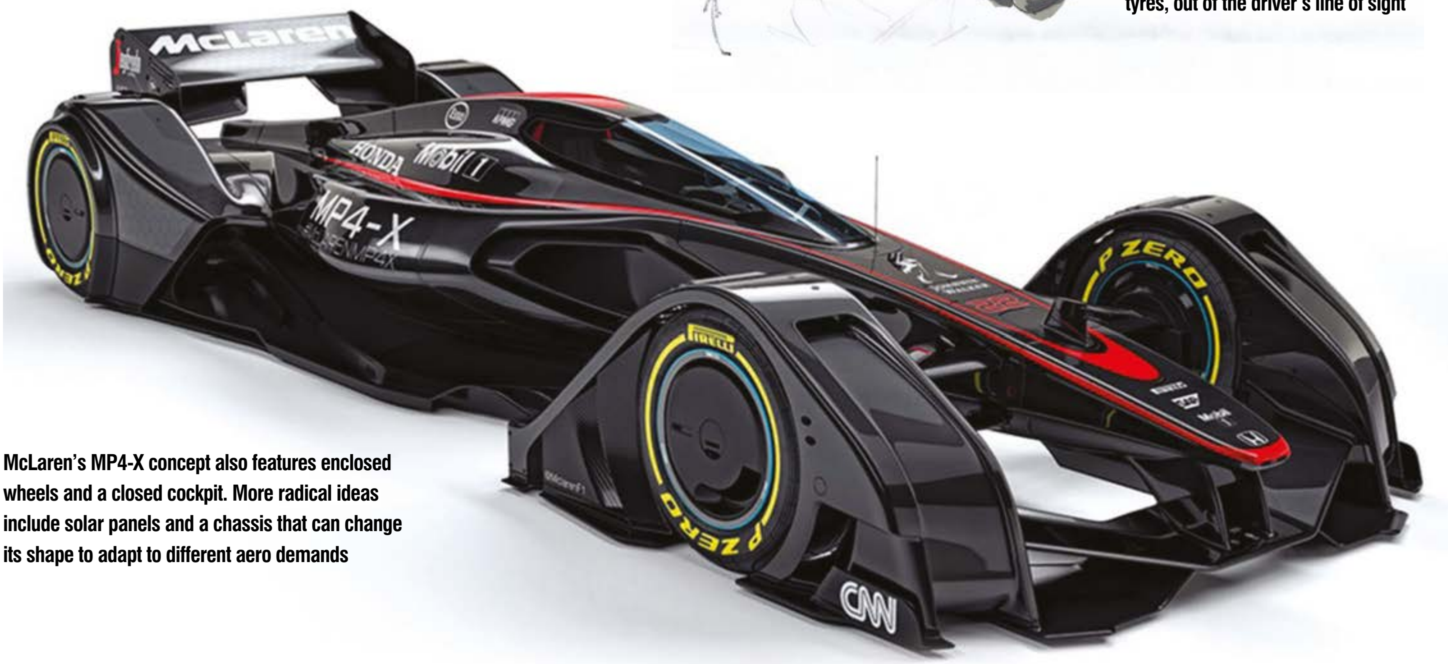
McLaren's MP4-X illustrates a slow convergence of designs of F1 cars and prototype sportscars



Yagami sketched this future racecar concept back in 1978. It shows an amalgamation of single seater and sportscar thinking; in common with more recent studies such as the McLaren MP4-X pictured below



Yagami's take on cockpit protection. Note front tube deflector on the nose and front struts in line with the front tyres, out of the driver's line of sight



McLaren's MP4-X concept also features enclosed wheels and a closed cockpit. More radical ideas include solar panels and a chassis that can change its shape to adapt to different aero demands

Williams F1 team races back into profit

The Williams F1 squad is reaping the rewards from its successes over recent seasons and it has now reported it returned to making a profit last year.

Williams made a £0.2m profit in 2015, a big improvement on the loss of £31.5m it reported for 2014, and this has been put down to increased Formula 1 revenues after two highly successful seasons, Williams finishing third in the constructors' standings in both 2014 and 2015. Thanks to its successful 2014 campaign it was paid £125.6m in 2015, up £55.4m on the £70.2m it received from F1's £700m commercial rights fund in 2014, which was based on its results in the 2013 season.

Williams tells us that the improved results are primarily due to this hike in its commercial rights payments, but also increased 'sponsorship income following a significant improvement in on-track performance during the 2014 Formula 1 season'.

Meanwhile, Williams Grand Prix Holdings PLC, the holding company of the Williams group, saw its revenue increase from £90.2m in 2014 to £125.6m in the same period. It reduced its EBITDA (earnings before interest, taxes, depreciation and amortization) from a loss of £37m in 2014 to a loss of £31.5m in 2015.

Williams CEO Mike O'Driscoll said of these results: 'Our 2015 financial results represent a major improvement, with strong revenue growth and positive cash flow. Over the past two years we have completely restructured our business, and our results reflect significant progress, both operationally and financially.

'We were able to continue our resurgence on the track, and balance revenue and expenditure, despite enormous levels of competitive spending in what is sport's most challenging financial environment.

'Our Formula 1 team achieved third place in the constructors' championship for the second successive season in 2015, illustrating the clear step change we have made in our racing competitiveness since we began our restructuring. Commercial rights income is paid a year in arrears, and these accounts reflect our much improved third place in the 2014 constructors' championship.

'Our improved performance on the track has also enhanced our power in the sponsorship market,' O'Driscoll added. 'With major brands such as Unilever, Avanade, BT and Hackett joining the Williams team. We have also seen a number of our partners increase their commitments, which demonstrates the continued strength of our brand. These financial results show that we are continuing to build a solid foundation for future sporting and commercial success.'

The Williams Formula 1 team returned to profit in 2015 as a result of its stellar season in 2014 (pictured above)

JLR Silverstone deal on hold after Tomlinson expresses interest

Jaguar Land Rover's plan to buy Silverstone has been put on hold after a late counter offer from Ginetta owner Lawrence Tomlinson was received, despite the fact that BRDC members have narrowly voted for the JLR deal.

The BRDC (British Racing Drivers' Club) is the owner of the British Grand Prix venue and its members were asked to vote on an offer from motor giant Jaguar Land Rover to buy the circuit in April. However, while sources say 54 per cent voted in favour of the deal, this has not been taken as a clear cut result and the board is now said to be considering the implications of the narrow 'for' vote.

Indian-owned JLR's bid for Silverstone was complicated by Tomlinson's decision to pitch for the track just before the vote took place, although because of an agreement the BRDC has with JLR it cannot negotiate with the Ginetta owner – who is also a BRDC member and a former director of the club – until July at the earliest.

Tomlinson made his offer after he and a group of fellow BRDC members wrote a letter to all 820 members of the club arguing that the JLR deal would leave it 'having to protect rather than promote British motor racing'.

In a statement before the vote took place BRDC chairman John Grant confirmed Tomlinson's offer: 'I can confirm that the members of the BRDC have received an offer from Lawrence Tomlinson that he wishes to put forward as an alternative to the JLR deal,' he said.

'The BRDC board have agreed to facilitate this because it is important for all the members to have all the relevant information to inform their decision,' Grant added.

JLR plans to lease the circuit for a 249-year period, with the BRDC keeping control of the operating company, Silverstone Circuits Limited – which would keep the club involved in racing at the circuit. Tomlinson's plan is to take over the entire business.

A Ginetta LMP3 at Silverstone last year – could Ginetta owner Lawrence Tomlinson now take control of the famous circuit?

Welsh circuit development set back after government pull out

The £357m Circuit of Wales development is on hold after the Welsh Government said it would not underwrite the public sector investment that has already been secured, although the company behind the track is adamant it will still go ahead.

Circuit of Wales, which has been confirmed as the future home of the MotoGP in the UK, confirmed that financing was in place and that the last planning hurdles had been negotiated at the end of last year.

The project, which is based upon developing infrastructure as much as the 3.5-mile circuit itself, had secured funding from private investors, chief amongst them insurance firm Aviva.

However, in April the economy minister in Wales, Edwina Hart, announced that the Welsh Government now considers the project too risky for it to underwrite, this despite the fact that it has already spent close to £9m on the development.

The project intends to create up to 6000 jobs in the Blaenau Gwent area, mainly through the infrastructure associated with the circuit, which includes an automotive business park. This has already borne some fruit, with reborn sportscar maker TVR announcing it's to set up its new factory in Ebbw Vale, which is where the circuit is to be built. At the time of writing the TVR decision was not being reconsidered, we were told.

Despite the setback the group behind the new venue, the Heads of the Valleys Development Company, remains bullish and says the deal is not dead. Its CEO, Michael Carrick, said he could 'respect and understand' the decision, and he now intends to explore other options.

'The Circuit of Wales is committed to the regeneration of Blaenau Gwent through the building of a leading automotive and leisure destination in South Wales,' Carrick said. 'We are developing financing arrangements with Aviva Investors and Public Sector Wales and have put forward two alternative options with revised commercial terms. These alternative arrangements will reflect a more balanced financial support package for both the public and private investment parties.

'We are working closely with all parties involved, including the local community and councils to conclude the deal over the next six to eight weeks,' Carrick added.

The Circuit of Wales had secured rights to host MotoGP in the UK until 2019 in a five-year deal, but with the build project yet to begin, Silverstone has stepped in to host the bike GP until the Welsh track is finished. The venue is also planning to host international four-wheeled competition.

Welsh Government will now not underwrite the public sector investment secured for Circuit of Wales (artist's impression)

SEEN: Chevrolet Cruze Brazilian V8 Stock Car

Chevy has unveiled a new body kit for its Brazilian Stock Car challenger, the Chevrolet Cruze, a car which has not actually been launched in Brazil yet – Chevrolet says its race campaign is part of a worldwide thrust to promote the model. The car is now more visually aggressive than its predecessor while the bodywork had been designed to be a little bit more slippery in a straight line, an area in which Chevrolet had lagged behind rival Peugeot in recent seasons.

'This shows the confidence Chevrolet has in Stock Cars', GM marketing director Samuel Russell said. 'It is part of a global strategy to promote the future generation of the Cruze worldwide. In Brazil, the option [we have taken] for the Brazilian V8 Stock Cars is due to the strong bond that we have with the series.'

SEEN: SEAT Leon STCC

Scandinavian Touring Car Championship squad PWR Racing has unveiled the car it's to campaign is this year's STCC. The design of the silhouette racer is based on SEAT's Leon model. 'To be able to present this partnership with SEAT is hugely positive for the team and underlines our long-term belief in the STCC,' said Poker Wallenberg, co-founder and co-owner of PWR Racing.

Infinite opportunities for budding Formula 1 engineers

Nissan luxury brand Infiniti has launched its F1 engineering search for the third successive year, although with a change in its involvement in Formula 1 the race team partner will now be Renault rather than Red Bull.

If you are an engineering student and you fancy working on a Renault Formula 1 car then the Infiniti Engineering Academy could be the chance you've been waiting for

This year Infiniti is offering six places as its prize in its Infiniti Engineering Academy scheme, and each lucky – and talented – winner will spend six months at the Infiniti Technical Centre for Europe (in Cranfield, UK) and also a further six months at the Renault Sport Formula 1 team based in Enstone, also in the UK.

So far six global Infiniti regions are participating in the 2016 competition: China, Europe (including Russia), Canada, Mexico, Asia and Oceania, while the Middle East and the US could still be added to this list – they had yet to be confirmed at the time of writing.

Bob Bell, Renault Sport F1 chief technical officer, said: 'We are looking for excellent students offering a mix of academic and professional experience across such disciplines as electronics, aerodynamics, mechanical design and composite design. The academy offers a compelling opportunity for up-and-coming engineers to experience the fundamentals of automotive and motorsport engineering.'

Tommaso Volpe, global director, Infiniti Motorsport, added that the company is looking for a particular type of individual: 'We want candidates that dare to be different. Candidates who think about challenges from fresh angles; brimming with the kind of creative human talents that we believe drive the greatest advances in high performance technologies. 'Game changers' may sound cliched, but the automotive industry and Formula 1 have never been more competitive, so we need the best of the best.'

Volpe also gave some indication of the sort of work the winners would be involved in: 'Infiniti is in the middle of a major product offensive, and the Infiniti Direct Response Hybrid performance hybrid powertrain technology is a pillar of the Infiniti range of high performance vehicles, now and in the future,' he said. 'Our performance philosophy is deeply rooted in hybrid technology; we are pioneers of electrified performance, and as F1 continues to develop and flourish in this area, so too will our engineers working within the Renault Sport Formula 1 Team.'

For more information on the Infiniti Engineering Academy, or to apply to be a part of it, visit www.academy.infiniti.com.

Roborace firms up on 'driver' and 'engine'

Roborace, the series for autonomous racecars which is set to hit the track later this year, has announced that its driverless cars will be equipped with 'engine' technology from Nvidia.

Nvidia will supply the series – which will support Formula E in its third season, which kicks off in the autumn – with its Drive PX2 device, which it says is the world's most powerful 'engine' for in-vehicle artificial intelligence.

Drive PX2 can fuse data from 12 cameras, as well as lidar, radar, and ultrasonic sensors, the California-based company tells us. This allows algorithms to accurately understand the full 360-degree environment around the car in order to produce a robust representation, including static and dynamic objects. Its two next-generation Tegra processors plus two next-generation discrete GPUs, based on the Pascal architecture, deliver up to 24 trillion operations per second.

Meanwhile, Roborace has also released the first design concept images of its robot racecar, which has been penned by its chief designer Daniel Simon – best known for his work with futuristic car concepts for feature films.

Simon was previously a senior designer at Bugatti, while he has also done some motorsport work, although this has mainly involved liveries – including one in F1 for the now defunct HRT team.

Roborace says that Simon's robot racecar design will generate most of its downforce from its floor and active bodywork, rather than aerodynamic wings.

Simon said of his design: 'We're living in a time where the once separated worlds of the automobile and artificial intelligence collide with unstoppable force. It's fantastic to be part of this journey; it triggers all my big passions – motor racing, design and advanced technologies.'

He added that the car's aesthetics were a high priority, and this was partly why the body is downforce-generating: 'Beauty was very high on our agenda and we worked hard to merge the best performance with stunning styling. It was important to us that we generate substantial downforce without unnecessary parts cluttering the car to maintain a clean and iconic look.

'This is largely made possible by using the floor as the main aerodynamic device and we are currently developing active body parts that are more organic and seamless than [usual] solutions.'

Roborace has released this design study of its autonomous racecar

RECORD DRIFT

One thing about Nissan, it's never afraid to do something just a little bit different; like the GT-R LM front-engined LMP1, or putting gamers into racecars, or now, shattering the speed record for drifting by getting a Nissan GT-R NISMO to hang out its tail at 189mph… The high speed drift took place on a 3km runway at Dubai's Fujairah International Airport. The car was developed by Nissan and GReddy, but there's not much detail about its prep, save for the fact that the power was increased to 1380bhp and all of this was sent to the rear wheels. The car was driven by Japanese drifting champion Masato Kawabata, who managed to slide it at an angle of 30 degrees at 189.49mph, smashing the existing record of Polish driver Jakub Przygonski's, whose fastest drift was at a mere 135.44mph.

CFD firm Converges with top-level NASCAR engine builder

CFD provider Convergent Science has clinched a technical partnership deal with NASCAR powerplant builder Roush Yates Engines.

Convergent Science, which is well-known in motorsport for the work it does with Ilmor on Chevrolet's IndyCar engines, will provide its Converge CFD package to the Mooresville, North Carolina-based engine builder, which will then use it for the design of its future race engines.

Doug Yates, president and chief executive officer at Roush Yates Engines, said: 'Their [Convergent Science's] continued passion to push the technological boundaries and constant pursuit of innovation perfectly aligns with Roush Yates Engines' vision and direction.'

Rob Kaczmarek, director of global marketing at Convergent Science, said: 'We are delighted to be partnering with one of NASCAR's largest and most respected engine builders. Our dedication to bringing our customers the most innovative CFD software for simulating flow and combustion is our passion.'

Convergent Science says that its software 'brings a superior level of efficiency, flexibility, accuracy and consistency to simulated fluid flow analysis. Its advanced fully coupled automated meshing capabilities will be a further enhancement to the development process.'

It adds: 'The unique meshing approach and advanced Adaptive Mesh Refinement (AMR) technology will be an instrumental tool moving forward. Converge CFD software automatically refines results with fluctuating and moving conditions; such as temperature and velocity, while improving through-put and achieving reliable CFD results.'

Doug Yates, president and CEO of Roush Yates Engines, says Converge is a perfect fit for his NASCAR engine build operation

SEEN: Volkswagen Polo R WRC 2017

Volkswagen has released an image of its next generation Polo R, which is to be built to the new-for-2017 WRC regulations. While VW says the final car may well look 'substantially' different to the car shown, it adds that the image does give a 'taste of things to come'.

The new regulations will mean more powerful and faster WRC cars, and the new Polo is set to have roughly 60bhp more than the current car (318bhp), while it will also be lighter, wider, and will feature more aerodynamic appendages.

Next year's increase in performance is to be achieved by widening the air restrictor from 33mm, as it is at present, to 36mm, while an electronic centre differential will also be allowed from 2017. The most visually striking changes will be the larger rear wing and broader front spoiler. The minimum length of the car will be 3900mm, while the minimum weight is reduced from 1200kg to 1175kg.

Volkswagen motorsport director Jost Capito said: 'The 2017 WRC regulations include many spectacular technical innovations for the World Rally Championship. The World Rally Cars of the future will incorporate all the experience that teams have gained in recent years. They will be considerably more dynamic, whilst at the same time being safer. As usual, we are working painstakingly on the development of the next generation of the Polo R WRC. The key between now and the start of next season is to achieve the best possible prerequisites to allow the 2017 Polo R WRC to be as successful as its two predecessors.'

VW has dominated the WRC since it returned in 2013, winning three championships in a row.

IN BRIEF

Strakka strikes out

Strakka Racing has put its Formula V8 3.5 Championship assault on hold after failing to find drivers with budgets for the series – formerly known as Formula Renault 3.5, until it lost the backing of the French motor giant last year. The team joined the series in 2013 and last year it finished fourth in the championship. Strakka's involvement in WEC LMP2 and the Renault Sport Trophy is to go ahead as planned. Strakka's withdrawal meant that just 15 cars contested Formula V8 3.5's first round at Aragon in Spain in April.

Souks you

Afriquia, which is part of the Akwa Group and is Morocco's leading fuel station operator, has signed a deal with the WTCC to become the sponsor of the Marrakech round of the championship – said to be Africa's biggest motorsport event. The race itself has also benefited from a redevelopment which has resulted in an all-new Circuit Moulay El Hassan, now transformed to incorporate a permanent track and a heavily revised layout, designed by F1 architect Hermann Tilke.

V8S's Ute contract pick up

V8 Supercars (V8S) has taken over the running of the V8 Utes Series in Australia – Ute is short for 'utility' and refers to pickup trucks. The promoter of Australia's premier racing series has replaced the previous promoter, Australian V8 Ute Racing Pty Ltd, which went into voluntary administration in February. V8S has now taken on the Confederation of Australian Motorsport Category Management Agreement for the series, after running this year's first pickup round as a one-off on its Adelaide race card.

INTERVIEW – Francois Ribeiro

World view

The boss of the World Touring Car Championship talks frankly about future regulations, a departing manufacturer, and the rise of TCR

Interview by ANDREW COTTON

XPB

'Manufacturers come and go, that is the essence of motor racing'

Nothing puts a championship on the map like manufacturer involvement. It's a seal of approval, and on a global scale a certain amount of works team presence is even part of the FIA's criteria for a series being allowed to call itself a 'world' championship. So it could have been great news for World Touring Car Championship (WTCC) manager Francois Ribeiro to hear in November of last year that Citroen was departing at the end of this season, with a view to concentrating its future efforts on the World Rally Championship.

Yet Ribeiro remains philosophical. The Frenchman goes in to his third season as the head of the WTCC this year, and before he took over as boss he worked closely with his predecessor, Marcello Lotti, for 11 years. So he knows how fickle motorsport at this level can be and was not surprised by the French firm's decision. He is also confident another manufacturer will be along to take its place, maybe even two of them, while he believes Citroen will still be present in some form. 'There will be a new manufacturer next year, and I think another one two years from now,' Ribeiro says. 'I think that we will still have Citroen cars on the grid next year, whether it is three or five I cannot tell you, but we are already working with Yves [Matton, Citroen motorsport boss] to have his cars running. In motorsport if you are not prepared to lose and win manufacturers then you had better find yourself another job. Manufacturers come and go, that is the essence of motor racing.'

Cost driven

In the meantime Volvo has come in to the WTCC this year (see page 36), while the focus for the future is squarely set on the new three-year homologation cycle (which starts in 2017). Unsurprisingly, this will be very much cost driven.

'It is the start of a three-year homologation cycle, and we have started to discuss with teams about cost reduction,' Ribeiro says. 'I want to work on two things; the chassis part and the engine part. I have a very clear idea in mind of what I want and what I don't want, but I can only bring an input into the discussion. The technical regulations are the FIA's responsibility, but I am spending time with the manufacturers one by one, and teams one by one, to see where the cost implications are and to see what can be done to reduce the costs of some parts of the car without killing the show – the essence of touring cars – without damaging the product that we have. I would like to reduce the running cost budget for a privateer by €200,000 per season.'

Costs are likely to be cut with new chassis and engine regulations, the latter because the price of powerplant lease deals are now very high, Ribeiro tells us. But he has also questioned whether the category's allowance of a carbon floor and other carbon goodies should remain in place. 'Is it absolutely necessary to have a carbon floor? I don't know if it was a mistake [bringing carbon floors in], the regulations are what they are and they were decided in 2013 between the manufacturers, the FIA and us. Certainly, we can revisit that part because I don't think it is necessary. If the cars weigh 20 to 30kg more and lose the carbon, get a wooden flat floor – and [also lose] the front and rear bumpers and carbon bonnet and roof – would that make the look of TC1 cars different? Would that affect the performance? A bit, maybe, but if we change tyre performance by half a second per kilometre, because we work with a completely different tyre product, [then] if everyone is on an equal footing, I don't see the problem.'

On the subject of tyres, a new supply deal is very much on the WTCC's agenda right now: 'We don't know who the new tyre manufacturer is yet, it is still under discussion,' confirms Ribeiro. 'It could still be Yokohama. I am [also] talking to two other tyre manufacturers, which could work very well, and one of them could take the WTCC tyre contract.'

Growth of TCR

The tyre situation should be sorted by June, says Ribeiro, and the fact that the WTCC is talking to three potential partners perhaps shows the worth of a global platform. But, of course, WTCC is no longer the only show in town when it comes to global tin top categories, with Ribeiro's former boss Lotti setting up TCR, which after a single year has proved to be a notable success. 'It [TCR's success] is no surprise to me,' says Ribeiro. 'I don't know how his [Lotti's] business is running, only he knows that, but the concept and the buy-in from customer divisions of the manufacturers is no surprise for me. It was a vacuum. As the

market expands, then the volume of cars sold will attract other manufacturers, I can guarantee this.'

But isn't that a threat to the WTCC? 'No, we need this, desperately. You cannot live isolated at the top of the pyramid with no local championships, with no grass roots competition, without any entry-level touring cars. Why do you think that the FIA is putting such an effort [with single seaters] into Formula 4, Formula 3 and the next step is Formula 2?

'But TRC is not a world championship, it is not a technical regulation that is strict and controlled like the WTCC, or other world championships. There is no comparison of media coverage. It is two different products with two different philosophies. I see no conflict.'

Customer sport

Yet while there may not be a conflict, there is no getting away from the fact that TCR is cheaper than WTCC. Is this a worry? 'No, it is not. [Look at] the models, the brands, the cars that are racing today in TCR. Is SEAT racing as a factory team? Is JAS Honda racing [as] Honda? Is VW there as a factory?

'If you follow the GT3 model, what are the manufacturers after? They are after a business. First and foremost they want to sell cars. It is a business, GT3, and a big one if you are Aston Martin or Porsche, or M-Sport with Bentley. How many Bentleys has Malcolm [Wilson, M-Sport boss] sold? Every time he sells one it is £1m in the bank. There is no problem to make money in motorsport. As a French person my first five years in motorsport were working for the FFSA [the French governing body], and I remember the customer divisions of Citroen, Peugeot and Renault, the first three manufacturers I worked with, and I remember the figures, how many customer cars they were selling to, through rallying or racing. Believe me, when you have that as an asset, and then you propose to your board that you want to do WRC, and say "this is my base, and this is the margin that I make, I can afford to ask you for 50 per cent of the budget I need to do a World Championship, because I already have this in the workshop", it helps a lot.'

The above argument seems sound. And if it is, and TCR continues to prosper in the coming seasons, then maybe the WTCC will soon find itself with a few more manufacturers involved on the back of the other category's success? As a world championship, it will certainly hope so.

Citroen is to pull its works squad out of the World Touring Car Championship at the end of this season but Ribeiro says there are other manufacturers waiting in the wings

XPB

RACE MOVES

XPB

Former F1 driver **Ivan Capelli** has resigned from his position as boss of Sias, the company that operates the fabled Monza race track in Italy. The circuit has hosted the Italian Grand Prix since the inception of the World Championship and even before that, but recently its place on the Formula 1 calendar has been the subject of some discussion. It's believed that Capelli's departure has much to do with these ongoing worries over its future.

Motorsport engineering veteran **Steve Hallam** has left the Australian V8 Supercars Series, where he worked at TEKNO Autosports, to take up a position with Toyota's motorsport programme in the US. Hallam, who has previously had high level experience in both NASCAR and Formula 1, worked for the works Holden outfit in V8S from 2012 to 2013, and then TEKNO for the 2014 and 2015 seasons.

Mike Carcamo, who was the programme director at the Nissan LMP1 operation before the project was binned just before Christmas, is now officially Nissan's global motorsport boss – a position he has filled on an interim basis since **Darren Cox** left the post in October of last year. Carcamo is also now the programme director at Nissan motorsport and performance arm NISMO.

Hugh Chamberlain, a well-known figure in the Le Mans paddock, is to return to the 24 Hours this year as team manager for the Murphy Prototypes squad. Chamberlain, who had held a team management post at Le Mans for every single year from 1987 until 2008, has also been recruited by the Anglo-Irish team for its European Le Mans Series campaign this season. Chamberlain has replaced **Alan McGarrity** in the position.

Mark Lyle, who was chief starter for US drag racing body the NHRA, has died. He was just the third chief starter in NHRA history, along with the late **Buster Couch** (1955 to 1996) and **Rick Stewart** (1996 to 2011). **Mike Gittings** has now been named as interim chief starter until a replacement for Lyle is found.

Multiple US race team owner **Roger Penske** is to be honoured by the International Motor Racing Research Center (IMRRC), which is to award him with its 2016 Cameron R Argetsinger Award for Outstanding Contributions to Motorsports. This will be the third annual Argetsinger award presented by the IMRRC, NASCAR great **Richard Petty** receiving it last year, while NASCAR and IndyCar team owner **Chip Ganassi** was the inaugural winner in 2014.

Well-known IndyCar engineer **Andy Brown** is to return to the series for the Indianapolis 500, where he will tend the Team Murray/KV Racing car of **Matthew Brabham**. Brown was the assistant technical director at the Galles squad when **Al Unser Jr** won the 1992 Indianapolis 500, and he then went on to engineer **Sam Hornish Jr's** Indy Racing League title-winning seasons in 2001 and 2002 at Panther Racing. More recently Brown has been working with Andrew Jordan in the British Touring Car Championship.

Matthew Brabham's Team Murray/KV Racing Chevrolet (see above) will also be tended by an 'honorary pit crew' made up of former servicemen at this year's Indy 500. The same crew, which is part of a fundraising programme by the Chris Kyle Frog Foundation, will represent the team in the annual Pit Stop Competition, which takes place on Carb Day.

The management at Nissan's NISMO motorsport arm has been restructured in the wake of the retirement of its president **Shoichi Miyatani** after five years at the head of the company. As part of the reorganisation Miyatani has been replaced by **Takao Katagiri**, who has more than 30 years of experience with Nissan.

Former IndyCar team boss and driver **Sarah Fisher** has opened a new indoor karting business just down the street from the Indianapolis Motor Speedway, a venture she owns and operates alongside her husband **Andy O'Gara**.

Ratel takes seat on board of directors for US series PWC

WC Vision, the company which promotes US sportscar series the Pirelli World Challenge (PWC), has announced that SRO Motorsport Group boss and serial GT promoter Stephane Ratel is now on its board of directors.

The news came at the same time as it was also announced that SRO had become a shareholder in WC Vision.

PWC first forged an alliance with the SRO Motorsports Group and its Blancpain GT Series last year, and this affiliation has expanded for 2016 with the two series now using similar technical regulations, including the SRO Balance of Performance formula.

XPB

SRO boss Stephane Ratel is now on the board of the Pirelli World Challenge series

Greg Gill, president and CEO of WC Vision, said: 'Working with Stephane and his SRO Motorsports Group, a great relationship has been established with WC Vision over the past year.

'We have an open forum with their officials, to work closely on the technical side with the GT3 regulations. Now, having Stephane join our board of directors, this definitely gives WC Vision and the Pirelli World Challenge a worldwide perspective from the leader in GT racing.'

Ratel said: 'Our alliance with WC Vision and Pirelli World Challenge has been outstanding. We have enjoyed working closely with Greg and his entire WC Vision staff as well as getting to know the WC Vision board members. I'm very enthusiastic about joining the board of directors and [about] the outlook for the company's future. I see great potential in the Pirelli World Challenge and I can't wait to work more closely within the series.'

In 2016 the Pirelli World Challenge consists of five categories, running in three separate series. Its top series runs FIA GT3 homologated cars.

Hollinger takes on director position at Williams group

Healthcare entrepreneur Brad Hollinger has been appointed non-executive director at Williams.

Hollinger is a major shareholder in Williams, having completed a deal to buy up the shares the Mercedes motorsport boss Toto Wolff had owned in March of this year.

The American now owns more shares in Williams than anyone other than company founder Frank Williams. Hollinger joins Nick Rose and Eddie Charlton as the company's third non-executive director and his appointment is for a three-year term.

Williams CEO Mike O'Driscoll said: 'Brad is extremely knowledgeable about F1 and as a long-time fan of Williams has a tremendous passion for our team.

'His appointment adds to what is a very strong team of non-executive directors who provide the company and our shareholders with the highest standards of leadership and governance.'

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Mike O'Driscoll (above) says the appointment of Hollinger will strengthen the Williams leadership team

Hollinger said he believes Williams has a bright future as both a race team and a commercial entity: 'I have tremendous faith in the potential of this business – both as a competitive F1 team and diversified advanced engineering business. It is for this reason that I have invested in Williams over the past two years.

'I look forward to working with my colleagues on the board to continue growing Williams and help the business fulfil its potential both on and off the race track,' Hollinger added.

Hollinger first became a shareholder in Williams in 2014, when Wolff sold him five per cent of his original holding. He then acquired a further five per cent in February of this year, before securing the final block of Wolff shares in March.

RACE MOVES – continued

XPB

Hyundai WRC driver **Hayden Paddon** has set up his own team with the aim of promoting rallying in his native New Zealand. The Hyundai New Zealand Rally Team, as it's called, will run a version of the Korean company's i20

IMSA race engineer **Catherine Crawford**, who works for the DeltaWing squad, has been released from hospital in Rome after undergoing emergency surgery to remove a brain tumour in March. Crawford was on holidays in Italy with husband Russ when she suffered a severe headache and was rushed to hospital. She will now continue her recovery at home in the US.

Tony Gibson, the crew chief for **Kurt Busch** at the Stewart-Haas Racing NASCAR Sprint Cup operation, missed the first two days of the Texas Motor Speedway round of the series, after electing to stay at home in North Carolina to care for his sick wife. Johnny Klausmeier served as stand in crew chief during Gibson's absence.

F1 chief **Bernie Ecclestone** has told the UK press that blocks have been put on the appointment of former Renault Formula 1 boss **Flavio Briatore** as his successor. Briatore left F1 in disgrace back in 2009 in the wake of the 'Crashgate' scandal (when the Renault team was found to have fixed the result of the 2008 Singapore GP).

NHRA drag racing team boss **Bob Vandergriff** has retired from the sport, shutting down his BVR organisation in the process. BVR has fielded two Top Fuel cars in recent seasons but Vandergriff, who stepped down as a driver in 2014 to focus solely on running BVR, says he now desires to spend more time with his family.

An MSA (Motor Sports Association) Lifetime Achievement Award has been presented to **David Morley**, who the MSA describes as a highly experienced and respected timekeeper. Morley has been a volunteer member of the MSA Timekeeping Advisory Panel for over two decades.

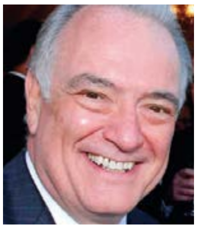
Alan Foster, a former MSA kart technical executive, technical commissioner and environmental inspector, has died. Foster, whose son Nick has competed in the BTCC, was awarded the title of *Officiel d'Honneur* by the MSA recently.

Dion Williams and **Jared Erspamer**, tyre carriers on the No.24 Hendrick Motorsports run car in the NASCAR Sprint Cup, have switched positions, with Williams now taking charge at the front of the car, and Erspamer the rear.

Dare to be Different, the initiative that aims to attract more females into motorsport, had its first event at the Daytona Sandown Park kart track in April. Founded by former race driver **Susie Wolff** and the Motor Sports Association, Dare to be Different aims to attract females into all motorsport fields, including engineering. The event included kart racing and engineering challenges.

The Haas F1 operation has begun a recruitment drive. Its team principal **Gunther Steiner** has said the team is particularly looking for aerodynamicists and aero performance engineers.

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



The pace of change

How F1's woes are good for sportscar racing; plus UK motorsport and Brexit

I feel as if I have seen the current situation in F1 happening before. The ongoing confusion on all levels, as demonstrated on TV, on-line and in the media, continues to diminish its appeal to fans, and yet the leaders do little to stem the tide.

Many readers will recall the period when NASCAR accelerated into the void created when ChampCar and IRL, mutually, devastated their fan base. As I see the rising numbers attending sportscar and GT racing, and the enormous number of competitors signing up to a wide variety of series in both disciplines, I suspect we are in for several years of watching sportscar racing increase its fan base, feeding off the decline in Formula 1.

I genuinely hope the leaders of Formula 1 wake up to reality, and move quickly to halt this decline, but the chances of that happening seem pretty slim. The structure they have created has made it impossible for anyone to take the lead, and in the meantime they are like Nero, fiddling while Rome burns.

We are in for several years of watching sportscar racing increase its fan base

XPB

While Formula 1 seems to be lurching from one crisis to another with little sign of any effective leadership, sports and GT racing might well be picking up its disgruntled fans

Millennials

However, this growth in sportscars and GTs *is* good news for business. They are open to a wide range of technologies, have substantial budgets connected to the main automotive manufacturers and really strong grids made up of professional teams as well as Pro-Am funded competitors using many different brands. They even have strong feeder series bringing young talent through. You need serious wealth to get on the first few rungs of the ladder in single seater racing, which is not true in sportscars. This is sure to deliver a very positive future for sportscars and is an area which it can perhaps teach Formula 1 many lessons.

The revival of Formula 1 is vital to us all. I am just adding one voice to many other voices appealing to those in control to get a grip of this sad situation, so it can regain the global top spot that it genuinely deserves, but is in danger of losing.

One change which is being overlooked is the rapidly changing demographics of the *millennial* group of fans. These are people aged between 18 and 35 whose spending power and choice is most important for the future. They are demonstrating distinctly different buying habits to those of the ageing leaders of motorsport.

A quick summary. The consumption of alcohol has fallen 20 per cent in the past decade, even though it is cheaper and more widely available than in the past. In the same period, drug use has fallen by 30 per cent in the UK. Experts in consumer marketing are keen to find the explanation for this change in behaviour. I think the single most important change is the wide use of smart phones, which are at the heart of all their activities. Social media use and digital games have taken the place of these now outdated pleasures, even socialising face to face has declined dramatically. Far fewer young people are learning to drive and a rapidly reducing number see any logic in owning a car.

These consumers will use e-commerce for future purchases, dispensing with cash altogether, never visiting a bank, and few will read a paid for newspaper or watch broadcast TV. But instead they will enjoy gathering news, information and entertainment on-line. This makes them far less loyal, but they are far more open-minded to new ideas. This generation are multi-taskers, tech-savvy and connected globally. They seek instant gratification and immediate access.

The divide that has been created between this group and the older generation, due to the widespread growth of the internet over the past 20 years, has changed relationships, leisure, and almost everything we do. There seems to be a pre-internet consumer and a post-internet one – and I question how well our 'innovative, hi-tech' motorsport sector has actually embraced this change.

The leaders of all our sports series must change gear and adapt far more quickly than is evident – many other sports are passing us by and yet we claim to be at the forefront of technology. There are small signs of change in certain series. Formula E seems the most liberal and open to new ideas. Its new, mostly millennial, fans are undoubtedly being well catered for, so this proves change is possible. Let's hope other series organisers wake up and invest some of the millions being made from the commercial side of our sport into engaging with this group of fans, before it is too late.

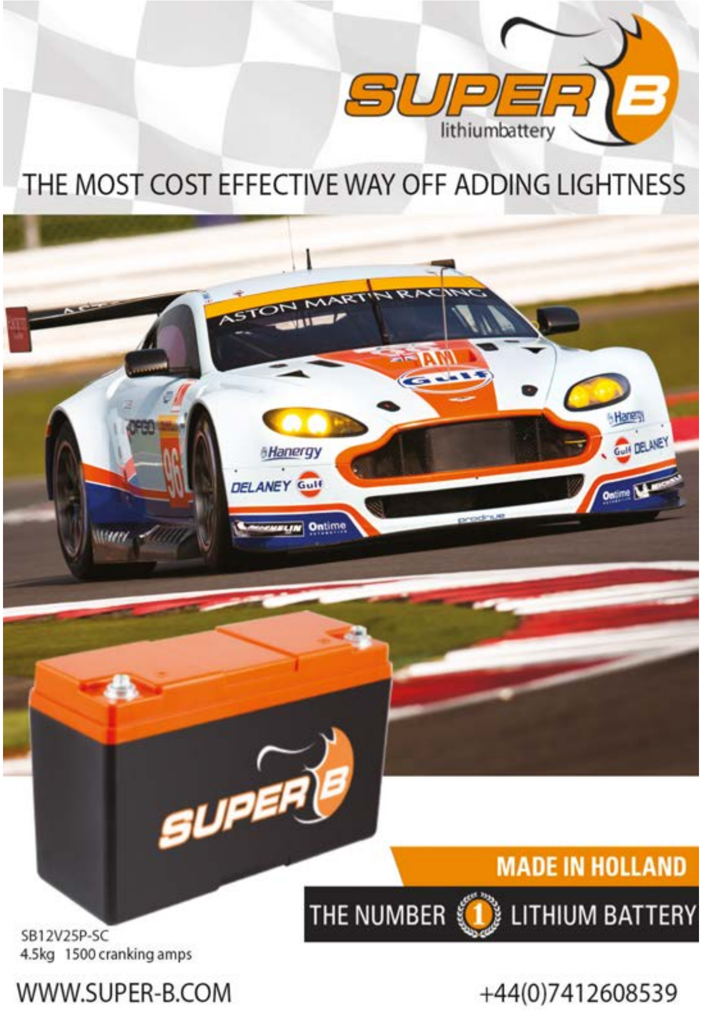
Brexit

Finally, Motorsport Valley UK suppliers have a few weeks to make up their minds whether or not they wish to stay within the European Union. On 23 June, the UK has a referendum to consider Britain's exit (Brexit) from the EU and the decision will affect future generations throughout motorsport. The relationship between the UK industry and the rest of the 28 states of the EU is long-standing, close and of enormous value. The MIA recently carried out a survey of the industry and early reports show that, by a large majority, most businesses in UK motorsport will vote to stay within a reformed European Union.

But it is important to these that if Britain stays inside the EU there will be significant changes to the way it operates. Time will tell whether this change can be better affected by taking a position within the camp, or perhaps would have been better served by staying outside, being free to handle our own affairs.

Polls show that voting will be exceedingly close and a great deal of personal emotion will affect this decision, but businesses must suspend emotion.

The motorsport world has successfully skirted engagement with the EU for the most part – there have been one or two investigations into the operation of F1, but for the rest, most are left to get on with their work. The restriction on employment hours remains to be ratified so we can still run race teams for 24 hour races as opposed to having to change the engineering teams every eight hours, which would be unsafe and chaotic. There are a few other pieces of legislation currently on the books where the MIA is leading a campaign to have them amended. The cost of such work is high and itself is a barrier to change, and many industries cannot hope to change such things, as we hope to do.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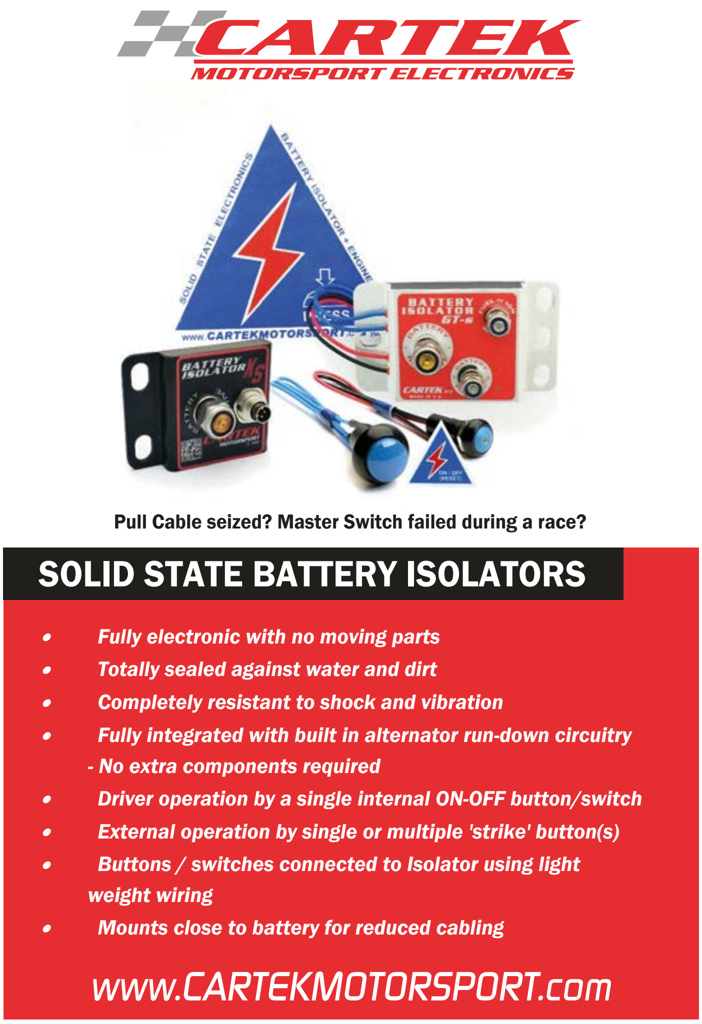
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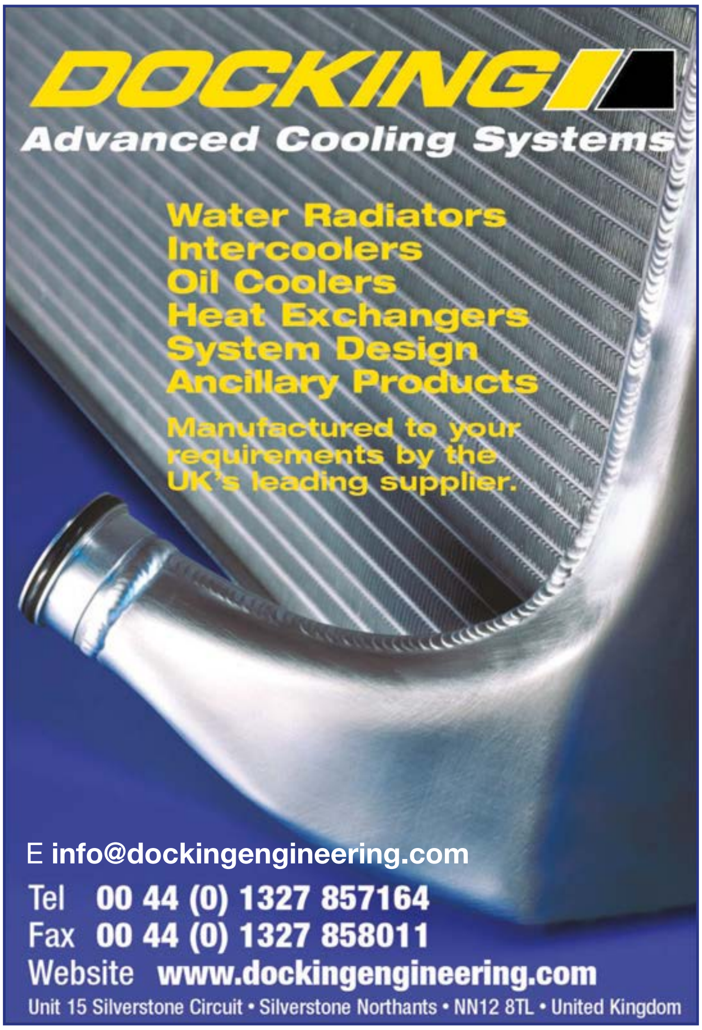
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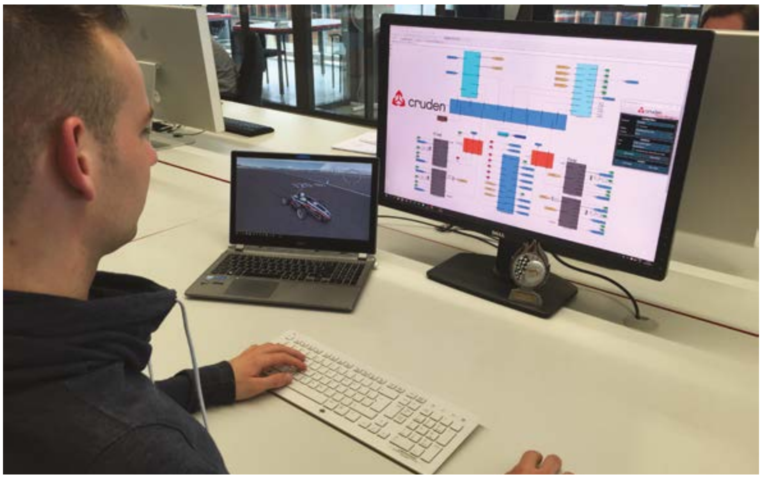
Software
Free simulation package

Simulator company Cruden has announced it is offering a complimentary version of its open architecture Panthera simulator software. The new version, Panthera Free, can be run on a single desktop computer with most vehicle models. Users will be able to run simulations, modify and expand vehicle models, add interfaces to hardware and use custom cars and tracks.

Panthera Free uses the same open physics integration technology and state-of-the-art rendering engine as the licensed version that is used by automotive OEMs and motorsport companies. It shares all of its desktop simulation relevant features. It will be supplied with Panthera ePhyse, an external physics module for Matlab Simulink that allows easy integration with many vehicle models, and Cruden's Simulink vehicle model, CSVM-Lite, is also part of the package.

In terms of rendering, the software is capable of generating over 120 frames per second at WQXGA resolution whilst keeping latencies well under 10ms. The use of Panthera is also not limited to Cruden products; it can be used with any hardware.

This freeware version of Panthera includes: Panthera Core – main simulation engine that enables users to simulate and visualise cars modelled in Simulink or using the internal vehicle model; ePhyse – the integration layer for Matlab Simulink; CSVM Lite – a Simulink model for driver-in-the-loop simulation that can be modified by the user at will; Session Manager Lite – the user front-end for configuring and controlling a simulation; and TrackEd– an editor to prepare tracks for use in Panthera.
www.cruden.com



Brakes
High calibre caliper

Alcon has released a new six-piston two-piece forged aluminium caliper which is called the CAR89.

This product is currently being used on Pat Doran's RS200 hillclimb car, which will be run at the Goodwood Festival Of Speed, and on Robb Holland's TCR racer, as well as in the China Touring Car Championship.

The caliper is hard anodised and features stainless steel pistons, a recessed external pipe and bleed screws, and weighs in at 3.1kg. It suits disc diameters of between 355mm to 390mm, with a thickness range of 32 to 36mm and pad thickness choice of 18mm or 25mm.
www.alcon.co.uk

Dampers
Bump and rebound

GAZ Shocks has released a new range of universal double adjustable coilover dampers in response to customer demand in the UK and overseas.

The new shocks are said to offer more scope in terms of set-up and are mandatory parts in at least one British club race series already.

The dampers enable the damping bump and rebound rates to be separately adjusted to suit the individual track conditions and personal driving style. The rates can be altered by means of two dedicated knobs on the side of the units; both are easily accessible and clearly marked and colour coded for bump and rebound.

The shocks are available as dampers alone, or as coilover height adjustable units with springs.

They can be made to order to the required length and with the appropriate top and bottom fixing points for particular applications. Appropriate springs can be supplied to suit the intended use.
www.gazshocks.com

Racewear
Dressing 'smart' to stay safe

During the opening round of the 2016 World Endurance Championship a new type of 'connected' driver suit made its motorsport debut.

This 'smart suit' has been developed by motorsport equipment specialists Fyshe Ltd and Otentico Ltd, in response to the challenges of authenticating brands and products in what is a growing counterfeit market.

The suit is fitted with a tamper-proof chip that authenticates the race suit as a legitimate product and confirms whether it complies with current regulations. The Adidas-made race suits each contain a smart tag with an embedded near field communication (NFC) chip with a unique identification number, which is digitally signed during the tag's production so that the tag cannot be cloned, tampered with, or electronically modified.

Otentico's smart tags are based on NXP Semiconductors' NFC chips and produced by one of the world's leading NFC tag producers, using the most secure production methods, we're told. Each tag is registered in and verified by Otentico's server-based authentication platform to offer the highest security architecture. The smart tags are said to be superior to static QR codes, that are easy to copy, and hologram-based labels, that require visual identification.

The smart suits can be 'read' and authenticated by swiping an NFC-enabled smart-phone using a free app. The app shows the smart suit's product details, including imagery, manufacturer, manufacturing date and homologation number and, in the near future, drivers' details which could include key medical data.

The information relating to each smart suit and its driver is managed in the cloud.
www.fyshe.com

Race seats
Trimmed for action

The Micro GT FIA bucket seat is now available with a limited edition trim design (pictured).

The 3D trim consists of hard-wearing and breathable fabric, making for a more comfortable race for the driver. The double white stitching is added as standard and can be selected in a range of up to three-dozen different colours.

The GT is for those with limited space in the cockpit, and has rolled off thigh support for easy access. The race seat is fully FIA-approved, suitable for all types of motorsport, and compatible with four, five or six point harnesses. If you compete in off-road racing the seat is available with water resistant vinyl, giving you a simple and effective wipe clean option.
www.gsmotorsport.co.uk

Data systems
Connecting drivers

A new off-the-shelf product has been launched to allow teams to add human performance information to data outings.

Wireless Motorsport's new biometric receiver includes a heart rate monitor and body temperature sensor and can be expanded with a range of additional sensors, including a less obtrusive armband type heart rate monitor, and an oxygen level sensor. The device can be used as a standalone system or can be integrated in to the common data acquisition systems, including via CAN bus or analogue outputs.
www.wirelessmotorsport.com

Fuel systems
Handling the pressure

Fuelab has announced its latest development in fuel pressure regulator performance. The 585xx Series Fuel Pressure Regulators combine new features and increased functionality to provide a precision instrument for fuel pressure regulation, the company tells us.

The four outlet port regulators are said to be engineered to deliver extremely high flow rates and a flattened curve for pressure stability.

Featuring an anodised billet aluminium body, the regulators use an aerospace poppet valve design to provide smooth regulating capability and maximised flow. They operate within a 4-10psi pressure range, and an adjustment mechanism with fine thread pitch allows for precise fuel pressure adjustment. A methanol and E85 compatible soft seat avoids fuel pressure creep.

This main seat assembly can be exchanged in case of seat damage from debris, and can be disassembled for replacement of the o-rings in the soft-seat design.

The 585xx features dual 10AN inlet ports, and four 6AN outlet ports arranged in-line for cleaner installation, and is said to have a port spread that allows for smooth fuel flow when using 8AN line size.
www.fuelab.com

Throttle bodies
Light and sound

A new range of lightweight throttle body kits has been launched by Jenvey Dynamics. Called TBU45, they are an enhanced version of the firm's popular TB45 bodies, and they are the first release from its new 'Ultra-Light' range – which benefits from a 43 per cent weight reduction compared to the original TB45 units.

Jenvey's new TBU45s will be sold alongside the existing TB45 kits, and include a new throttle linkage design, which is lighter, made of less components and easier to assemble. The reduction in the throttle body weight has been achieved through Finite Element Analysis (FEA) and by using a design that incorporates extra bracing to ensure reduced weight is complemented by extra strength. All Jenvey Dynamics' throttle bodies are designed, tested and manufactured in-house using modern CAD and are available in the company's trademark 'Crackle Black' finish.

'The new TBU45s maintain Jenvey Dynamics' reputation for innovation and demonstrate our commitment to providing customers with continually evolving, market-leading products for road or race use,' says Jenvey Dynamics managing director, Mike Jenvey. 'TB45s have been enormously successful, but we identified a number of areas where further improvements could be made, the most eye-catching being a 43 per cent weight reduction from the original design without compromising durability or performance. In fiercely competitive race series where every ounce or lb.ft of usable torque is key, the Ultra-Light range can provide an invaluable competitive advantage.'
www.jenvey.co.uk

Machining
Formula 1 CNC capability

The Haas UMC-750SS is a 5-axis 40-taper vertical machining centre which has already found applications in F1 (and not only with the Haas works team.)

It has 30in x 20in x 20in travels and an integrated high-speed trunnion table which offers 150-deg/sec capability; to quickly position parts to nearly any angle for five-sided (3+2) machining, or to provide full simultaneous 5-axis motion for contouring and complex machining.

The machine is equipped with a powerful 15,000rpm in-line direct drive spindle driven by a 30 horsepower vector drive system, and it comes standard with a high-speed 40+1 tool side-mount tool changer. The UMC-750SS's 630 x 500mm trunnion table features standard T-slots, as well as a precision pilot bore, for fixturing versatility. The trunnion provides +110 and -35 degrees of tilt and 360 degrees of rotation for excellent tool clearance and large part capacity.
haascnc.com

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The win that wasn't

In conversation with a Japanese journalist last year, we discussed Le Mans 2014. She was firmly of the opinion that it was not an honourable race, that the leading LMP manufacturers had arrived with illegal parts that were somehow allowed to run. I thought it was the best Le Mans for a long time. To recap, at the pre-race test Porsche had rear bodywork that was flexing at high speed, and had to secure it for the race. All three manufacturers turned up with floors that were sprung, in order to protect the chassis in case of impacts with kerbs, but which could in theory be a performance generator. Toyota turned up with a rear wing that flexed, and a fly by wire braking system that was necessary to deal with hybrid systems under braking, but which could account for brake wear throughout the course of a race.

The manufacturers were allowed to run with the floors as they did protect the monocoque; Toyota was allowed to run with its rear wing flexing as it was not a movable aerodynamic device, and was also allowed to run with its braking system as it was deemed to be within the regulations, and has now been adopted by Audi and Porsche. The only change was Porsche's rear bodywork, but the team put that down to not having the car completely ready as they lined up on the grid at the pre-race test for a photograph.

All the issues were sorted out pre-race, and the fun was in establishing who had done what, why they had done it, and whether or not it was legal. In the mix, the FIA had issued a remit that none of the above could be discussed in public. That has all been written about previously here, but the next stage of the problem arose at the opening round of the World Endurance Championship at Silverstone last month.

At Silverstone, Audi won on the road, but long after the race the winning car was excluded as the skid plank had been found to have worn beyond the legal limit.

There are two arguments to be had here. One is that it takes so long to declare a result that by the time it is final, most spectators will have moved on to the next item on their weekend agenda anyway. The second is to question whether exclusion was actually the appropriate punishment?

In the past, in many other series as well as the WEC, the process of declaring cars legal or not post race can take many hours. I understand that it is not the work of a moment; the car finishes the race, is wheeled into the technical scrutineering bay and is analysed. Any irregularity is then reported, and the team given a chance to respond, the stewards decide on the appropriate penalty and that is then issued. This all takes time and it is a process that simply cannot be rushed. That's just for one car, and more than one is scrutineered post race, which takes time. But there are many implications associated with throwing out the winning car late at night.

In an increasingly digital age, it is possible to modify a race report and news and actually, by the time everyone woke up on Monday morning, the exclusion of the winning car was plastered all over the internet, the race reports modified accordingly. Audi's exclusion dominated the coverage, and Porsche got very little by way of return having been declared race winners. Nor did the Rebellion team, which finished third.

Audi won the race. It crossed the line first, it was recorded on television as having done so, the reports from the manufacturers and journalists said it had done so, but there was a technical problem discovered long after many had gone home. Without analysing Audi's defence (I don't have access to it and it has since been dropped anyway), there has to be another way of dealing with this eventuality.

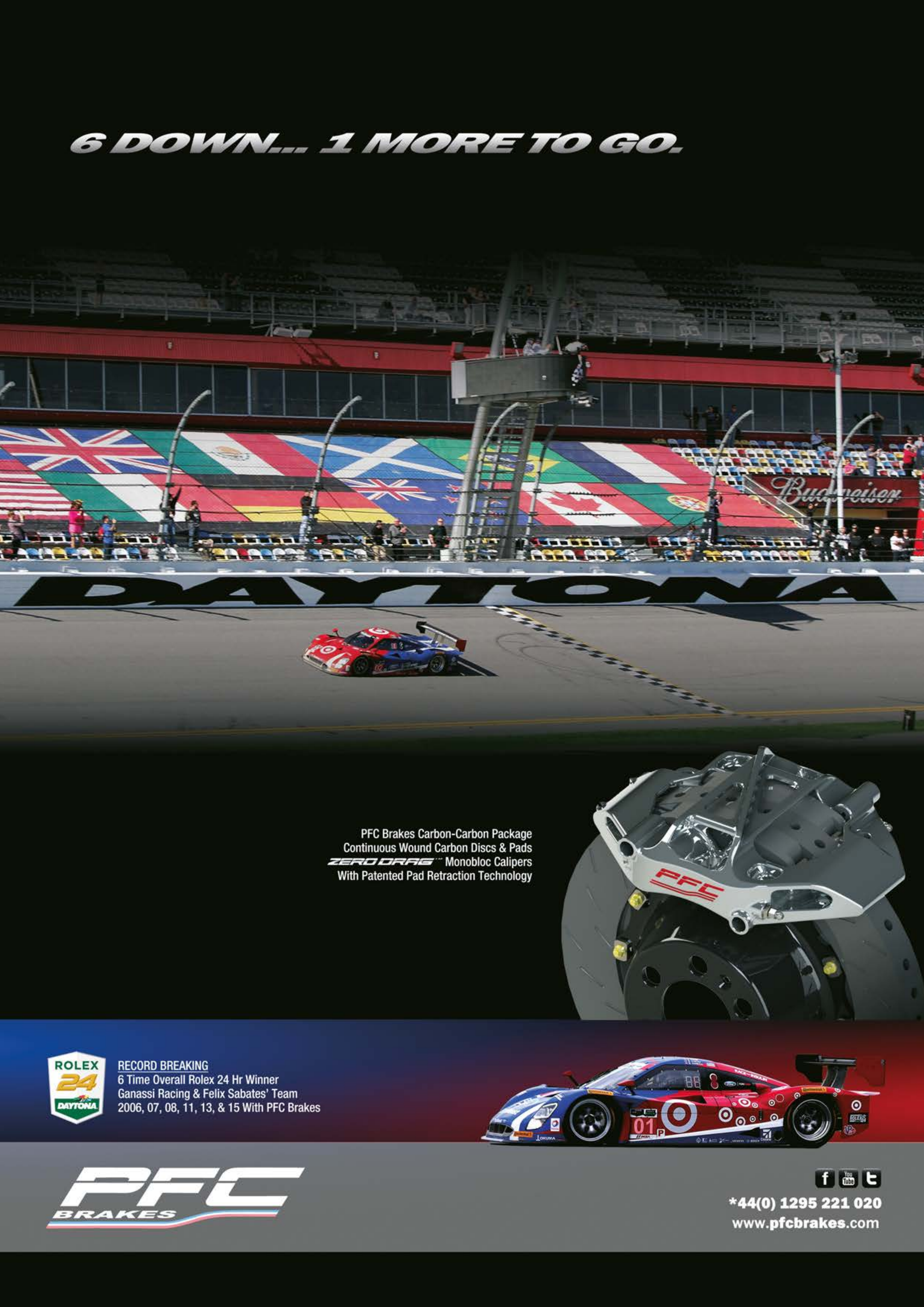
The cars were scrutineered at the start of the weekend and declared legal. What the team does after that is monitored by various marshals and suppliers, so the opportunity to actually cheat is limited. Did Audi deliberately falsify the car? I doubt it, it's simply too much of a risk. But clearly there has to be provision for an outright cheat in the event that someone does come up with a way around the rules and takes the risk, but perhaps that's not a worn skid plank.

There has to be provision in case of an outright cheat, but perhaps that's not a worn skid plank

Should the punishment be exclusion, or something that will not cause unnecessary confusion? Given that the car was deemed to be running too low, should the penalty not be that the car should run with a raised ride-height at the next race at Spa? That rather invalidates the aero measurement that Audi will get from that race, ahead of Le Mans, and would mean that the car would probably not be as competitive as it should be at the Belgium race either.

The bottom line is that the spectators saw something that was deemed not to have happened; that Audi won. The biggest punishment will come at the end of the season, when points will be tallied, and Porsche will undoubtedly be delighted to have got its first win of the year while Audi's challenge started with a non-score. But shouldn't the FIA take a leaf out of NASCAR's rulebook? Sunday's results stand, but when you are caught, you are punished for at least the next race, and perhaps for more further down the line too.

ANDREW COTTON Editor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