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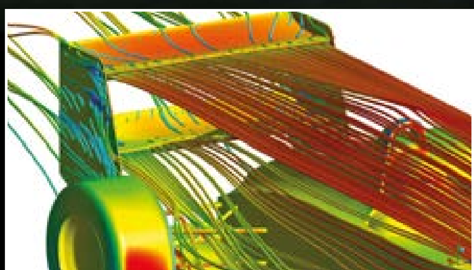
The secrets of the British team's Formula 1 success



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After a prolonged technical dispute, the ArtTech F24 made its Formula 3 debut in September. Turn to page 71 for more on this and other happenings of note in the world of Formula 3

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The rules of the game

While rules are natural and necessary they often have unplanned consequences

The Prince Otto Eduard Leopold von Bismarck, Duke of Lauenburg, was supposed to have said: 'The less the people know about how sausages and laws are made, the better they sleep in the night.' In this he was alluding to the often Machiavellian way things are discussed and negotiated when laws are being made, and it also applies to the commissions of most racing series that elaborate the rules, technical and sporting.

Rules are brought into just about every human interaction, for disparate reasons. In business, in society, even in warfare, there are ways and means defined about how to behave, catering to the innate sense of fairness that seems to be part of our psyche.

Any sporting endeavour, given that it is a fundamentally artificial construct, to mimic real life, either as a sublimation of our hunting instincts or as a simulacra of real life for educational or training purposes, also has rules.

Game theory

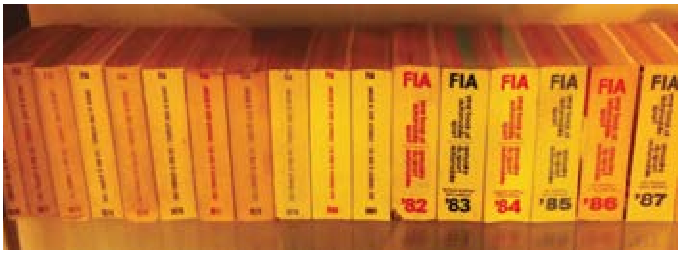
Most animals residing on the upper reaches of the food pyramid indulge in play: young tigers, lions, dogs and cats, rehearsing and honing their hunting skills in anticipation of adult life. In them, and in humans, it can also be used to bind the group and train them in working collectively.

We understand this interaction, and the saying that 'the Battle of Waterloo was won on the playing fields of Eton' reflects that. We constrain the game to how the participants behave, what they can use and in what environment they will exercise the sport. It would not surprise me if one day we will have a particular set of regulations that define exactly how we should proceed in the case of pushing a peanut with our nose to the top of Mount Everest. Just about everything else has been codified, for an intrinsic social reason.

The problem is that in sports that are not static just the natural acquisition of technology subverts the whole process, leading to the whack-a-mole churning of rules to contain the continual evolution of equipment. And in this eternal battle my money will always be on the engineers.

This does not only apply to motorsport, it is also in tennis, pole-vaulting, ping-pong or any other pastime. Basic athletics have not changed much; the marathon or wrestling being pretty much the same as when first done, but even the evolution of foot wear in the first case has been enhanced.

In this eternal battle my money will always be on the engineers



There are few sports that have quite as many rules as ours; but do they solve problems or simply create issues which then leads to even more rule making?

Mechanical sports pose a particularly difficult case for the rule makers. In the first place they try to maintain an equal playing field (see what I did there? Sport permeates our consciousness) for all competitors, exemplified by the general rule in all sports that we are not all equal despite the declaration of human rights. Splitting boxing, say, in different classes of weights, much as we can classify engine capacity for cars, or having equivalence formulas for NA and supercharged engines.

Balancing act

In a second instance we can direct a particular enterprise towards a goal, say by limiting the use of a particular fuel or technology, much as governments do with taxation, where they nudge a societal behaviour or consumption pattern to a desired paradigm.

Handicapping has been used in horse racing, but even more extensively in the Balance of Performance (BoP) to enable disparate cars from different manufacturers to race in the expectation of close results. The real performance of individual cars would never permit them to be raced together without one of the car reaching the Darwinian summit of victory by being the most capable under the given track conditions.

Success ballast is another way of bringing down the performance of the winning car in line with other competitors. This does not comply with good engineering practice, as it artificially constrains your efficiency, but is rendered palatable by at least producing a stage on which to compete. No Balance of Performance, no championship, or in the worst case scenario, single-make races.

The examples of different fuel taxation and emission controls today are but the result of laws that were implemented. The consequences are sometimes unexpected, not least because not everyone will play by the rules, but also because what is logical today is not necessarily valid tomorrow, as circumstances change. In the worst cases the law does not understand the problem, or does not take into account human nature.

The one-child rule in China is a prime example of how rules can skew society, bringing in long-term changes difficult to correct.

The wholesale condemnation of Formula 1 today is but the working out of rules that were brought in to correct and direct the sport to a particular vision, not necessarily the only one that could exist, but as soon as we are constrained by trying to keep it equally pleasing to the participants and spectators, the differing needs or reasons to do it are in instant conflict.

It must be paid for, either by sponsors or the public, and the choice of bringing manufacturers in by appealing to their marketing needs in the case of engine rules has the fallout of not pleasing because of the sound of the engine not being germane to an engineering problem, but directly related to the reasons the public watches, amongst others.

Noise for words

The limiting of aero to restrict car performance is the result of trying to keep cornering forces down and not surpass the safety capability of given race tracks, but it brings in complex interactions between competing cars that limits the possibility of overtaking due to the impossibility of starting a straight further behind.

And so forth, in a myriad welter of unexpected results. Just to look upon the front wing arrays on a modern F1 shows to what degree of bizarre results it can lead to. Efficient? Yes, but only in the constraints of today's particular regulations, not necessarily the best possible in an unconstrained environment.

So we can postulate that rules will never be the best solution to any game, just the result of the need to balance a moving target. The downside is the Parkinsonian growth of articles restricting, or banning, of items or concepts, and the even more complex 'clarification' of sporting rules. The recent recrudescence of 'track limits' has taken on a hilarious bent, one would think that it is self-evident and does not need four hundred words to define.

'Thus, we see that one of the obvious origins of human disagreement lies in the use of noises for words,' as Alfred Korzybski once said.

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Magical history tour

What might we learn from the engineering adventures of yesteryear?

Tucked away in Bedfordshire, England, just off the A1 is one of those jewels of engineering fascination that happily still exist in our highly-commercialised digital world.

Called the Shuttleworth Collection and based at Old Warden aerodrome, it holds an amazing assortment of historic aeroplanes, largely original and dating from the earliest days of flight up to the 1950s. Many of them can be observed being restored and maintained to the highest standards. Wonderfully, most of these aircraft regularly take to the air from the grass strip to give public displays. It also contains a variety of interesting aero engines, from rather crude Edwardian-era devices through mighty WWII multi-cylinder motors to the first examples of jet propulsion.

Sanity check

What, you may be wondering, has this to do with *Racecar Engineering*? Well, in his article in last month's edition Danny Nowlan argued strongly in favour of the 'sanity check' that the ability to carry out hand calculations brings. Standing back a little from the purely computer-generated results can often show up a miscalculation caused by a wrong input or value, and as such it is a very useful real world cross-check. In a similar way, but in a different context, viewing some basic pre-digital age engineering such as that on show at Old Warden can be enlightening to an engineer – especially one in the early stages of a motor racing career.

Who could fail to be inspired by, for example, studying the beautifully-made intricacies of a French-built Le Rhone Gnome WWI rotary engine, stripped and laid out in exploded-view form? Not to be confused with a radial engine, although on first sight it might look like one, this concept is that the crankshaft is fixed, and the cylinders rotate around it, driving the propeller via gearing. It was light, smooth and powerful and very successfully employed in Allied fighter aircraft. The mind boggles at the complexity involved and of the quality of the workmanship required in creating it, given the material and manufacturing limitations of over a century ago, also at the originality of thought of the Laurent brothers who designed it.

Such inspiration should encourage engineers to be willing to think outside the box and be prepared to consider technical solutions that don't just follow established practice. Frustratingly, the overly-restrictive and unnecessary technical regulations in so many areas of contemporary racing make this much harder. At least today's immensely powerful simulation tools permit even wild flights of imagination to be considered and evaluated, without the implications in time and financial risks of first making physical prototypes. I doubt, for instance, that Ben Bowlby would have taken such a major step as he did with his controversial front-engined Nissan LMP1 car had he not had computer simulation and previous track/race data to input into these programmes. So far it hasn't worked, but then neither did pushrod engines at the Indy 500 until Ilmor/Mercedes spectacularly got it right. Significantly different concepts take time to develop and prove.

It's not always recognised, but the Wright brothers attained the first heavier-than-air manned flight after years of belief, total commitment and meticulous research, including testing dozens of aerofoil and propeller shapes in their own-designed and built miniature wind tunnel (a copy of which resides in the Shuttleworth museum, as it happens). Their ingenuity in the design and operation of this measurement tool was at least as important as their vision and the engineering of the 1903 Wright Flyer itself. Eventual success was not just the result of crude trial and error and they were not put off by the many failures experienced along the way.

Huw Hopkins

WW1 fighter planes recreate a dogfight at the Flywheel festival in Bicester – young engineers might learn a great deal by studying the approach of aviation's pioneers

Along with notable feats of imagination and engineering evident in current disciplines outside of motor racing – the Solar Impulse 2 endurance-record breaking aeroplane immediately springs to mind – studying long-past technologies can sometimes provide the spark to set inquisitive minds along a path previously not considered. So much of modern racing car performance is buried in the various anonymous electronics boxes within, containing increasingly powerful and clever software. At least, with predominantly mechanical designs, most of it is in view and it can be a fascinating exercise to work out how and why the originator created the concept and made it work – even if some were a bit barmy. Studying some of the details, even of minor items, can be instructive and thought-provoking.

Past masters

The same applies to the engineering on display at historic racing car events like Goodwood and Silverstone, of course, and at VSCC hillclimbs such as Prescott and Shelsley Walsh, where there are some very quirky creations indeed. After all, the fundamentals don't change; more efficiency leads to higher performance, on the ground or in the air.

As a footnote and as a salute to those greats of design and engineering of the past, consider that jet engine pioneer Sir Frank Whittle's design of turbine blades has apparently still not been significantly improved upon, despite the more than 80 years that have passed and the vast computer power now available. Similarly, Brunel's nineteenth century ship's propeller design is considered to be within five per cent of the best efficiency since achieved. Alloy steel specifications developed by Rolls-Royce before and during WWII are still in constant use in aerospace and motor racing and have not been bettered. Anyone who has viewed the first-principle design calculations employed by Keith Duckworth in his iconic Cosworth DFV racing engine cannot doubt the benefit of sheer engineering knowledge and application, as well as his grasp of how it should contribute to and be part of the whole racing car package.

So nobody should believe that there is nothing to be learned from studying engineering principles and solutions of the past, while taking full advantage of the materials, processes and tools of the present – and of the future.

Such inspiration should encourage race engineers to think outside the box

The antagonist

Honda's top brass would not compromise with the design philosophy of its Super GT NSX – but did this mean the engineers were left with a compromised racecar?

By SAM COLLINS

The new rules meant the use of the DTM's single design monocoque and component list. But these rules did not suit Honda

Honda's Super GT NSX hit the track a long time before the street version hit the road – yet the latter dictated the major design themes for the racecar

The Honda NSX. One of those rare examples where a manufacturer launches a competition car before the production car is actually completed and on sale. Indeed, as the new production ready Honda NSX made appearances at motor shows around the world in 2015, the racing version was already most of the way through its second season of race action.

Launched in the summer of 2013, the Honda NSX Concept GT was built to Super GT's new-for-2014 technical regulations, which were aimed at the eventual unification of the GT500 class with DTM. This included the use of a Japanese-built version of the DTM's single design monocoque and component lists. But these rules did not suit Honda. DTM mandated the use of a front-engined rear-wheel-drive sports or touring car, but Honda simply did not have such a model in its line-up. It did not want to pursue the route it took with its previous design – the HSV 010, built around a non-existent production car concept – so it was decided at a senior level that Honda's GT racecars would have to be fully representative of its production cars. As the forthcoming NSX model was a mid-engined, rear-wheel-drive car (commonly referred to as 'midship' in Japan), then the new GT cars would have to be as well, despite what the rules said. What happened subsequently resulted in Masaaki Bandoh, the head of Super GT's promoter, describing Honda as 'antagonists'.

Midship mishaps

JAF, Super GT's sanctioning body, grudgingly permitted Honda to develop a mid-engined car around the DTM rules using the same components used by Toyota and Nissan (both of whom were building fully compliant cars), but this immediately caused issues for Honda's engineers. Masahiko Matsumoto, GT project leader at Honda R&D, explains: 'The DTM chassis is simply not designed to be a midship layout, it does not work. At first we had a problem with the aerodynamic devices because the DTM chassis is designed to have tunnels under the floor ahead of the rear tyres, but with a mid-engine layout the tunnels must be smaller so that was immediately a problem. Then, as the design progressed, we found another more serious problem. On our car with the midship layout, the monocoque sits 300mm further forward than it does on the front-engine cars, and that created a clash between the chassis and the steered front wheels.'

This was a potential showstopper for the Honda engineers. They simply could not meet the length and width requirements of the rules with a mid-engine layout using the DTM chassis design. They would have to do something different. Again they turned to JAF, which permitted them to use a special adaptation of the DTM chassis for their car, produced like the other GT500 chassis by Toray composites in the former Dome facility in Maibara, Japan. 'We had to change the chassis, we had to increase the scalloping on the front end of the tub which reduced torsional rigidity compared to the front-engined chassis and gave us a more central driver position. So that is another issue,' Matsumoto says.

Under the front bodywork of the NSX; showing the front impact structure, suspension, front subframe and the location of the front water coolers. But no engine, as that's in the middle

Once the design of the new car was completed it was given its first laps of testing at Suzuka, where yet another problem with the mid-engine layout surfaced, and although not unexpected it was a lot worse than Honda's engineers had hoped; the engine was getting far too hot. 'We had a big problem with heat on these cars at first,' Matsumoto says. 'The rear engine layout is hard in terms of cooling, especially with the intercooler which has to sit behind the chassis firewall, as we wanted it close to the engine. Because of that location it was always going to be hard to feed air to it. On the front-engined cars this is easy; to get the air to the intercooler, as there is little in front of it. So what we've done is feed ducting from the nose of the car, right through the car, to the rear for the intercooler.'

These twin tunnels, which run right through the car, are mounted low on the leading edge of the NSX and could easily be confused for brake ducts – though those sit just inside of the ducts to the intercooler. Twin water coolers are mounted at the front of the car, too, fed by a segment also within the nose ducts. The ducting used on the car at its launch and early specification was clearly not sufficient, and even before the teams took delivery of their cars the side scoops used for general cooling had to be substantially increased.

Trial and error

'Increasing the size of those scoops brings a big drag penalty,' Matsumoto admits. 'The ones we have are quite inefficient, but we need them that size. At first we put the intercooler layout next to the right side of the engine, but it was very small, so to increase engine performance we had to change the whole charge air cooling layout. We got some calculations wrong, I think, initially, so that is why we needed to make such a big change at the rear. The cooler was then relocated to a position above the engine, but it raised the centre of gravity a lot.'

Aerodynamic development of the NSX Concept GT was a departure for Honda. Its previous GT500 designs, the old NSX and HSV-010, were developed by Dome at its wind tunnel, but that facility and most of its staff are now part of Toyota Racing Development (TRD) and it was no longer available to Honda. 'This car was developed in our own wind tunnel at the new Sakura City R&D facility,' Matsumoto reveals. 'At the end of the third era of Formula 1 activity we built a full scale wind tunnel to support the Formula 1 project. It's a very good facility, featuring a moving ground plane and everything you need. The old facility at Tochigi only had a fixed floor tunnel which is why we used Dome's. We do all of our testing at 60 per cent and we used a smaller scale at Dome. The new tunnel is a big step forwards.'

The HR414E engine used in the NSX in common with the other GT500 cars has been built to the 'Next Racing Engine', or NRE, rulebook, introduced along with the new chassis at the start of the 2014 season. The NRE engines are 2-litre turbocharged in-line 4-cylinder units featuring direct injection and they produce upwards of 600bhp. For Honda this was somewhat uncharted territory as it had only designed one turbocharged racing engine

'We had a big problem with heat on these cars, the mid-engine layout is hard in terms of cooling, especially with the intercooler position'

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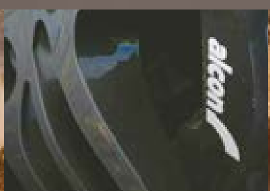



The launch spec NSX had inadequate cooling which led to a redesign. Note the size of the side scoop compared to the 2015 version (opening picture)

The rear end of the NSX with the 2015 specification intercooler just visible. The packaging and positioning of the intercooler was just one of the design problems faced during development


The monocoque of the Super GT Honda NSX had to be reshaped to avoid a clash with the steered front wheels – but as can be seen here it is still a very tight fit

in recent memory, the highly regulated GRE specification World Touring Car Championship unit. The NRE rules allowed much greater freedom in terms of design, but also created some new challenges, not least because of the lack of experience of the team behind it.

'The engine project saw only two or three people come over from the old Formula 1 engine project, and the rest were young guys,' Matsumoto says. 'While it was our second direct injection engine, we did not carry much knowledge over from the WTCC engine because of the rules; the NRE has so much more freedom. For example, the boost pressure is unlimited. The only real limits are the 200bar fuel pressure and a minimum weight limit of 85kg.'

Also, unlike with the WTCC, the NRE units are not frozen in specification. They can be updated, and towards the end of the 2015 season Honda introduced its fourth iteration of the HR414E. 'We are still developing always, we are now introducing a new version, which we call the D spec engine,' Matsumoto says. 'The A spec was just the initial test engine in 2013 and early 2014, the B came in later in 2014 and we started 2015 with the C, which had improved combustion. So by the end of this year all NSXs will use D spec, which has significantly reduced internal friction. Unlike the Formula 1 project we do not have a dedicated lubricant or coatings development programme. We just take an off the shelf Mobil 1 oil and that is run in all of the cars. Sometimes we have tried other oils in the engines, notably Motul, just to see how it compares, but the performance is very similar.'

Honda invested a great deal in the development of the NRE, not least because it has had a direct impact on the firm's F1 engine project, which shares many design elements and technology with the GT500 unit. 'There is a lot of information exchange between myself and Arai-san [head of the F1 project], especially to discuss the combustion,' says Matsumoto. 'It took a long time to get the combustion right, lots of learning and trial and error and in that respect the F1 engine was based on ours initially, as we started earlier. Both series have a fuel flow restriction, but the F1 engine needs more efficiency and has a larger turbo. The combustion shape is very similar, but the pistons, rods and everything else are very different; there are different materials used due to NRE engine being close to production parts.'

One difference between the GT500 NRE unit and the Formula 1 combustion development is the specification of fuel used in each series, something that has a significantly detrimental impact on the performance of the 2-litre engine, says Matsumoto: 'We both tried each other's solutions on the test bench but the

The NRE rules allowed much greater freedom in terms of engine design

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GT500 uses a Toyota-designed fuel flow restrictor which limits flow to 100kg/h. Super GT racecars are required to run on pump fuel

There's a free area for turning vanes and other devices on the side of the GT500 cars, in common with DTM. The DTM cars actually produce more downforce, but Japanese cousins have more grip thanks to free tyres

fuel is becoming an issue, because they have a good fuel made for this kind of engine and we do not. For us there is no fuel development. By regulation we have to buy the fuel at the tracks, from whatever supply there is available and we have no control over what that is. The combustion must be quite versatile for this reason. Before each race we go to the track and buy fuel from the pumps and go and try it on the dyno so that we can map the engines as best we can for that fuel. Some tracks have two suppliers so we have to test both. Sometimes the fuel we test ends up not being what we expected, so it's important to go before the race and test.

'We once put the Formula 1 fuel in the NRE and we easily had more power. If we had that fuel the NRE would have so much more power,' Matsumoto adds, though he would not be drawn on whether the NRE unit in the GT500 car would have more power than the RA615H V6 engine used in the McLaren MP4-30, simply smiling in response to the question.

Another controversial element of the design is again due to the no-compromise attitude of Honda's management over similarities between the production car and the competition car, and as result of this the NSX GT500 is a hybrid.

'We once put the Formula 1 fuel in the Honda NSX NRE engine and we easily had much more power'

'Our hybrid layout has a battery at the front of the car weighing about 35kg, the motor is mounted on the gearbox, and with the inverter the total system weight is about 70kg,' says Matsumoto. 'That includes everything; the cooling system and wiring harness. The system is capable of 60kW but the regulations force us to use no more than 21kW. The system modes cannot be used for push to pass or similar – it just works in unison with the engine. I think with the full 60kW we could lap around 0.4 seconds a lap faster.'

The MGU and much of the hardware used on the NSX hybrid system comes from British company Zytek, something of a surprise when you consider the expertise Honda has amassed as a company in the development of hybrid cars and technologies. But the reason this work has been outsourced was largely down to an abandoned concept which would have seen all of the cars racing in GT500 and Super Formula (which also utilises the NRE power units) running as hybrids.

Spec hybrid

'Zytek has very good technology for small hybrid systems and it is at a good cost,' Matsumoto says. 'We developed the whole system together as they have good knowledge of racing hybrid systems. We could have done it alone as we did in Formula 1 in 2008 and 2009, but initially, when the idea was that all cars in GT500 would be hybrid, we had to outsource it as Toyota would never use a Honda hybrid system, for example, and the costs were controlled if we all had the same.'

The Formula 1 system which Matsumoto alludes to was developed for use on the stillborn Honda RA109 grand prix car, and like the GT500 system featured a 60kW MGU-K, which was both smaller and lighter than the version used by Zytek. But the units built for the 2009 Formula 1 season remain tucked away in a storeroom somewhere in Honda's former research establishment at Tochigi.

'The Formula 1 component was much smaller and lighter but at much higher cost. I think the cost would be too high to maintain and operate on these cars so we won't use it,' Matsumoto says. Despite this there remains a close link between the hybrid systems used by Honda in Super GT and that used in Formula 1 today. But not in the GT500 category, rather in the smaller GT300 class where Honda runs a hybrid CR-Z powered by its LMP2 specification V6, the system used on that car is also supplied by Zytek but was used as a direct research tool for the 2015 Formula 1 project.

'While the system overall is quite different between the GT300 and F1, the two are in the same family, the usage strategies and design ethos is the same in both and was done by the same people. The GT300 was important in developing the MGU-K for F1 while the GT500 system is like a brother of GT300, it has a bigger battery capacity,' Matsumoto says.

Development on the GT Hybrid system has now concluded and all of the effort is now on the Formula 1 programme, though Matsumoto claims that as long as the NSX continues to race in GT500, it will remain a hybrid.

Throughout the 2014 and 2015 seasons the NSX has not seemed quite as competitive as its rivals from Nissan or Toyota, though in the wet and late in both seasons it seemed to become stronger. This apparent performance deficit is not just down to the less than optimal design route forced on the engineers by

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The rear wing on the Honda NSX is a spec part and is identical to that used in the DTM in 2013, although the Super GT cars do not use any form of DRS. At the sharp end the front spoiler is also a spec part, as is the car's underfloor and the diffuser

Honda's management, but also by a balance of performance applied to the car by the organisers of the series.

'Because we have a midship layout we are given a weight handicap by the organisers of 29kg,' says Matsumoto. 'In addition to that, as a hybrid we are given another 28kg handicap in exchange for the additional 21kW we can use. So we start off with a 57kg handicap, but as the season develops other cars start to get more success ballast and our cars get stronger as the year goes on. The top speed is about the same but the apex speed is down with our weight, even with the better distribution.'

The weight distribution of the Honda unsurprisingly does differ to that of its rivals, which in some situations gives the NSX a performance advantage, but again, overall, it is detrimental. 'It is much better than the front-engined cars, we have a 47/53 distribution while the front-engined cars obviously have a more forward bias,' Matsumoto says.' This is very good for traction, which means we are really strong in the wet, but it's difficult in the dry because we struggle badly with tyre life. We wear the rear tyre out too fast and then lose performance, and sometimes even struggle with heating the fronts.'

In Super GT, tyres are a major area of development, as it is an open tyre war with multiple compounds and suppliers: Yokohama, Dunlop, Michelin and Bridgestone all supply rubber into the GT500 class with the NSX primarily fitted with Bridgestones – although one of the cars uses Dunlops, which are specifically developed for it.

'Tyres are both crucial and very difficult for us with this car. We also have different suspension geometries to suit either Dunlop or Bridgestone tyres. The Michelin and Dunlop tyres are very similar in terms of set-up and geometries, but Bridgestone is quite different,' Matsumoto says. 'To optimise this we do a lot of driver in the loop simulation, but the tyre modelling data varies a lot as the tyre manufacturers are very secretive, even with us. We try with each team to get the drivers on the simulator, to drive a certain way with the tyres, which we guess. Of course, we do get some data but not as much as we like.'

'It's difficult in the dry because we struggle badly with tyre life. We wear the rear tyre out too fast and then lose performance'

Growth of simulators

Simulation is a major area of development for the three manufacturers, and it is still seemingly in its infancy, with expertise being imported from Europe. Matsumoto would not disclose which simulator Honda uses, but says that it is not a McLaren one. Further investigation amongst the English speaking Honda team personnel suggest that it is supplied by Ansible Motion, though this has not been confirmed.

'Every one of our drivers comes to Sakura to drive the simulator,' Matsumoto says. 'Getting the best out of it with the limited tyre data and the various teams and drivers is really quite difficult, there is a lot of trial and error. Each driver often feeds back very different information about the set-up or the tyre model, but sometimes we get them all feeding back the same thing. I think it is down to both a difference between driver ability and the data used on the simulator, so it's really a work in progress.'

TECH SPEC

GT500 specification (2014 and later)

Dimmentions(mm)
Length 4650mm
Height 1150mm
Width 1950mm
Wheelbase 2750mm
Overhang Front: 875mm Rear: 1050mm

Tyres
Front tread width diameter 300/680R18
Rear tread width diameter 320/710R18

Engine
2000cc Straight-four Direct Injection Single Turbo

Mnocoque: unified-use monocoque (same unit for all cars)
A designated common-use monocoque made in Japan is used by all cars. Functionally (weight, rigidity, center of gravity height) it is the same as the unit used in the DTM. These are developed jointly by the carmakers according to the designated dimensions

Aerodynamic devices: front spoiler, underfloor and diffuser have the same specification
Rear wing is a designated common-use unit. DRS is not used but the structure is the same as for the 2013 DTM cars.

Main components: designated common-use parts
Tyre supplier: multi-make
Note: all cars are left-hand drive and in Super GT the positions of the fueling port and exhaust pipe positions are changed (because of the mid-race driver change)

Overall it is clear that the Honda has been held back by decisions made for reasons of marketing rather than engineering, and those choices have seen its future involvement in the forthcoming DTM *vs* GT500 challenge races left up in the air. 'I hope that the Germans will accept our car, but right now, as it stands, we cannot race with the DTM cars. Maybe we will be allowed to attend the challenge races, but it's not clear at the moment. If we are allowed to then we will take part.'

Looking to the future Matsumoto admits that he is not fully satisfied with the current rules, but is resigned to working within them. 'If I could change anything about GT500 I would go back to the old regulations, because I am an engineer. I liked the old regulations and the freedom of them, but in terms of cost reduction the DTM regulations are much better, but they are not so free.

'What I would like within the DTM framework is more areas to develop on the car, to let in more parts from other makers, and actually that could reduce costs. With the HSV 010 we had many brake suppliers, for example, and now we have one and that is more expensive for us, plus there is no development for those suppliers,' Matsumoto says.

The engineering-driven ethos of the GT500 teams still remains at odds with the marketing-driven DTM teams. While in GT500 engine development is free, in DTM it is to be frozen even after the German series introduces its new NRE style engines. All of this remains to be resolved before the first challenge race takes place at Fuji Speedway in late 2017.

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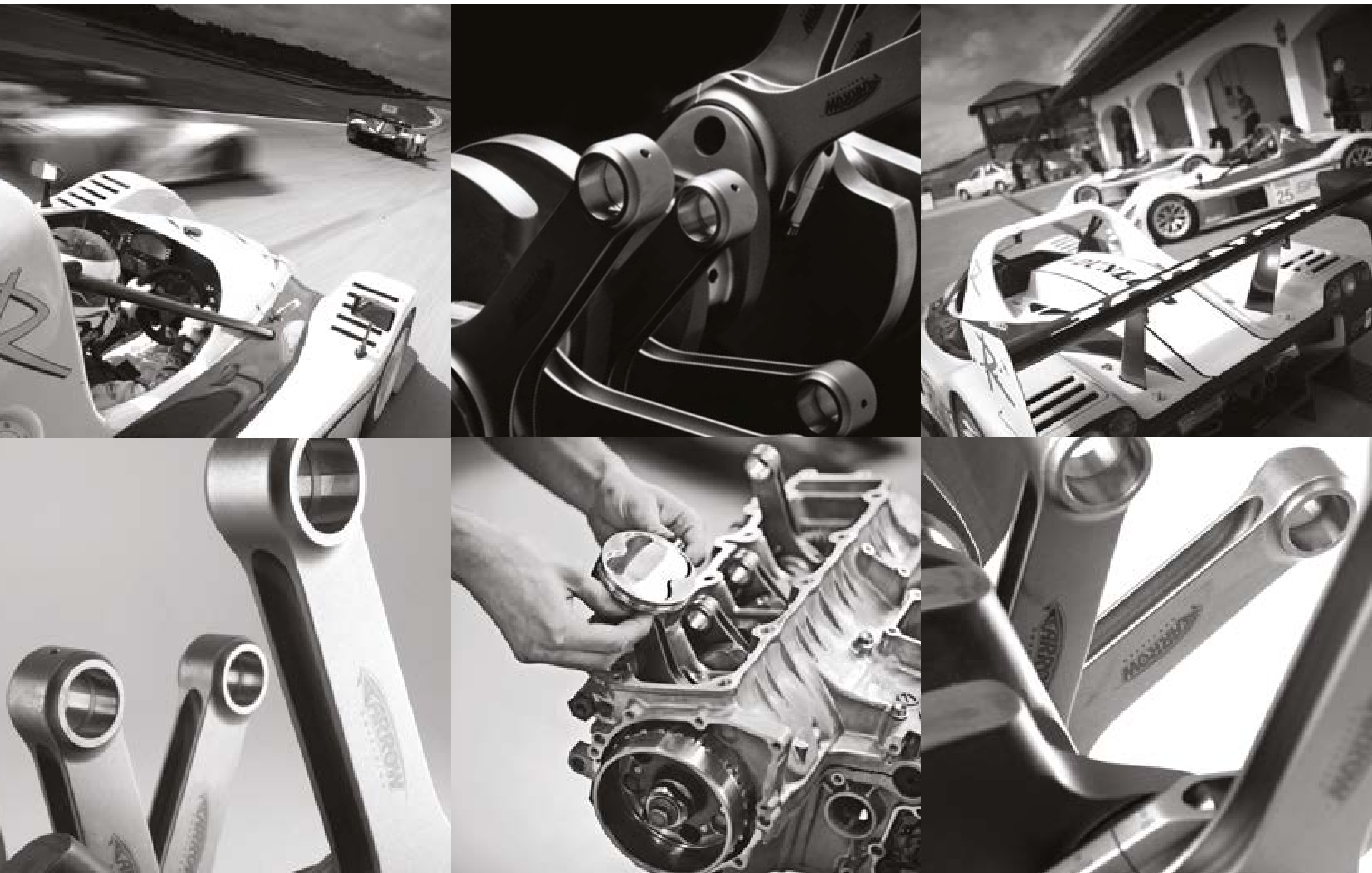

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Punching above its **weight**

Williams may be the ‘poorest’ of the grandee Formula 1 operations but its FW37 has propelled the team to a clutch of podiums this year – *Racecar* uncovers the secrets of its success

By SAM COLLINS

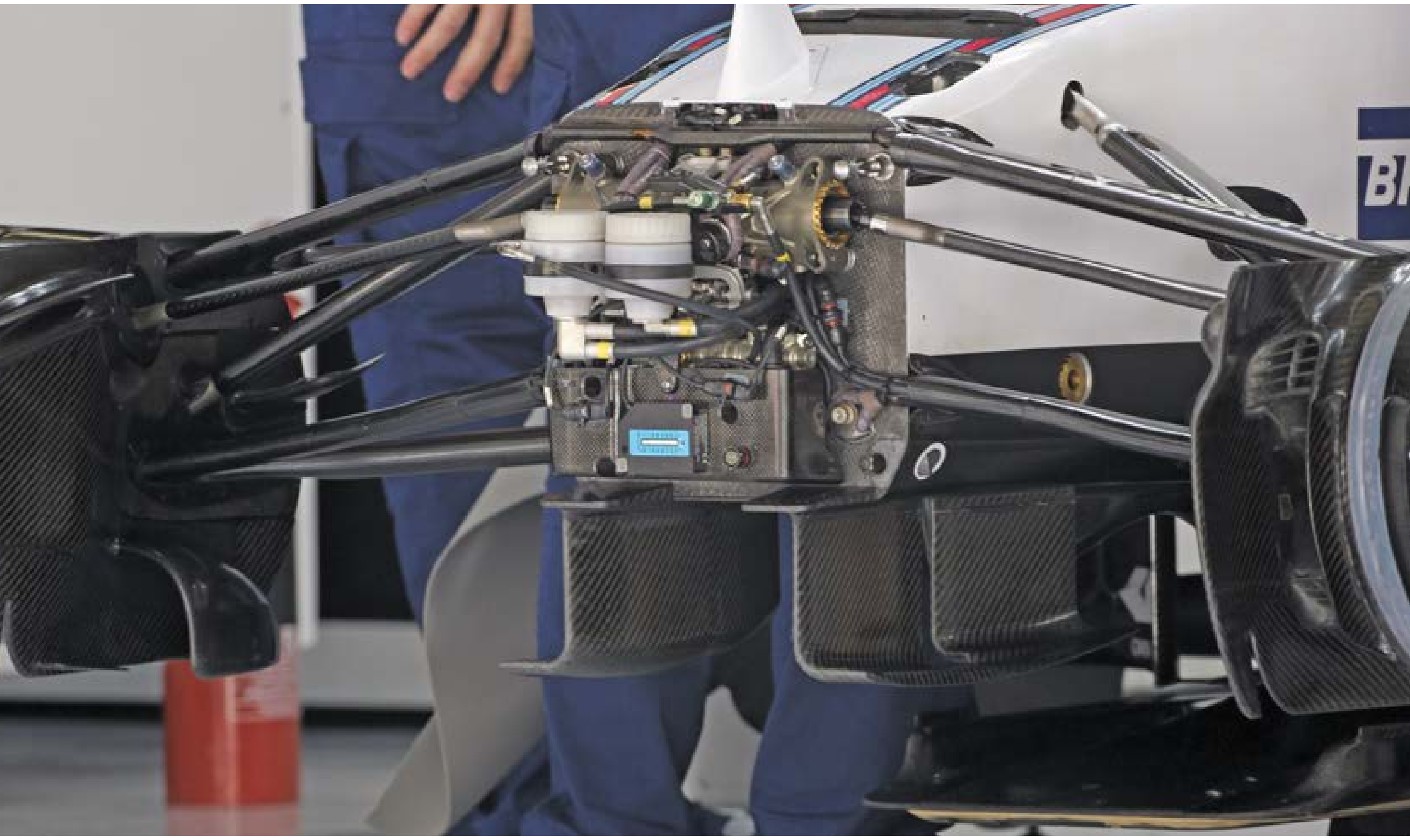
It is the most reliable car of the 2015 F1 season and despite its distant third position in the constructors' championship, at the time of writing, it is also one of the fastest. Work on the Williams FW37 started before its predecessor the FW36 had even turned a wheel, despite the arrival of the new rulebook last season. But as soon as the strengths and weaknesses of the 2014 car were understood, those lessons started to feed directly into the development of the 2015 model.

'The notion for the FW37 was to look closely at the FW36 and its performances,' says Williams chief technical officer Pat Symonds. 'We then went about recognising what had worked well and identifying and resolving the areas that we felt needed to be improved. The desire to beat Ferrari to third place in the constructors' in 2014 meant we pushed our development through to late autumn, but the size of the team is now at a point where it was able to sustain this development whilst still working on the FW37.

'We felt we came up against design barriers in the FW36 and so took the opportunity to remove those barriers for the benefit of the performance,' continues Symonds. 'From that process our main objectives were to improve the aerodynamics as that is where most of the performance comes from, and in addition we were also carrying an awful lot of ballast last year and decided to turn some of that into performance, so I guess those were the main goals; aside from that there were a lot of little things to tidy up year on year, but that is normal. As a result it's absolutely a refinement, very much an evolutionary change.'

Indeed, the car itself is visually similar to the FW36 and as Symonds states the overall concept is similar, too, with front pushrod actuated front suspension and a pullrod actuated rear. As with the 2014 car the FW37 is propelled by the best in class Mercedes power unit, but the details of the car have been heavily revised throughout, not least in the engine compartment. Mercedes

'Our main objective was to improve the aerodynamics as that is where most of the performance comes from'

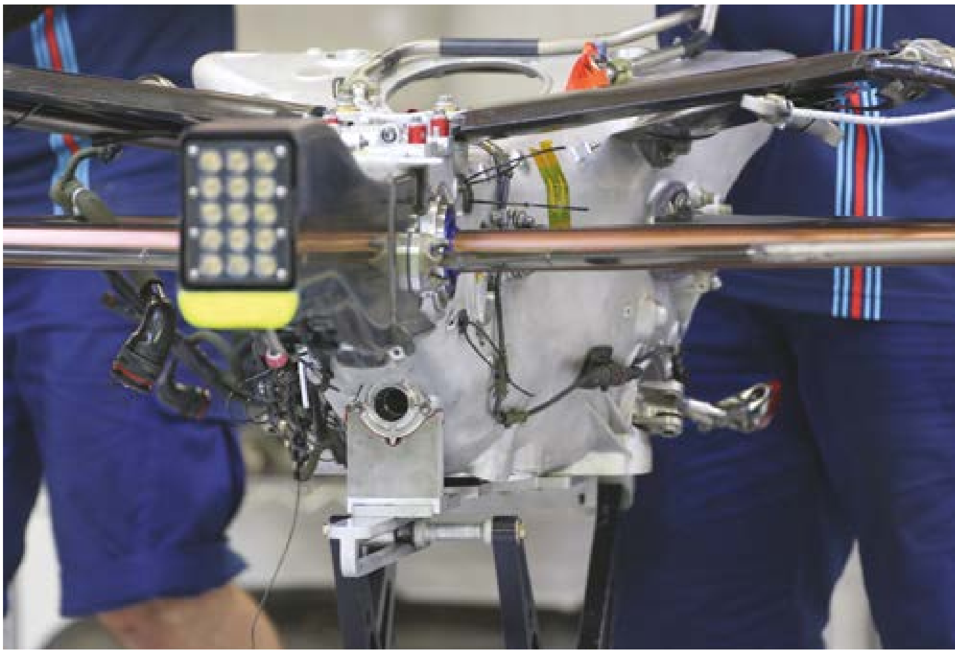


claims that its 2015 power unit is 'all new' and it is indeed visually very different to the design used in 2014. Gone are the distinctive log type exhaust manifolds in favour of a more conventional layout, the plenum has also grown significantly to accommodate a variable inlet system. In terms of the car's weight it is impressive that Williams in 2014 was able to run a large amount of ballast when a car using an identical power unit, the Force India, was struggling to get down to the weight limit at all.

Weighty issues

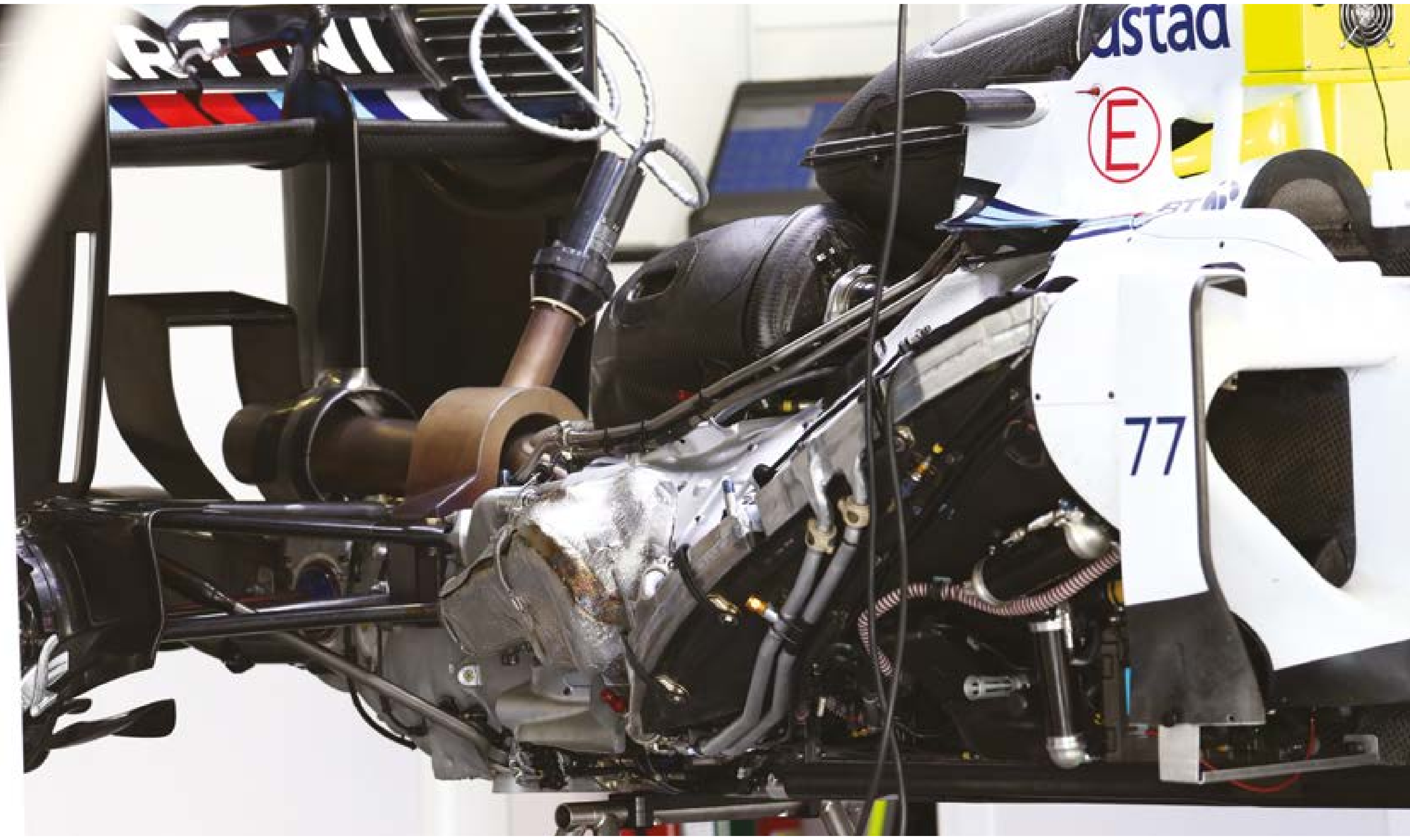
This allowed the Williams engineers to revisit areas of the car where they had traded off possible gains in favour of the lighter weight. A good example of this can be seen on the rear suspension of the FW37. 'The FW36 somewhat unfashionably retained a lower rear wishbone mounted relatively low on the upright, on the FW37 we raised it for an aerodynamic gain,' says Symonds. 'This had many implications, not least that the loads through the wishbone were increased significantly, which meant that we then had to increase its mass in order to retain the required stiffness.'

But even with the power unit's improvements, lessons learned in 2014 were crucial in optimising some components of the 2015 car. 'We learned a lot more about the true characteristics of the power unit, especially the torque characteristics; the understanding of what that did with the tyres. I guess we



Above top: The front suspension is pushrod actuated, as it was on FW36. New regulations for this season resulted in the front torsion bars being mounted on top of the chassis and behind the bulkhead
Above: Williams designs and builds its own gearboxes and for the FW37 most of the work on the eight-speed unit was concentrated on tidying up the packaging, while there is now no longer a separate bellhousing

The car is visually similar to the FW36 and the overall concept is similar too, with front pushrod and rear pullrod suspension

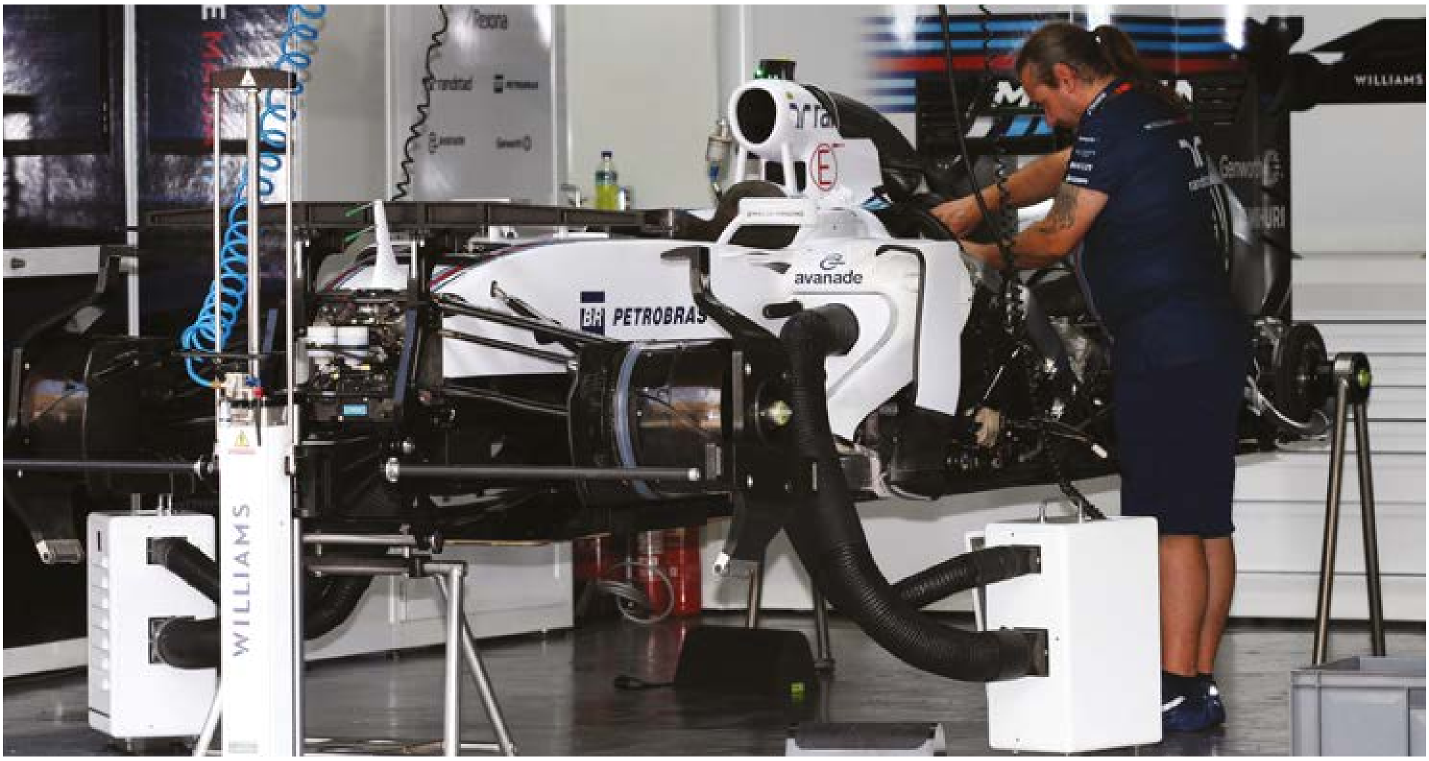


Above top: While the FW37 is a neat and effective car there is no hiding from the fact that it also packs the best power unit on the Formula 1 grid by some margin, in the shape of the all-conquering Mercedes PU106B
Above: The lower rear wishbone has been raised for aerodynamic purposes, but this meant Williams had to increase its weight in order to strengthen it, to counter increased loads going through it in this new position

'We no longer have a separate bellhousing; that gives a benefit in terms of stiffness as well as a small weight saving'

confirmed our efficiency curves, but we were ahead of the game on that,' Symonds adds.

One area where these lessons made a notable impact was with the transmission design. Williams designs and builds its own gearboxes rather than following the route of many other teams and simply buying in a design from the works supplier. The FW37's 'box is a good example of what Symonds describes as 'tidying up' the car. 'There is not that much to be gained in transmissions now. Even with the move to the eight-speed last year I think the shape is pretty much optimised, it's difficult to pull them in and make them any narrower, though we did a lot of tidying up on the casing,' he says. 'For example, the dampers were on the outside of the gearbox last year and now we have them in the bellhousing. Last year we also had the separate titanium bellhousing with the gearbox bolted to that. We did that because we were not sure what kind of temperatures we were going to see around the turbine and tailpipe, so this year we realised that those concerns were not really an issue, so we got rid of one joint face and took the casing all the way forwards up to the engine so we no longer have a separate bellhousing; that gives a benefit in terms of stiffness as well as a small weight saving. I think that kind of layout is becoming standard with all of the parts tucked up in the bellhousing and I would not expect to see much change in that area on cars next year.'



The FW37 is very much an evolution of last year's FW36 and, as with last season's car, it's shown good pace in most races in 2015, although it has lost some ground to Ferrari

Williams opted for a so-called 'short nose' for the FW37, where the leading edge of the nose structure sits very close to the trailing edge of the centre section of the front wing; this resulted in a small shift of the aero balance to the rear of the car

The Williams gearbox features a cast aluminium casing, something that is perhaps not seen as cutting edge as some of the other composite casing designs on the grid, but Symonds and his team believe that it is perfectly adequate and the best solution for the car. 'In terms of the material, the aluminium 'box is a bit cheaper than others, I don't think it really compromises things at all. Composite gearboxes are very nice but they are very labour intensive to make, so we choose to use our resources in other areas,' he explains. Chief test engineer Rod Nelson adds: 'The transmission is a complex thing that for most cars will be frozen throughout the season because it's one unknown you just want to nail. Where is the performance? Well it's usually in the power unit, the ERS, and putting more downforce on the car.'

After the deeply ugly 2014 cars were seen for the first time a relatively late and seemingly minor change to the front crash structure regulations was made, but this had a much larger impact on the car design overall than anybody had expected. The new rule forced the front of the chassis to be lower, which in some cases meant a smaller front bulkhead. In the case of the FW37 it resulted in the front torsion bars being mounted on top of the chassis and rearward of the bulkhead itself, an approach seen on a number of 2015 cars.

'That offered us a slight headache,' Symonds says. 'The rule change had some relatively innocuous wording, the packaging itself was not that difficult, we had to move a few things around but there was nowhere where you pinched the packaging space. In fact in some areas the packaging is now a bit more elegant than when the chassis was a little bit higher. When we got into the wind tunnel we were quite surprised there was a considerable loss of downforce and the concentration was then on bringing it back, but the effect on the aero was profound.'

Nose job

Williams is one of a number of teams which started the season with a so called 'short nose', where the leading edge of the main nose structure sits almost at the trailing edge of the centre section of the front wing with only a small protuberance for the front impact structure. Some other teams, like McLaren, started the year with long noses, and struggled to get shorter versions through the crash tests mid-year once they realised the benefits of doing so; while other teams such as Sauber and Ferrari retain their longer noses.

'Overall I suspect that most people got back to where they finished the previous year in terms of downforce rather than moving forward much,' Symonds says. 'The main challenge with the noses was understanding what it all did to flow structures. The aero balance did move rearward but perhaps not as much as you may think. It was all about those flow structures off the front wing and ways to get them back and getting them doing what we wanted to. Those structures don't influence front downforce they influence the rear more. It was overall a bit more front loss than rear.'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As with much of the car, the FW37's roll hoop concept is largely a carry over from the FW36, although the twin forward-support design dates back to the FW35 despite the change from Renault V8 to Mercedes V6 that has taken place since

Nelson adds: 'The more you optimise around one architecture the more of a hit you're likely to get when that's changed all of a sudden. If you've got a really complex system of vortices coming off your front flaps and it all works with your nose and with the diffuser and everything then you're going to take a big hit, whereas if you've got something that's less optimised you're likely to take less of a hit when you change things a little bit.'

Throughout the season Williams, much like every other team, has introduced new parts around the front of the car such as turning vanes under the nose and differing iterations of front wings. 'That whole area is quite productive in terms of aerodynamic development as it is an area that was significantly impacted by the lower bulkhead we had to incorporate,' Symonds says. 'It was a high gain area through the year in terms of development parts but it is peaking out a bit now. It's always the case with new regulations, you get a steep learning curve then the diminishing returns; that is one of the reasons that it is quite nice having stable regulations as it does tend to close the field up.'

Indeed, while in 2014 the Williams was battling with Ferrari for third in the championship, it has comfortably held that position for most of the year, yet Ferrari has leapfrogged the English team to secure second in the points standings. Despite this Symonds feels that Williams has in fact closed the gap to the 2015 World Champions, Mercedes, though they remain dominant. 'On average this year we are 0.9 per cent off the Mercedes; last year we were about one per cent off them, though we had hoped to be closer this year,' he says.

'It is just a very good racing car. It has fabulous reliability, it's easy to set up, it has a wide sweet spot, it is easy to drive'

Mind the gap

In terms of the gap to Ferrari, despite the gap between second and third in the championship being over 100 points, Symonds feels that the FW37 is not generally losing too much in terms of its chassis and aerodynamic performance: 'I think that Ferrari have certainly gained an enormous amount on the power unit relative to ours and particularly, I think, their ability to use the power unit strongly right through the race, that looks quite impressive,' Symonds says. 'But we have followed them at various times in the races and our drivers don't really identify particular areas of weakness. They do identify that we are much stronger in the quick corners, but that's about it.'

While he did not want to be too drawn into discussion on where the deficit to Mercedes could be found, Symonds did suggest that the car's aerodynamics were a significant part of it: 'We have a car that is a pretty good all-rounder. I'm not trying to make out that it does not have weaknesses on the slower circuits, but it is bloody good in quick corners. It has very good aerodynamic efficiency even if it does not produce as much load as we would like. It is just a very good racing car. It has fabulous reliability, it's easy to set up, it has a wide sweet spot, it is very easy to drive, it is all of the things that a racing car should be. I think if there is an area where we needed to improve it was on the lower speed corners, and we worked hard on that after Monaco. I think Singapore showed that we made some progress in that.'

TECH SPEC

Williams FW37

Class: F1 2015
Power unit: Mercedes Benz PU106B, 1.6-litre 90-degree V6 single turbocharged (electro turbo compounded). High-pressure direct injection (max 500bar, one injector/cylinder), pressure charging single-stage compressor and exhaust turbine on a common shaft. Max rpm exhaust turbine 125,000rpm; 120kW MGU-K (MGU-H performance not disclosed)

Transmission: Williams eight-speed seamless sequential semi-automatic shift plus reverse gear; gear selection electro-hydraulically actuated.

Chassis: Monocoque construction laminated from carbon epoxy and honeycomb

Suspension: Double wishbone, pushrod activated (front) and pullrod (rear)

Brakes: AP 6-piston front and 4-piston rear calipers with carbon discs and pads

Clutch: Carbon multi-plate

Cooling system: Aluminium oil, water and gearbox radiators

Steering: Williams power assisted rack and pinion

Fuel system: ATL, Kevlar-reinforced rubber bladder

Cockpit: Six-point driver safety harness with 75mm shoulder straps and HANS system; removable anatomically-formed carbon fibre seat

Wheels: Apptech forged magnesium

Tyres: Pirelli
Fronts: 245/660-13
Rears: 325/660-13

Electronic systems: FIA SECU standard electronic control unit

Dimensions
Width:1800mm
Length: 5000mm
Height: 950mm

As attention turns from the 2015 season to the 2016 season, Williams remains driven to improve its performance and it is clear that it wants to return to the top step of the podium on a regular basis. Rob Smedley, head of vehicle performance at Williams, sums up the aims for the FW38, which will again likely be an evolutionary car, with the rules being largely stable. 'Every single bit on the car is weak for me, we never stop working on all of them. I think what we did for those slow corner type [tracks] is that we closed the gap a lot. We understood a lot more about what to do with the car and we are making steps in that direction, but until we are the quickest car then all areas need to be improved and even when we are, they still need to be improved even more.'

So then, despite having a smaller budget than many of its rivals Williams clearly intends to move back to the very front of the field just as soon as it can.

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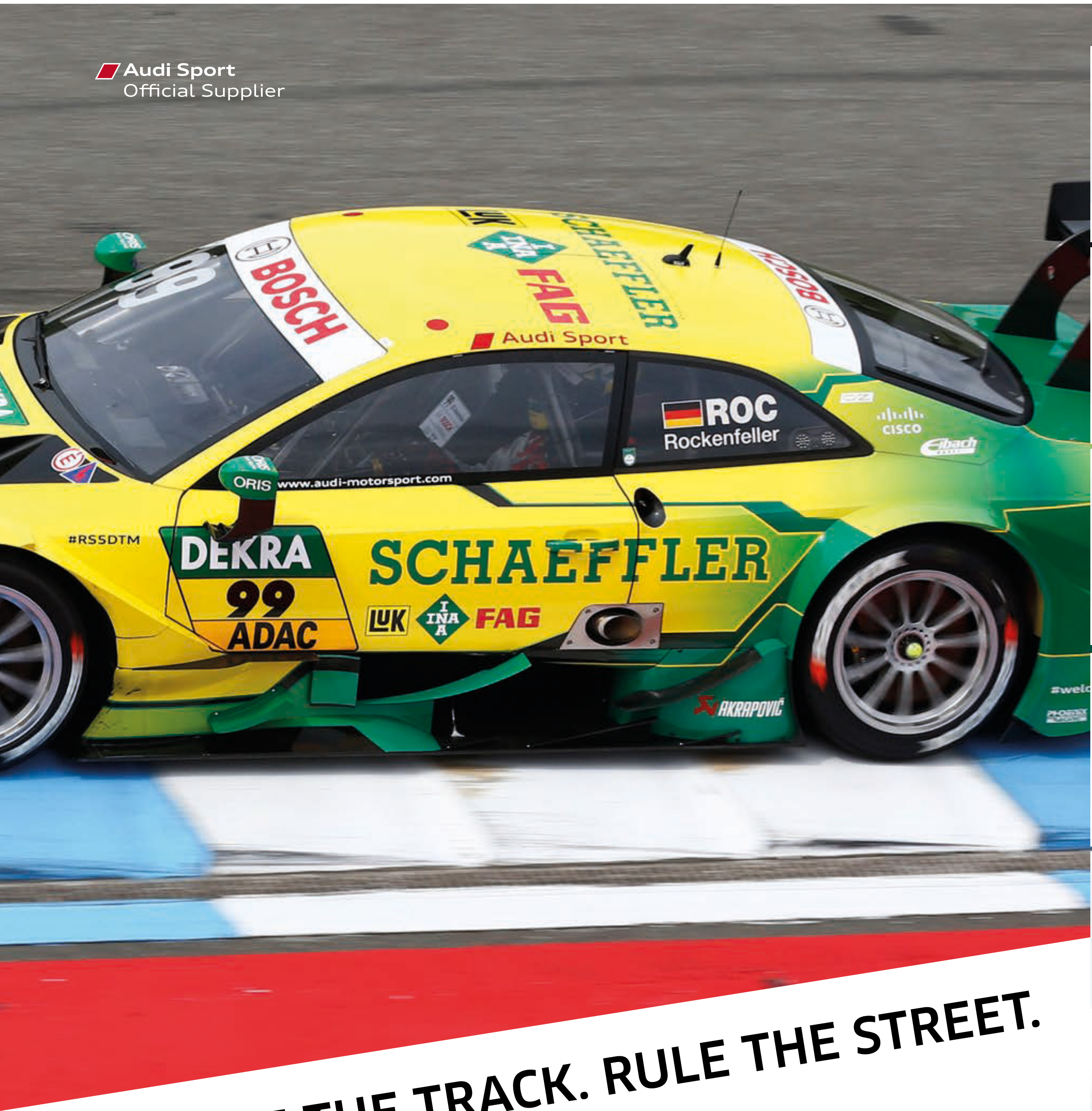


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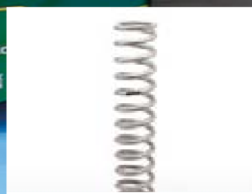
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MC squared

The Kelsey MC2 is as close to a modern-day take on the Metro 6R4 as you're likely to find – but what makes it truly special is that this 460bhp creation is largely home-built

By DR CHARLES CLARKE

'With the engine and the gearbox in the middle of the car we get an almost perfect weight distribution'

The 'MC' in Kelsey MC2 stands for 'mad creation'. Yet while the concept of a self-built mid-engine high spec rally car might be considered just a little left field, the project itself is actually a triumph of pragmatism and good old fashioned New Zealand ingenuity. The Peugeot 207-based car is the brainchild of Alex Kelsey, an unassuming 22-year-old Kiwi who likes building things – and then likes to go on to build other things which are better, and faster.

Kelsey's father owns a quarrying and contracting business in the Coromandel, an area of the North Island of New Zealand, which is a cross between 17 Mile Drive and Martha's Vineyard, and is the home of the NZ Leadfoot Festival. Richard Kelsey was a successful rally driver in his youth and Alex helped him build a Mazda RX7 wankel-engined rally car when he was 12, and went on to be a winning co-driver by the time he was 14. Kelsey junior has also been karting since he could reach the pedals, while his many YouTube videos testify to his serious driving skills.

The MC1 was his first rally car, a Subaru WRX with which he competed in the NZ Rally Championship. While he was still at school he modified the Subaru suspension to give 50 per cent more travel than the Group N rally Subaru. This was also where he started making shock absorbers and getting involved with modifying suspension geometry to give him the driveability he was looking for. 'I basically made all the suspension components from scratch, the shock absorbers, the struts, the cross members, were all my own design and construction,' says Kelsey. 'I just bolted them into the Subaru body. So I learnt an incredible amount there.'

Need for speed

But eventually the lust for more speed took over. 'I thought that what I was racing was boring and the noise wasn't there. I needed something that looked awesome, that sounded awesome and was easy to work on. So I set about finding the right engine and putting the whole car together.'

Kelsey decided to build his own dream rally car from the ground up. To help him with his quest, his parents bought him a copy of SolidWorks for his 18th birthday and three years later, the MC2 turned a wheel. But before

It may look like a Peugeot 207 but under the skin this manic creation packs a 460bhp ex-WSR 3.5-litre V6 and oodles of original thinking

that the second most important application kicked in. Google allowed Kelsey to find the bits he needed to turn his creation into reality. He sourced a 3.5-litre V6 World Series by Reanult engine from France. This was a bargain, since the racing series had shifted to the V8s in 2012.

He found a special Sadev 6-speed sequential gearbox, again in France and linked this to a Sadev transfer box that split the drive 50/50 to two Sadev differentials front and rear. The engine is mid-mounted while the gearbox is located between the seats. 'It's a bit of a special Sadev box as it's the smallest one they make so that it can fit between and seats,' says Kelsey. 'With the engine and the gearbox in the middle of the car we get an almost perfect weight distribution.'

The transmission is similar to a lot of four-wheel-drive installations, with the closest to the MC2 perhaps being a Metro 6R4. The difference between the two is that the MC2 engine is about 700mm further forward of the rear axle, which also helps with the weight distribution.

Lion skin

There is also a clutch by the engine/gearbox mounting plate that is linked to the handbrake. This disconnects the drive from the back wheels when the handbrake is applied, thereby turning the car into front-wheel-drive to help it negotiate the tighter corners.

As far as the car itself is concerned, Kelsey started with a Peugeot 207 Rallycross body. He chopped it up, modified it and made his own moulds. 'I was really lucky to have the help of Brian Hayton from Possum Bourne Motorsport with this part of the project. The Peugeot 207 defined the overall dimensions and gave us the hard points for the suspension.

'The reason we went for a Peugeot body was that it was the only one wide enough to accommodate the mid-mounted engine and transmission tunnel, and still allow two normal sized seats either side,' Kelsey says.

Because there is so little of the original Peugeot left, apart from the overall external shape, the car is registered as a Kelsey MC2, not a Peugeot, and it appears in competition entry lists as such, too. 'To be honest I should have made the whole body rather than keep body components that resembled the Peugeot, but it saved a lot of time in the initial build process,' Kelsey explains. 'In fact the only panel that is original is the roof, everything else has been reshaped or modified to work around the internal components. The removable clamshells front and back makes it really easy to work on.'

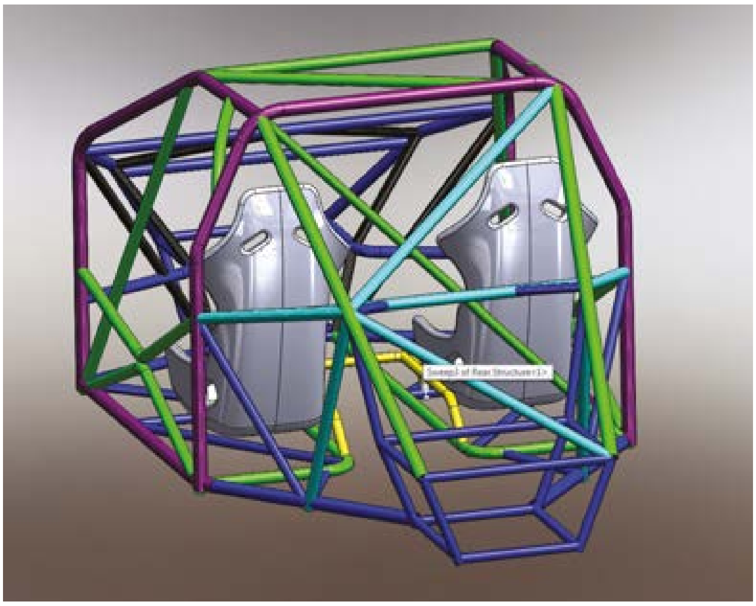
The chassis is a chrome-moly spaceframe designed in SolidWorks. 'All we had to go on was the width and the wheelbase. We put the engine and gearbox models into the CAD frame and adjusted the positioning in the software,' Kelsey says. 'We set about building the chassis and I was really lucky to have the help of Dan Slater in Auckland – we built the chassis and other various parts together. The whole chassis weighs about 140kg so it's not very heavy.'

Bridge support

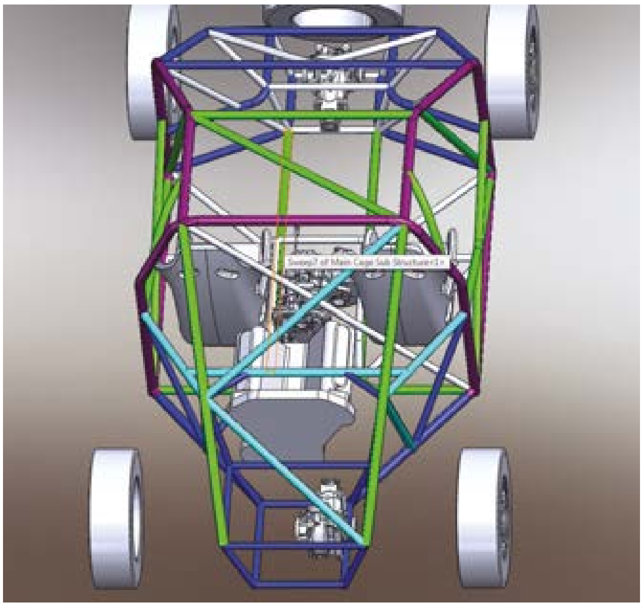
The chassis frame looks very similar to others as it uses the familiar chrome moly 4130 tubing. As with most other components the chassis was made in-house. A piece of bridge steel, recovered when a local road bridge (Tauranga Harbour Bridge) was dismantled, was used as the surface plate to build up the chassis as he could weld straight on to it. (Kelsey has been welding since he was about 14). The tubing was laser cut and welded in place on the surface plate. The resulting chassis is true corner to corner, plus or minus about a millimetre.

The suspension is double wishbone front and back. 'This was a bit of a change from the experience I'd had with the Subaru MacPherson struts,' says Kelsey. 'With double wishbone you don't have the mechanical interference that you get with MacPherson struts. I was really lucky to have help from Matt Houston, a friend of mine. We came up with a very good set-up that works very well and now that I've had some seat time in the car I wouldn't change a thing.'

Kelsey used the SolidWorks bundled FEA software to analyse the components and a program called Susprog3D to design the suspension with Houston. 'We used Susprog when I was working on the Subaru – it did a good job then so I decided to use it again,' says Kelsey. 'It's not the easiest piece of software to use but you can get the hang of it relatively



The spaceframe was designed on SolidWorks and it's built from chrome-moly 4130 tubing, which has been laser cut and mounted on a chassis plate which was once part of a bridge



At the heart of the machine is the V6 race engine, mounted in the middle in a similar fashion to the Metro 6R4. The powerplant is high power but low torque

Because of the costs involved with high-end rally shocks Kelsey decided to design and build his own dampers. To protect the IP in the shocks he made sure parts were machined by different companies while also making some bits himself on his lathe

A piece of steel recovered when a local bridge was dismantled was used as the surface plate to build up the chassis

quickly.' It should be noted that Kelsey hasn't had any specific training to do any of this, other than growing up helping his father build his car – but then that is a pretty good apprenticeship for this kind of project.

'We decided to design our own shock absorbers because of the cost of sophisticated rally shocks, and it was a lot easier to get what I wanted from the shock absorbers instead of trying to tell someone else the kind of suspension response I was looking for,' continues Kelsey. 'The experience with the Subaru meant that it was far easier for me to make my shock absorber of choice than anyone else.'

It's much more difficult to tune suspension for rallying conditions than it is for relatively consistent tarmac conditions. Because of the variability in the surface it is essential to have a suspension package that can be adjusted to accommodate the likely surfaces found on a single stage and there is a great deal of adjustability in the shock absorbers to suit different road conditions. 'There is also a feature inside the shock that makes it progressive,' Kelsey says. 'Let's say you're on a slippery surface and the car's not moving around much, so the suspension will be quite soft. When you come into a dry section, the car will start moving around so the suspension will stiffen up to accommodate change in surface.'

Shock and awe

Kelsey adds: 'We bought a lathe from China in order to manufacture the parts for the shock absorbers. Once we perfected the shocks we got the various bits machined in Belgium. They made enough components to build 12 sets.

'There is quite a lot of IP in the shocks so we were careful not to give too much of that away when we were getting parts machined. No one machining company machined all the bits,' says Kelsey. 'Everything is checked when it comes back from any external manufacturing process and everything is crack tested.'

The first set of shock absorbers were bush guided items which attached at the front side of the axle. This produced significant loading on the shock and internal interference with the main piston because the shock absorber was located at an angle. 'The suspension was continually trying to bend the shock and pull it away from its mounting,' says Kelsey. 'So I went to a roller bearing guided solution, which meant that I had to remanufacture the shock absorber starting with a solid rod, and line boring it. This is quite hard to do on a manual machine but I got there eventually.'

Travel tales

The seeds for the shock absorber design were planted in Baja, California. 'I went to the Baja 1000 with my father and I was looking at the Trophy Trucks that had huge suspension travel, which I felt would work really well for a rally car,' Kelsey says. 'So I went to work on the Subaru and modified it until I got the suspension travel that I was looking for. In the end I completely remodelled the body of the car.'

The main limiting factor with the shock absorbers at the time was the fact that there was an external adjustment tube. 'This is not particularly useful in a rally car with coil over suspension, so I set about achieving the same result using an internal adjustment mechanism,' says Alex. 'This adjustment is also position sensitive. The shock absorber adjusts the dampening depending upon where the wheel is and the extension of the shock absorbing unit. At full droop the shock absorber is quite soft and as it shortens it gets stiffer.'

This worked really well on the Subaru so it was refined for the new car. 'Now it's a lot more compact and having SolidWorks available I can make it a lot better. There are some special

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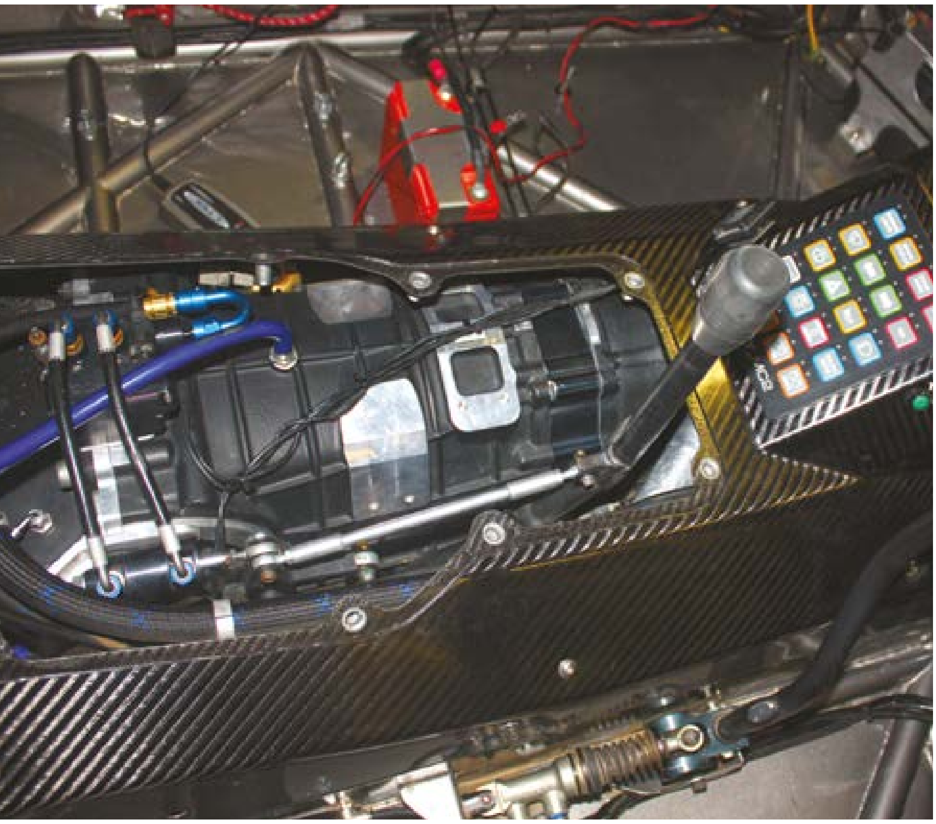


The Sadev gearbox is mounted between the seats and cogs can be selected either with the paddle-shift or with a conventional lever

Kelsey is a great believer in plenty of suspension travel, a design philosophy he picked up on a visit to California to watch the Baja 1000. The brake system is from a stillborn Subaru World Rally car project

components that I have to make myself, but about 95 per cent of the shock absorber manufacturing can be subcontracted.'

The design of the bottom eyelet is such that at full droop it releases the rebound, so if the car goes over a jump the wheels just hang until they touch the ground, when the progressive nature of the shock absorber takes over.

Homemade goodies

Because of the extent of the suspension travel, off-the-shelf steering racks wouldn't work so Kelsey had to design and make a custom power steering rack for the MC2. The other major 'homemade' components are the CNC machined uprights. These look like parts from a formula car that hold the bearings and stub axles and connect the suspension and brakes to the wheels and the driveshafts. 'The idea behind the uprights was to save money and to accommodate the CV joints,' says Kelsey. 'In order to provide a robust set-up for rallying we decided to use the biggest wheel bearings we could find that were generally available almost anywhere – we selected some of about a 150mm diameter. Because of their size they will probably outlive the car.

'The whole process of rallying, with the jumping, the varying surfaces and the wheel ruts, puts significant stress on factory wheel bearings and that's a real weakness in factory based rally cars,' Kelsey says. 'Because of the large wheel bearing it allowed us to put the CV joint right inside the axle; we use A$55 [£26] CVs from B&T [a local motor factor]. I chop them up, machine them, put some splines on them, and they are good to go.'

While the costs can be kept down a bit with such thinking there are still some expensive components in the car, but this was far from a budget-no-object build. 'We were trying to save money everywhere we could and this car wouldn't have been possible if we hadn't made savings all along the way,' says Kelsey. 'At every stage our objective was to find the very best component for the least amount of money. Yes the engine was expensive, but we got it for a fraction of the cost of a new 400-plus brake horsepower racing engine. The transmission was also expensive, but we simply couldn't use any other existing drivetrain for the performance we were looking for.'

Kelsey did save money on the CVs, though, while he also made his own axles. The wheels came from the Ford World Rally Car programme in the UK, and cost about £50 each – the most expensive part in their acquisition was actually the shipping. 'Ford basically use the rims once and when the tyre was worn out, they would throw them away,' says Kelsey. 'So I designed my hubs to suit them. I've got 30 of the main rally wheels, with an extra 10 18in tarmac wheels.'

When Subaru pulled out of the World Rally Championship there were also plenty of parts left over from a new car they had designed but never homolgated, so Kelsey grabbed the brakes from that project. 'The brakes are interesting because they are water-cooled,' he says. 'This was completely new to me and we had to discover how to install them with the cooling circuits and the radiators.'

The main cooling radiator is ducted through the bonnet to keep the cabin cool and to make use of the aero benefits of discharging the air through the hood. 'There is some cooling air going under the car as we had to retrofit a small radiator to keep the gearbox cool, as there's not much air circulation round the gearbox in the compact tunnel between the seats. We also installed some ducting fans at the front of the tunnel to keep it cool under extreme conditions,' Kelsey explains.

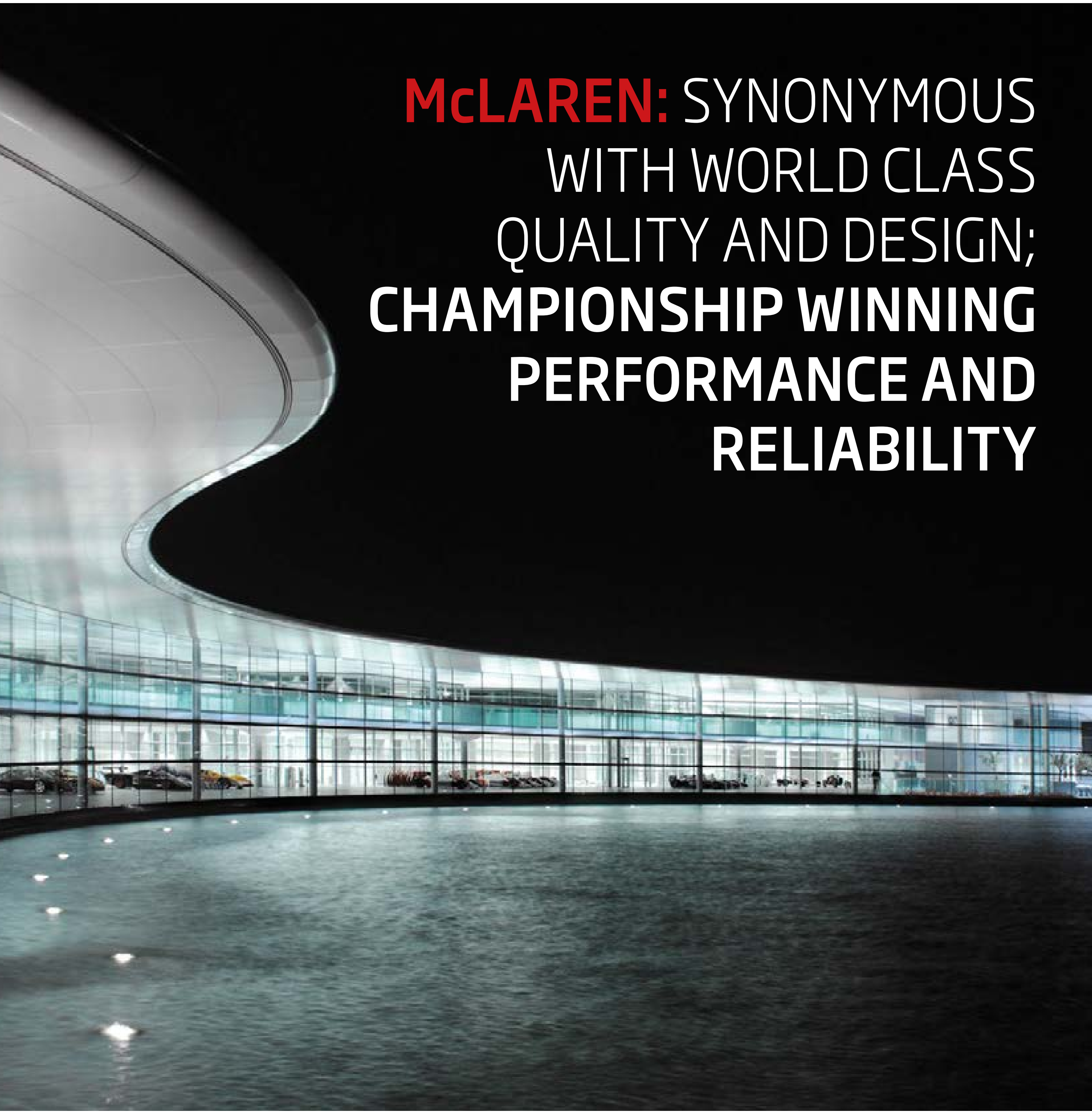
Cool box

'We used a water-to-oil heat exchanger to cool the gearbox down,' Kelsey adds. 'There's a separate electric pump which pumps water through two radiators to cool the gearbox. If I was to use a radiator to cool the gearbox oil directly, it would have to be two and a half times the size of the water radiators. There was no room for that, so we had to use a water-oil cooling method. It's a cooling nightmare as there are so many radiators – about six in all.'

As mentioned, the engine is a naturally-aspirated World Series by Renault (FR 3.5)

Kelsey had to design and make a custom steering rack for the MC2

McLaren
APPLIED TECHNOLOGIES



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The Kelsey MC2 retains the Peugeot 207 silhouette and styling cues, such as the distinctive rear wing arrangement (below), but inside it's full of ingenious home-grown inventions and cost-saving devices

3.5-litre V6. 'The engine's producing around 450 to 460bhp,' Kelsey says. 'It's a lot of horsepower for a rally car, but because it's a high revving racing engine the torque goes right down. We are down some 200lb.ft on what the Subaru used to be. The upside of that, apart from the increase in horsepower, is the incredible noise it makes revving to 8500rpm.'

Staying with the powerplant, Kelsey adds: 'I negotiated the tuning of the engine before I bought it. We made a dyno loom and we sent the ECU over to the engine builder in France, they tuned it and sent it back. I haven't really had to do any tuning here.'

The engine is mid-mounted, and in front of it there is the Sadev sequential gearbox. 'It's a 6-speed sequential and we've included a homemade pneumatic paddle-shift arrangement,' says Kelsey. 'The paddle is a typical rally size paddle about the size of a quarter of the steering wheel mounted centrally behind the wheel. We can also go back to a manual shift by inserting a gear stick into the top of the box very close to the driving position, so it functions very effectively as either manual sequential or paddle-shift.'

The development of the paddle-shift was quite tricky because it had to be able to be used at virtually any steering angle. It needed to provide up and down shifting with minimal movement, and yet it had to be sufficiently robust so as not to change gear accidentally when brushed by stray hands that were concentrating on steering input. There was another long series of prototyping to get it right.

The way the gearbox is fitted snugly into the transmission tunnel actually makes it look difficult to remove, but every effort was made during the construction process to make essential maintenance as easy as possible, and the gearbox can be dropped out, in the field, in about five minutes. There are two quick-change gears, which can be swapped out to change the ratios of the whole transmission. This can be done from underneath without removing the gearbox. Something Kelsey enjoyed in the Subaru was a lock centre differential with 50/50 four-wheel-drive. 'I like that set-up, it seems to give me really good braking. The only time that it's an issue is in tight corners, and for those I've got a clutch in the rear driveshaft, which makes the car fwd.'

Top floor

The whole floorpan/undertray is ballast because the car is so far underweight. The floorpan is a sheet of 5mm aluminium with a 10mm polyethylene skin on the outside. The polyethylene protects the underneath of the car from the shotgun spray of the gravel, and by happy coincidence also helps to quieten the whole experience.

Another interesting feature of the car is that the internal wheel arches are made from composite Kevlar/carbon/urethane material that can be moulded to shape, and when deformed springs back to its original shape with little or no damage. This material wasn't actually available, so Kelsey made it himself! He experimented with different combinations of materials until he found one that worked. The beauty of it is that it can be moulded and then almost folded to destruction to get out of the mould, then it springs back to its original shape.

The wiring is full Mil spec, and the MC2 packs a Life Racing ECU, a MOTEC C125 dash and PDM (Power Distribution Module). 'The main reason for selecting Life Racing was really cost, and their single component could run the engine and the paddle-shift for the transmission,' says Kelsey. There is also an OBR keypad which is on the CAN Bus, which allows it to talk to all the other electrical and electronic components throughout the car. The whole point of streamlining the electronics and reducing the level of complexity to a minimum is to beef up the reliability, Kelsey tells us.

Worth the work?

Kelsey's pleased with his creation, but the work is not quite finished: 'The most important thing at the moment is getting seat time in the car as it is so different from the Subaru and other competition cars I've driven. We're also busy refining the reliability of the whole package and things are going really well in that respect. For me the best part of this project was the engine – when the going got tough I just went on to YouTube and listened to the engine to get my motivation back. It's also very important to do things the way you want to do them and to configure things in a way that you're comfortable with.' This entire build, although it was relatively expensive, comes in below the sort of budgets that local rally drivers are spending on their historic Group N cars. But this isn't about money, it's about a dream project, the sort of thing most talk about, but few attempt, let alone complete. And Kelsey's enthusiasm for tinkering and making stuff work is as inescapable as it is infectious.

'The upside is the incredible noise the V6 makes revving to 8500rpm'

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Formula 4-tune

Crawford Composites has secured the chassis supply deal for US F4 – and with series for both east and west coasts mooted it could prove lucrative

By ANDREW COTTON

FIA Formula 4 racing will arrive in the US in 2016 with a 15-race professional series organised by the SCCA across five venues. The F4 United States Championship will join FIA Formula 4 championships already established in Australia, China, Germany, Italy, Japan, northern Europe and the United Kingdom, with other new championships to be launched in Mexico, Southeast Asia and Spain.

Each market has its own technical partners and in the US it is Crawford Composites that won the tender for the new series, with Honda providing its K20 C1 2.0-litre engine – which will produce the FIA-mandated 160PS (158bhp).

The car Crawford will produce is widely based on the FL15 that the company made for the Formula Lites series, which was its first full car since 2009. But there are aero tweaks and some modifications that needed to be made in order to stick to the FIA-mandated price cap for the series; $45,000 for the chassis, including paddle-shifters, data acquisition and camera. The Honda engine will carry a one-year lease price of $6600, while the Pirelli tyres will be priced at approximately $250 per tyre, with a maximum of three fronts and three rears per race weekend.

F4 is, according to Stefano Domenicali, president of the FIA Single Seater Commission, a cost-effective single seater category and the proposal for a World Cup for Formula 4 cars has already excited the market. The question this raises is, of course, who will provide the cars, or will each market provide its own chassis and create a multi-brand F4 series?

Profit potential

Whatever happens on the world stage, the American F4 series could be one of the most lucrative contracts to be secured in the fledgling category, because although a single series is proposed initially, in order to keep the travelling costs under control there's the real potential for east and west coast championships.

Crawford Composites has based the Formula 4 car on its FL15 Formula Lites car, and meets the cost cap set for the series. Its order book for its Honda-powered racecar is already beginning to fill

'Not everyone can afford our Formula Lites car, which is $120,900; but this chassis is less than $50,000! That's a big difference'

North Carolina-based Crawford Composites unveiled its Honda-powered F4 racecar at the Circuit of the Americas in September, with 12 of them scheduled for delivery for the first season in 2016 and all of them already accounted for.

As mentioned, Crawford's car is based on its FL15, built to the 2014 FIA Formula 3 technical regulations. The Formula 4 car is a little narrower than the FL15, and does not have the aero tweaks of its older brother, but does share a commonality that has helped to drive down the cost of production.

'The F4 regulations are very specific, so we have to do the chassis absolutely to the championship regulations,' says Crawford's aerodynamic engineer, Catherine Crawford. 'The basic construction is the same with a carbon fibre tub and the intrusion panels, so it is a little bit of a different shape but is generally the same. The F4 has a drop nose, the wings you have to do the same as everyone around the world so they are metal, which is really odd for us.'

While the FL15 carries aerodynamically sculpted wishbone suspension, the F4 package will have a more standard layout. 'The geometry will be similar, but we can't do [the sculpted wishbones] because we have to meet the cost cap,' says Crawford. 'It will feel the same, the geometry will be very similar but it will not have aero tubes.'

The final specification of the car was not yet finalised as the US F4 was launched, but the company subsequently signed a deal with Sadev. The FL15 has a Hewland gearbox, but that was considered to be too expensive for F4's very restrictive cost cap of around $115,000 in 2016. This also meant that Xtrac was out of the running, and it seems likely that the car will feature the favoured Sadev gearbox.

Crawford's involvement has come about principally due to its relationship with Honda with which it partnered with the Lites car. 'We had such a great relationship with them for that car, and it was really that car that got us thinking about this,' confirms Crawford.

The car has been set up to allow for a little tweaking here and there, not only for drivers to learn the nuances of developing a car, but for the young engineers who also need to learn their craft

... Likewise the wooden floor, which adds weight but on the other hand is cheaper to make and to replace, so while it may seem a little agricultural for a modern racecar it should be effective

Crawford specialises in carbon composites so for it to make a metallic, and rather impotent, front wing was an alien concept for the organisation, although one it had to accept in order to meet the FIA's Formula 4 specification ...

The Formula 4 category is also designed to cater for new engineers working with downforce cars for the first time

The 'Lites' engine will last a full season, and nothing less is expected of the Formula 4 engine either. 'We are pleased to partner with the FIA and SCCA on the launch of the United States Formula 4 Championship series, which further reinforces Honda's long-standing commitment to open wheel racing in America,' says Steven Eriksen, vice president and COO at HPD (Honda Performance Development). 'The new Honda K20 engine will provide a fun, reliable and cost-effective solution to power the dreams of racers honing their skills for a future in racing.'

The right decision

For Crawford, the decision to return to full car construction is a welcome one. The company considered a tender for the new North American LMP2 chassis deal, but opted for the Formula 4 car instead, and expects to produce a significant number of cars for its series.

'We have been doing a lot for other people, chassis and bodies, and some of the chassis work for the LMPC cars that are out here,' she says. 'We have done a lot, but not a full car since 2009, before the FL15.'

Crawford is not underestimating the task ahead, though: 'Based on the interest that we have had [for the F4], it is a little frightening. We have to ready 12 cars for next year, delivered in time for the beginning of the season. That is what we have committed to. I know Sim Raceway have the first six. There are a couple of other people that have committed to more, and some schools that have expressed an interest, and that is a big number. A few guys in the FL15 want to run them alongside each other, and that makes sense. The kids that are in there, we have people from all over the world. It is international, but not everyone can afford that car, which is $120,900; this is $50,000! It is a big difference.'

Electric connection

A partnership with electronics manufacturer GEMS has allowed the Crawford team to combine the electronic and gearbox control units into one complete unit, reducing the price, and 'making it so that everything is controlled through one unit which is great especially for these classes where you don't want people messing with too much stuff,' says Crawford.

However, the category is not only about providing a step up from karting for the driver; it is also designed to cater for new engineers working with downforce cars for the first time. Crawford has designed the car to be open to adjustments, despite the rather impotent and heavy wing at the front.

'The worst thing for me is to have a driver who can't talk to me,' says Crawford. 'It is hard enough when you get a driver who doesn't speak the same language, you have to learn each other, but once you do and you click, it is amazing. Yet, this has to be cost-effective, so the wishbones are interchangeable side to side on the top, the uprights are the same all the way around the car. The minute you make those things the same, the costs come down.

'There is a slug in the wheel assembly, so all you have to do to change the roll centre is

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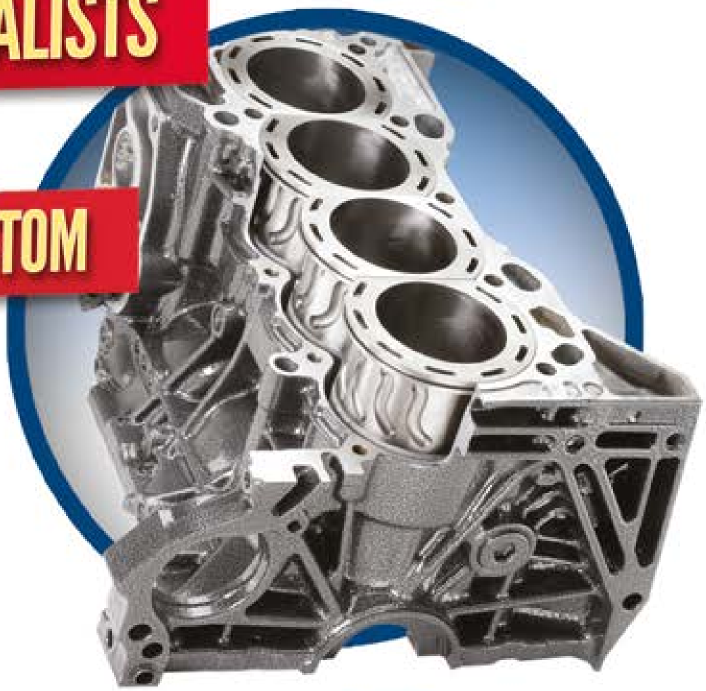

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US Formula 4 will be powered by the Honda K20 C1 2.0-litre engine which will give around 160bhp, the maximum power mandated by the FIA. Crawford has previously worked with Honda with its Formula Lites car

change the slug. It is cost-effective. It doesn't cost me any more to be able to do that so I can still make this a car that I can engineer and play with, and they can learn.

'We learned that with the FL15 – they have roll centre adjustments, anti adjustments, spring adjustments. I don't want a driver who can drive but can't tell me anything. That's not useful. What's the point in having a ladder series if they are not going to learn anything?' Crawford says.

'With the FL15, there was a lot of adjustments in the wings, so that is different, but we have had guys stepping into the FL15 who have never driven downforce before and so when I ask them how's the aero balance, they have no idea. It is probably not a bad idea for them to step into this, feel downforce for the first time with a balance so that when they do step up into the next class, and they can adjust it, they understand what they are adjusting because right now, some of them don't.'

The car has yet to see a wind tunnel, but the plan is that it will before the company starts to deliver cars. But the development has to be limited as the performance is expected to closely match that of similar cars in other markets around the world.

However, as mentioned, at the launch of the series a World Cup idea was tabled. So if the cars have to go head-to-head, development time now could prove to be fruitful in the future. 'That will be interesting,' says Crawford. 'That's the first I have heard about that. That would be very interesting, and exciting.'

TECH SPEC

Crawford F4-16 Formula 4
All new single seater for use in new-for-2016 United States Formula 4 Championship

FIA certified monocoque: 2016 F4 specification. Carbon composite monocoque; front and rear roll-over structure; anti-intrusion side panels

Engine: Honda Type R 2.0-Litre, normally aspirated

Electronics: GEMS Performance electronics; LDS3R display; EM80 ECU; MPI Steering Wheel

Gearbox: Sadev 6-speed sequential; tripod CV joints; Crawford pneumatic paddle-shift

Brakes: Brembo 2-pot calipers; Brembo discs; Tilton adjustable pedal box; cockpit adjustable brake bias; accessible fluid reservoirs

Suspension: double wishbone, front and rear; pushrod adjustable ride height; adjustable anti-roll bars; adjustable shocks; Eibach springs; Aurora Bearings

Tires: Pirelli

Wheels: Jongbloed

Steering: Titan rack and pinion steering; quick release steering wheel; height adjustable column which is also collapsible for safety reasons

Electrical: starter motor; sealed battery

Bodywork: lightweight composite bodywork with adjustable wings front and rear. Engine air intake with filter

Safety: FIA specification 6-point harness; on-board fire suppression (Lifeline); HANS compatible headrest; nosebox crash structure; rear attenuator; wheel tethers

Dimensions
Wheelbase: 108in
Width: 69in
Weight: 1254lbs

'I don't want a driver who can drive but can't tell me anything. What's the point in a ladder series if the drivers are not going to learn?'

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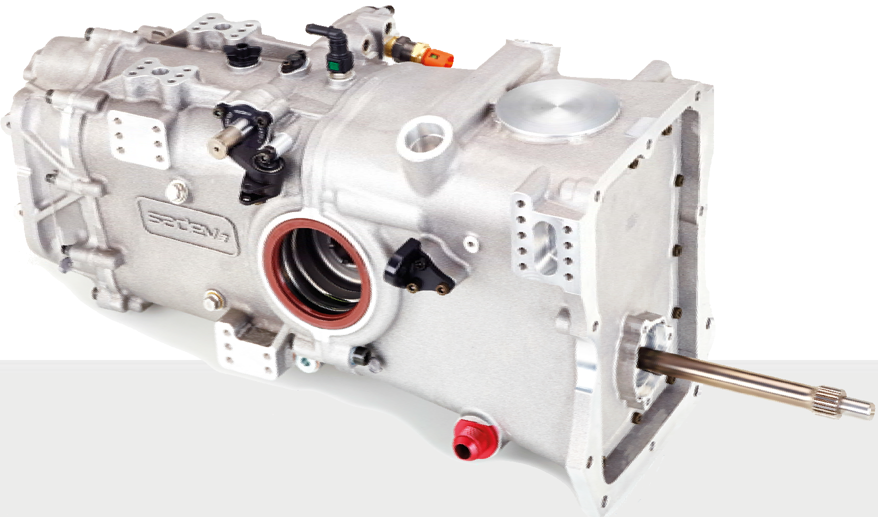

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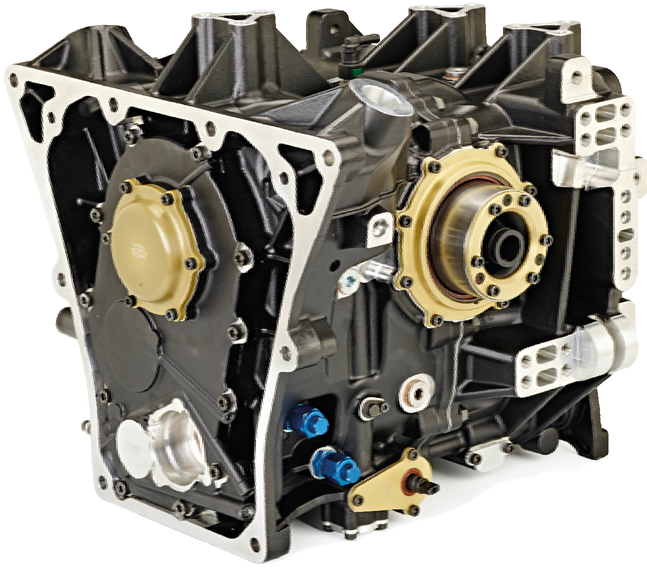

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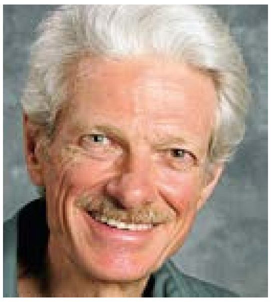

Pedal of honour: the big brake out

All you need to know to sort brake pedal pressure for FSAE

Question

How do you calculate line pressure and pedal force for a brake system? If the line pressure or pedal force is too high, what can you do?

The consultant says

This question comes from the UNC Charlotte Formula SAE team. The team is trying to run a legacy design, making the fewest possible changes. The legacy design, however, has a persistent brake problem which caused the car to DNF in the endurance event in 2015 due to the brake overtravel switch being tripped, shutting off the engine. This was also a problem in the brake test that is part of tech inspection. The brake system does not have a sufficiently firm pedal, and also gets some heat fade in protracted use. This, combined with the softness of the pedal, results in the pedal travelling far enough to trip the required overtravel switch. The switch can be tripped in limit braking with cool brakes, and it becomes easier and easier to trip it as the brakes fade.

The system has some problems that are immediately apparent. The master cylinders, which are under the driver's heel beneath a removable panel, are mounted on their sides to reduce height. The banjo fittings through which the hoses from the remote reservoirs feed the master cylinders are at 3 o'clock and 9 o'clock, not 12 o'clock. That creates an unbled high spot inside the master cylinder. Two of the calipers are mounted with the bleed screws pointing down. These can be bled, but only by removing the calipers. The reservoirs are very nearly at the same height as the calipers; there are no residual pressure valves.

In sum, there are a number of ways that air in the system might be causing soft pedal. If we are willing to live with taking calipers off to bleed the brakes, all these potential sources of air in the system can be addressed at the master cylinders, pedal, and reservoirs.

But is that likely to be the whole problem? Can we deal with this by revising the layout of the pedal, master cylinders, and reservoirs? Can we keep the existing uprights, discs, and calipers? Or are there further problems relating to the brakes themselves? It is to answer this that we need to see if line pressures and pedal forces are within reasonable limits.

The car is built very light. With the lightest driver in 2015, it weighed about 512lbs. It uses a single-cylinder engine and 10in wheels. Tyre outside diameter is about 18in. Front and rear brakes are identical. Calipers are the very light AP CP4226-2S0. These are popular in FSAE due to their small size and weight, but they are designed for use on the rear of racing motorcycles. In the original application they are intended to actually produce less rear braking force than stock calipers, and also provide a small weight reduction. The reason for wanting less braking is that motorcycles on road courses, at least in the dry, are limited in straight-line braking by rear wheel lift rather than grip. AP says that when these calipers are used in FSAE applications, there is a danger of fade, caliper flex and excessive line pressure. They also say that line pressure needs to be kept below 1000psi.

It should be obvious why caliper flex will cause soft pedal. High line pressure will also reduce pedal firmness because the fluid has some compressibility and the hoses have some compliance. AP's recommended guidelines are that if line pressure in any brake system exceeds 1000psi the system is undersized, and if it is less than 400psi the system is oversized. An oversized system works fine; it's just bigger and heavier than it needs to be. An undersized system is likely to have precisely the problems we are experiencing, especially with calipers optimised for lightness rather than rigidity.

So what line pressures should we expect our system to generate? First, we have to figure out what force the system has to generate at the contact patches. In our case, we have identical brakes front and rear, and roughly 50% rear statically. Some amount of the car's weight will transfer forward in braking. So we need to look first at the front brakes.

The team has not measured the car's c.g. height. It's probably somewhere in the 10 to 12in range. The wheelbase is 60in. How much of the car's weight will transfer forward? We can work this out with free body diagrams, but here's a shortcut: the portion of the weight that will transfer per *g* of rearward acceleration is the c.g. height divided by the wheelbase. For a 12in c.g. height, that's 12/60 = 1/5 = 20% per *g*. For a 10in c.g. height, it's 10/60 = 1/6 =

There are a number of ways that air in the system might be causing a soft pedal

It's a delicate task to get the brakes right on a small and light Formula Student racecar – Delft aced it with its DUT 15

Many FSAE teams will use brakes designed for motorcycle racing, but these can create their own peculiar problems

16.67% per *g*. AP suggests assuming that the car brakes at 1.25*g*. That's perhaps a bit lower than FSAE cars will achieve on a good surface with no downforce. With downforce, the accelerations can be much larger. The current car has no wings or other downforce devices, but the team is considering adding some.

Normally we might start with a heavy driver and a high assumed c.g. But let's see what we get, given charitable assumptions: 512lb total weight, 10in c.g. height, 1.25*g* braking. The portion of car's weight that transfers is a sixth times 1.25. That's 20.83%. The front wheels have 70.83% of the 512lb weight on them. That's 362.6lbs for the wheel pair, or 181.3lbs per wheel. For simplicity, we'll assume that the coefficient of friction at the front contact patches equals the acceleration of the car in *gs*: 1.25. Friction force at each front contact patch is then 181.3 x 1.25, or 226.7lbs.

The radius of the tyre is 9in. The brake disc is 7in diameter, and the pads sweep a surface on it about an inch wide. The acting radius is then about 3in; about a third of the tyre radius. Therefore the two brake pads combined have to generate a friction force roughly three times the contact patch force, about 675lbs.

The pads have a coefficient of friction of about .42 to .40. Using the .42 value, the two pads have to press on the rotor with a combined force of 675lbs divided by .42, or 1607lbs, or about 800 pounds each. The pistons are an inch in diameter. The area of each piston is the diameter squared times π/4, or .7854 sq.in each. The hydraulic pressure needed to generate 800lbss of force from a piston that size is 800lbs divided by .7854sq.in, or 1019lbs per sq.in. We're over the recommended limit, using the most charitable assumptions. With a lower pad coefficient of friction, a grippier road surface, a heavier driver, a higher c.g., and/or some downforce, we could easily see 1200psi or more.

We can conclude that the front brakes are seriously undersized. What about the rears?

We can conclude that the front brakes are seriously undersized. What about the rears? They only need to generate about 25 to 30% of the stopping force, so they will see at the most 30/70 or 43% as much pressure as the fronts. Even with a lot of downforce, they are within safe operating limits, provided that the master cylinders and pedal are sending them only as much pressure as is needed to have them lock at about the same pedal force as the fronts.

Although the front brakes are operating at higher than recommended pressure, there have not been any leaks or catastrophic failures. We just have a spongy pedal and some fade. We don't really know how much of the compliance is due to the high hydraulic pressure. We can reasonably predict that we won't get really good operation as long as the front brakes are undersized, no matter what we do with the pedal and master cylinders. On the other hand, we know that the current configuration doesn't permit proper bleeding, and we're bound to get a significant improvement just from correcting that.

We also know that we can shorten the pedal travel by going to bigger master cylinders and/or a smaller pedal motion ratio. We can't just let the pedal travel more, without changing the frame design. The overtravel switch is close to the front bulkhead now. Moving that forward means lengthening the frame, which in turn means the current nose won't fit. Having the pedal further rearward when the brakes are not applied is not an option either, because our tallest drivers can barely fit now, and the rules require us to accommodate a 95th percentile male. The only way to shorten the pedal travel via pedal or master cylinder changes is to add to the pedal force required, one way or another.

So where are we now on pedal force? The front master cylinder is 5/8in diameter. That's .307sq.in of piston area. 1000psi acting on that piston produces a push rod force of just over 300lbs. 1200psi produces just over 360lbs push rod force. The pedal motion ratio is 6.5:1, and there are two push rods. At mid-adjustment on the balance bar, force on each push rod is 3.25 times pedal force. Pedal force is then about 92lbs for 1000psi, or about 111lbs for 1200psi. Recommended pedal force for a 1.25*g* stop is 80lbs. 100 is heavy but not unmanageable. More than that may be tolerable.

The rear master cylinder is ¾in. That means that at mid-adjustment on the balance bar, the rear brakes are generating about 41% of the braking, not the 25 to 30% they would require if the front wheels are to lock before the rears. At around 1*g*, at mid-adjustment on the balance bar, the rear wheels lock. As further pedal force is added, the rear calipers continue to deflect, the fluids in the lines continue to compress, the hoses continue to swell, but none of the added pressure does anything to stop the car because the rear tyres are already contributing as much retardation as they can.

Some reduction in deflection can be had by not overpressuring the rear brakes. This can be accomplished by balance bar adjustment up to a point. Beyond that, either a larger rear master cylinder or a proportioning valve in the rear line could be used. Using a proportioning valve along with a balance bar makes sense because it allows us to have less rear brake percentage at high apply pressures, where forward load transfer is greatest, without having premature front lock-up in conditions of poorer grip, and still having enough rear brake to free the car up in trail braking. A rear proportioning valve would not reduce pedal force required and wouldn't reduce deflections occurring on the master cylinder side of the valve. However, it would reduce deflections occurring on the caliper side of the valve.

Hopefully, this discussion provides some useful info on how to calculate hydraulic pressures and pedal forces in brake systems, and an insight into the complexities.

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.

E: markortizauto@windstream.net
T: +1 704-933-8876
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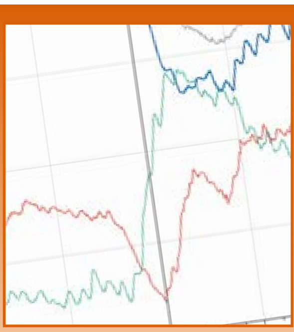


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Logging individual rates for variables

Take the time to log the rates for variables and the effort will certainly pay you back in the longer term, as our analysis clearly illustrates

When logging the data received from a vehicle, serious consideration should be taken of the individual logging rates of variables. It is very easy to simply place each variable at a maximum logging rate and ignore this fundamental aspect of data analysis. There will come a point in time where the amount of data being logged is too high for the system to deal with and it will result in a loss of data, which could potentially prove crucial for your set-ups or analysis with the driver post-race. It only takes a few seconds to consider the logging rate of a new channel or sensor which could save you lots of time in the future and also enable you to spot relationships that may not have been previously visible.

Paying attention to logging rates also means that the logged file will be smaller, which means the offload speed will be quicker, this can be critical if a download during a pit stop is needed.

Identifying sensible logging rates for variables can be very easy for certain channels and can make a significant difference to the amount of logging capacity taken up. For example, take a look at the trace below (**Figure 1**). A channel monitoring the selected gear position does not need to be logged at a very high rate as its value is discreet and it doesn't fluctuate rapidly. Therefore, this channel could be logged at a rate of 10Hz comfortably without causing inaccuracies in the data that make it hard to read. On the other hand, a wheel speed channel is continuous with rapid fluctuation. It is also dependent upon external effects such as the road surface. A speed channel is also a crucial indicator of driver performance with respect to lap time – the fundamental variable that everyone strives to improve upon in order to win races. With this in mind, a channel such as this should be logged at a much higher rate, such as 100Hz, so that the small fluctuations around a lap are seen in the data and any relationships that occur over short periods of time can be easily spotted. This enables instances such as a loss of traction to be identified and acted upon to improve the performance of both the car and the driver.

It only takes a matter of seconds to consider the logging rate of a new channel or sensor, which could save you a lot of time in the future

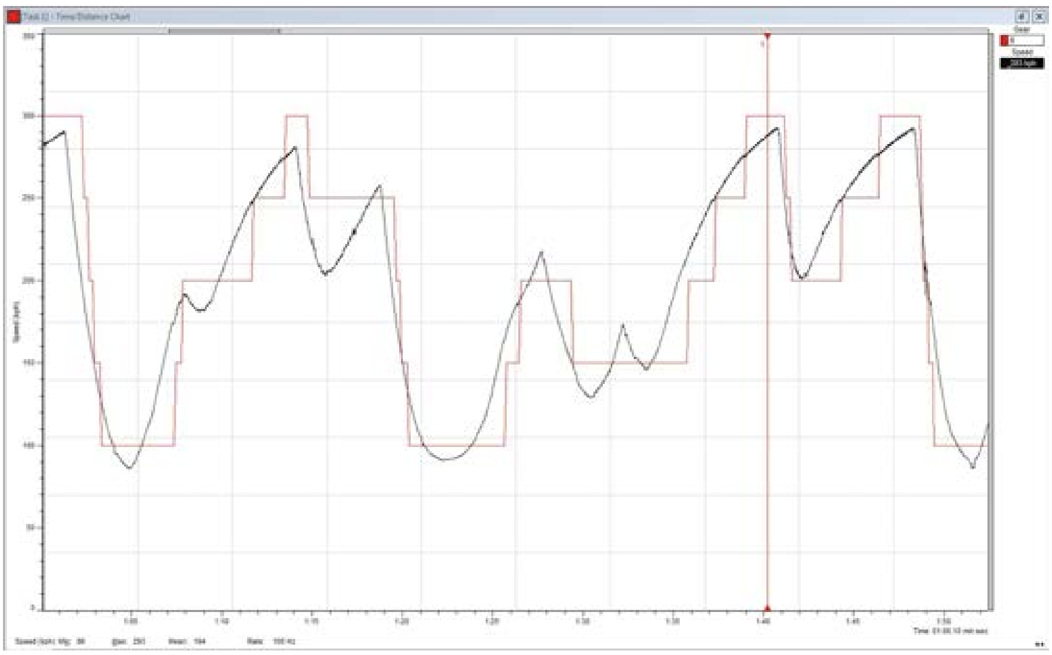
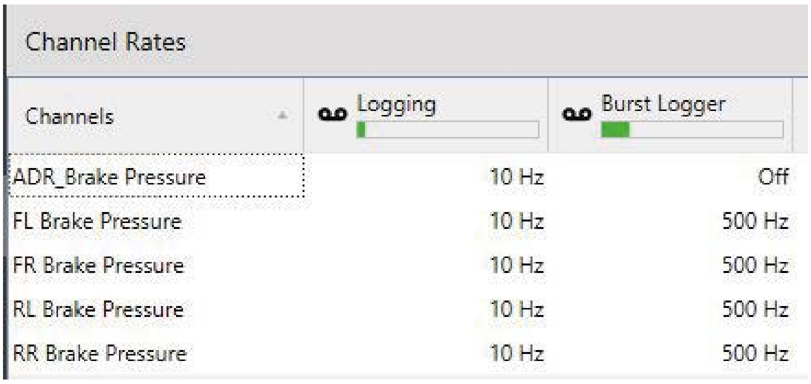


Figure 1: A selected gear position doesn't need to be logged at a high rate as its value is discreet and it doesn't fluctuate rapidly

Burst logger

Taking the time to adjust logging rates accordingly allows you to use your bandwidth efficiently and increase the accuracy of your data in significant areas with minimal influence on the more insignificant areas. If your system is capable of supporting it, utilising a burst logger in certain instances can be incredibly powerful. For instance, brake pressures tend to be relatively constant when the brakes aren't being applied but can fluctuate drastically when they are applied. This can make it difficult to identify an appropriate logging rate (**Figure 2**). A burst logger identifies when a sudden rate of change of value occurs and adjusts the logging rate of the channel accordingly so that the important sections of data aren't missed. This also operates in reverse, so that the logging capacity is kept to a minimum when in near steady-state conditions.

Being able to identify relationships within data is a crucial part of data analysis. The



Channel Rates

Channels	Logging	Burst Logger
ADR_Brake Pressure	10 Hz	Off
FL Brake Pressure	10 Hz	500 Hz
FR Brake Pressure	10 Hz	500 Hz
RL Brake Pressure	10 Hz	500 Hz
RR Brake Pressure	10 Hz	500 Hz

Figure 2: Difference between standard logging rates and burst logging rates. Burst loggers identify when a sudden rate of change of value occurs and adjusts the logging rate of channel accordingly

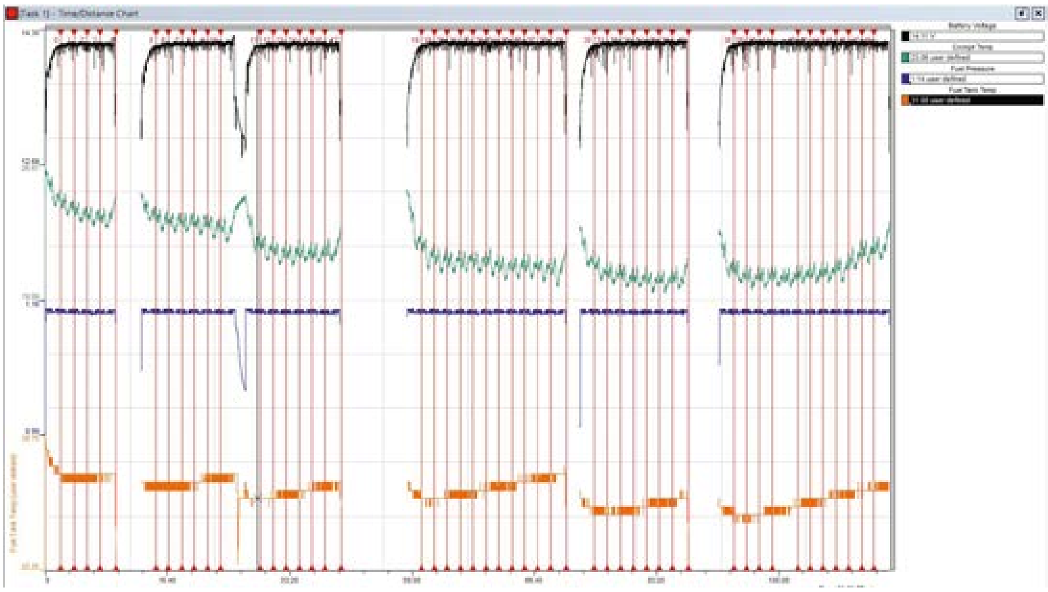


Figure 3: Stacking of multiple outings can reveal trends that can otherwise often be overlooked; the example here is the cockpit temperature that on average goes down. But it's important not to include too many channels

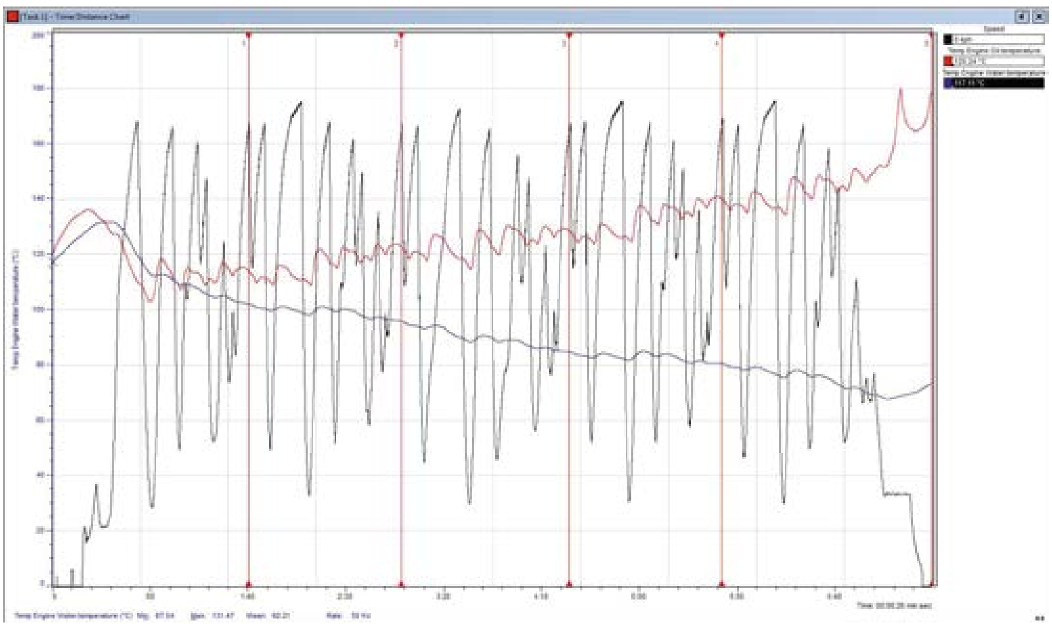


Figure 4: An increasing/decreasing water pressure or oil temperature which can be seen as the blue and red traces here – looking at the entire outing can show obvious trends that aren't visible over short periods of time

A method that is often overlooked is to view the data from an entire outing

inability to do so renders all the time spent achieving sensible logging rates useless. Sometimes these relationships aren't immediately visible and it often requires a different perspective to be taken in order to see them. Many data analysis software packages offer different ways to view variables and it is essential that this is exploited. A valuable method of identifying relationships is to view data as a stacked data plot (**Figure 3**). Careful use of a stacked plot can make it much easier to spot insignificant events in the data that could be linked. Consideration must be taken, however, not to include too many channels as the plot can quickly become too crowded. Limit yourself to only viewing a few channels at a time and remove unused channels before adding new ones, this enables the new channel to be identified quickly when it appears on screen. It will also help you keep a mental note of which channels could still potentially be having an effect.

Big picture

A method which is often overlooked is to view the data from an entire outing, rather than a specific segment of the data. It's very easy to forget about this as a lot of issues tend only to show themselves in specific positions, but looking at the entire outing can show blindingly obvious trends that aren't visible over short periods of time, simply due to the lack of change that is seen. A perfect example of this is would be an increasing/decreasing water pressure or oil temperature which can be seen in **Figure 4.** What this shows is that the axes of a plot can sometimes be misleading to the eye. Changes that could appear on the plot to be insignificant in size could actually be a red flag that can't be identified due to the scaling on the axes.

If a stacked data plot isn't available, exporting the data and manually producing a plot in an external spreadsheet could be a useful tactic to employ to replicate this style of data display.

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Examining the effect of LMP3 diveplanes

Further findings from our examination of Ginetta's baby prototype

Endurance racing's latest stepping stone for drivers, teams and constructors, LMP3, presents challenges to constructors to build cars to cost caps and weight limits (see our September issue, V25N9). Last month we also saw that it has its own aerodynamic limitations; diffuser volume is less than in LMP2 and the rear wing is limited to a single element of 300mm maximum chord and 1600mm maximum span. Thus, with a front end package not dissimilar to that of an LMP2 car, total downforce is obviously short of that produced in LMP2 and obtaining an aerodynamic balance – that is, getting enough rear end downforce – was one of the first tasks the Ginetta-Nissan team tackled.

New insights on dive planes

We saw in our first episode last month that a 25mm rear wing Gurney (large for a wing of 300mm chord) and an increase in rear deck Gurney height (by 30mm) made useful progress on the aerodynamic balance, and in fact these changes correlated with the balance found during track testing. The rear wing appeared to be operating at its peak downforce angle. So, the team then moved to the front of the car to investigate the effect of the dive planes.

We have looked at dive planes on a range of cars in the past and, although efficiency has varied, they have without exception been effective balance adjusters. In baseline trim the Ginetta featured a pair of dive planes on each side of the car, so we looked at all the (symmetrical) options and the 'delta' (Δ) values relative to the 'no dive planes' case are shown in **Table 1** in 'count's, where one count represents a coefficient change of 0.001 (balance changes are shown as the absolute change in %front).

First, the incremental drag contribution was fairly similar whichever combination of dive planes were used, and was in all cases relatively modest. Second, the biggest gain in total downforce came from the lower dive planes alone; hence not surprisingly this was also the most efficient configuration in terms of the gain in –L/D. The upper dive planes alone were the least effective and least efficient combination. However, the biggest balance shift to the front was achieved using twin dive planes, and for this to be the case, clearly more downforce had to have been lost at the rear tyre contacts with this configuration than was the case with the lower dive planes only. **Table 2** confirms this by showing the front and rear gains and losses in –CL, and we can see that twin dive planes and lower dive planes on their own gained much the same downforce at the front but the twin dive planes caused a 10 count greater loss at the rear. The upper dive planes didn't achieve the same front end gain on their own, and also caused more loss at the rear than the lower ones only.

The precise cause for these differences is not immediately obvious. Clearly some of the rear losses would be down to the mechanical leverage from the overhang of the dive planes ahead of the rear axle, but there were obviously small additional aerodynamic losses too, more so seemingly from the upper dive planes. The simplest assumption, that their wake may have been impinging on the rear wing's flow field, as we have clearly seen with high-mounted dive planes in the past, does not seem initially to be borne out by the smoke plume, which could be seen rolling downwards into a vortex from the upper dive plane. Furthermore, the wing is 300mm narrower than the car's width, so the outer ends are set 150mm inboard from each side of the car. Nevertheless, after its initial downturn the smoke did then appear to rise and the dive plane wake can be seen outboard of the upper rear wheel arch. Here it may have

The biggest gain in downforce came from the lower dive planes

Table 1 – the changes achieved with dive plane combinations, relative to no dive planes

Dive planes	ΔCD	Δ-CL	Δ%front	Δ-L/D
Lower only	+15	+89	+7.27%	+110
Upper only	+14	+66	+6.69%	+67
Both	+17	+77	+7.60%	+79

Table 2 – front and rear changes with the dive plane combinations, relative to no dive planes

Dive planes	Δ-CLfront	Δ-CLrear
Lower only	+118	-29
Upper only	+102	-35
Both	+117	-39

The dive planes on the Ginetta came under the spotlight as focus switched to front of car

Here the smoke in the dive plane wake can be seen outboard of the upper wheel arch

Table 3 – the effects of adding upper dive planes on two different sports prototypes

Add upper dive planes	ΔCD	Δ-CL	Δ%front	Δ-L/D
Radical LMP1	+16	+49	+2.00%	+17
Ginetta LMP3	+2	+12	+0.33%	-31

LMP3 was tested in a variety of dive plane configurations, including their removal

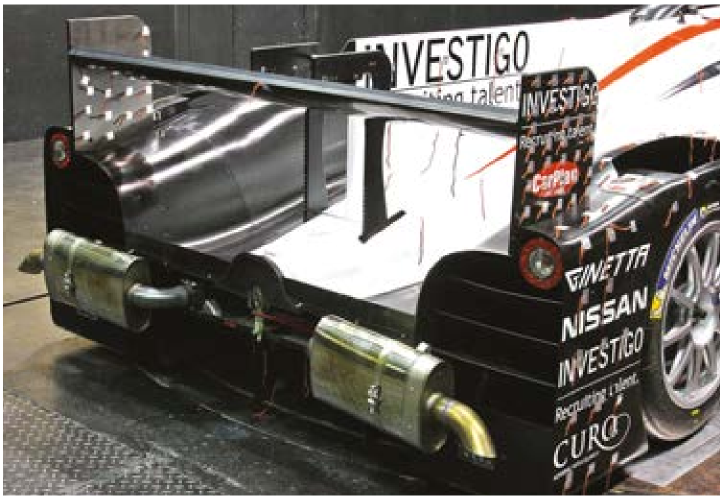
Table 4 – the effect of external silencers

	ΔCD	Δ-CL	Δ%front	Δ-L/D
With silencers	-3	-22	+0.41%	-30

Table 5 – the effect of the elements in the rear openings of the rear wheel arches

	ΔCD	Δ-CL	Δ%front	Δ-L/D
Without elements	+3	+7	+0.29%	+2

The Radical SR10 LMP1 racecar, as featured in Aerobytes back in 2008, had steeper dive planes and responded differently when an upper pair was added



The car had been out at a noise-limited test session before we put it in the tunnel and was fitted with a pair of silencers; the impact of these was surprisingly small

Removing the elements inside rear wheel arch rear openings – to study the impact of an incoming regulation change – had a small yet doubly surprising effect

been having a slightly adverse effect on the rear wing, if not directly then perhaps by steering slightly less energetic airflow, from the wheel arch top apertures for example, to the wing.

As a cautionary note on the dangers of trying to generalise about a particular device though, let's briefly cast back to 2008 when we tested the effect of extra upper dive planes on the Eco Racing Radical SR10 LMP1 car, and compare with the figures for adding the upper dive planes to the Ginetta, as **Table 3** illustrates. The responses of the two cars were really quite different, and this example is as good a way as any to illustrate the risks inherent in making assumptions, as opposed to actually testing and obtaining data.

Quiet please

A recent track test session had necessitated the use of a pair of large silencers to remain within local noise regulations, and aerodynamics engineer Stephan van der Burg was keen to ascertain their effect on the aerodynamic numbers. **Table 4** illustrates, and while there was some discernible effect on downforce (18 counts of the reduction was, not surprisingly, at the rear) the effect of the silencers on external aerodynamics was relatively small.

While we're examining this area of the car, a change in the regulations is going to force the removal of the angled elements in the rear openings of the rear wheel arches (in favour of a single angled panel), so this was an opportunity to assess their effect. The elements were removed and **Table 5** shows the outcome. In this instance there was a small downforce increase when the elements were removed, most of which was felt at the front, hence the small gain in %front. This might initially seem curious but was presumably related to improving mass flow from the front end, which may in a small way have helped the front splitter's performance.

Next month we'll round off this project with a look at the effects of changing ride heights and yaw angles on the Ginetta.

Thanks to all at Ginetta for their cooperation and hard work in enabling this session to take place.

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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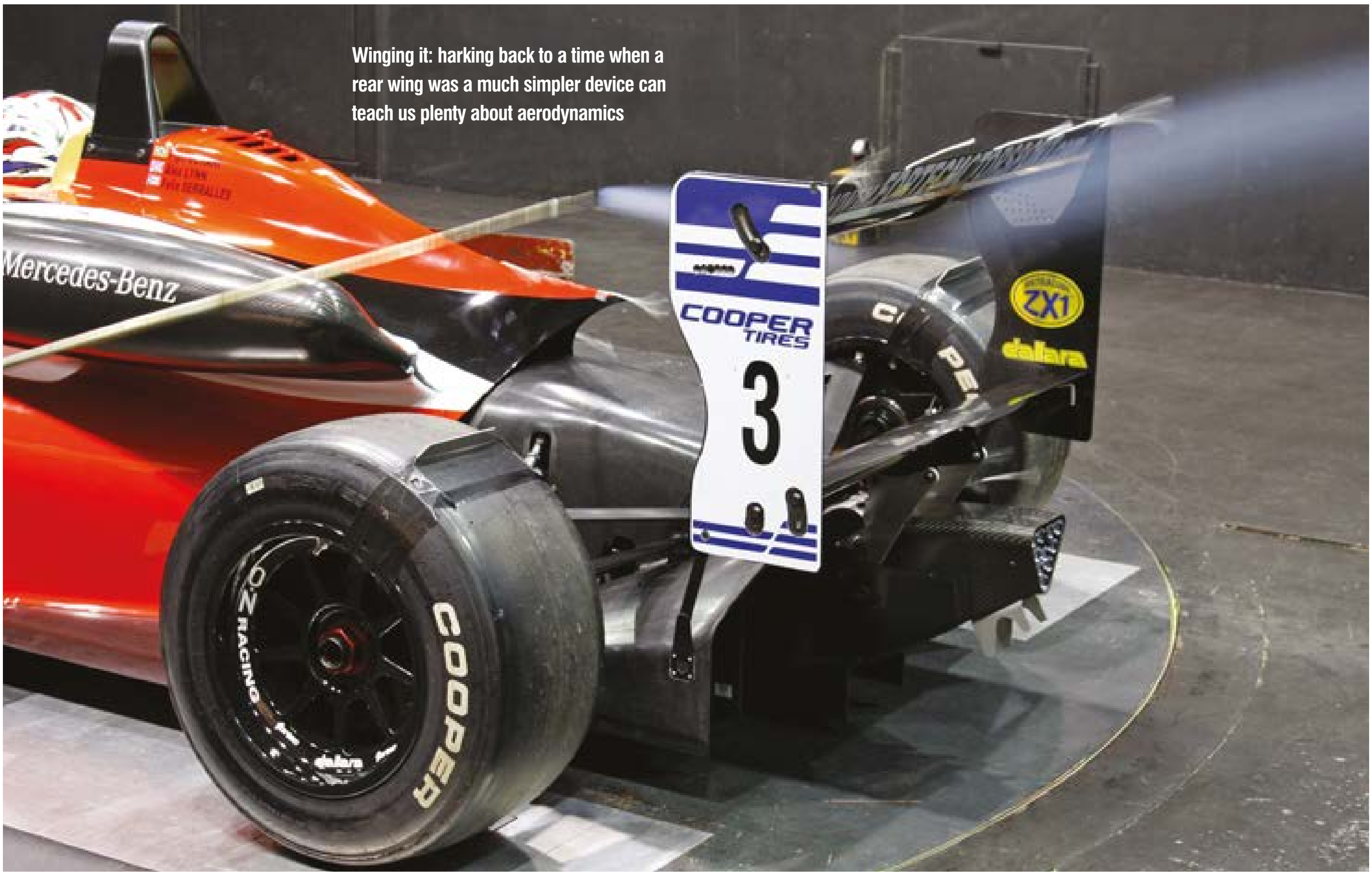
Rear wing rudiments

We're used to seeing rear wings on high-end single seaters incorporating complex features – but what about the fundamentals? We use CFD to go back to basics

By SIMON McBEATH



Winging it: harking back to a time when a rear wing was a much simpler device can teach us plenty about aerodynamics

Perhaps one of the reasons that rear wings in F1 and other senior (heavily regulated) single seater formulae incorporate complex details is that most of the basic design criteria are defined in the technical regulations. With limited or no freedoms on the fundamentals such as span, location and so forth, attention has to turn to more intricate features to try to extract performance advantages. But if some or all of these basic parameters are not already defined in technical regulations, where do you start, and what really matters? With the help of ANSYS CFD-Flo, a batch of simulations has been run on a single seater model to put some of the usual assumptions to the test. As ever, the picture is not as simple as those assumptions might have you believe.

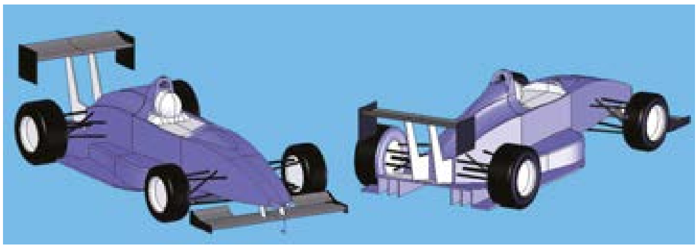
Our model

Regular readers may recognise the CAD model **[CAD Figure 1]** that has been used for this latest investigation; it was utilised in our April 2014 feature 'Front wing fundamentals'. However, some changes have been made to the model to make it more generally applicable. The 2014 version was a design that had UK speed hillclimbing regulations in mind, and as such featured long rear diffuser tunnels extending well forwards, as well as the wide wing spans permitted in that category. This time the model featured a flat bottom between the wheels and a shorter diffuser. The front wing had a span of 1400mm with a part span flap either side of the nose, and it was moved 100mm closer to the front axle relative to the April 2014 study (which featured a dual element rear wing) to better balance the rear wing that was to be used in this exercise. The sidepod had been re-styled to eradicate some aero deficiencies seen in that 2014 study, notably some flow separation over the forward, upper parts and in the 'waist' ahead of the rear wheels. A 'bow divider' and splitter were added to the forward underbody to make the underbody flat between the wheels. And the baseline rear wing span was 1000mm, although other spans have been examined as one of the variables under investigation.

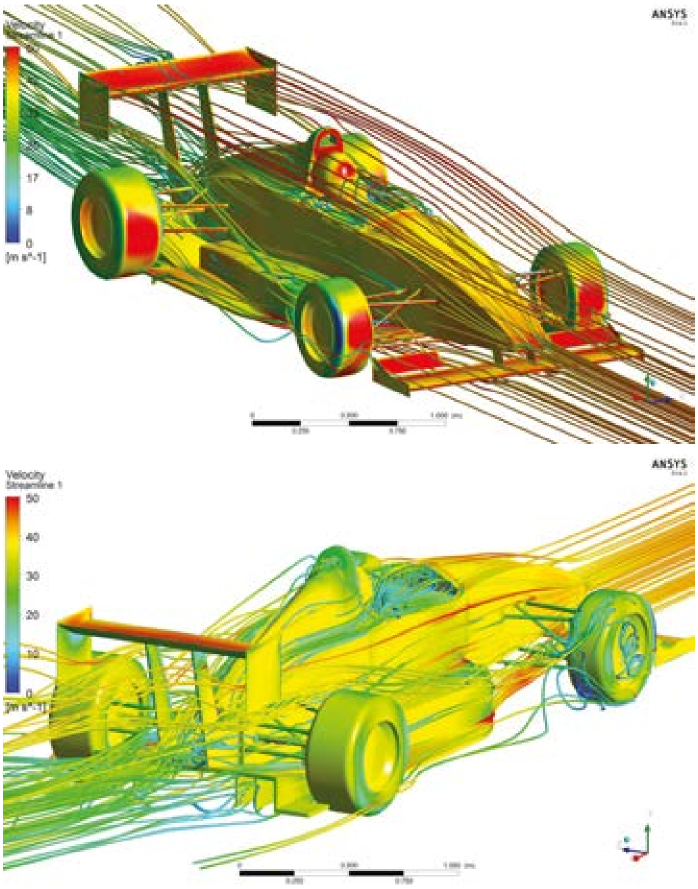
The author's usual ill-disciplined mix of imperial and SI units was employed, with air and ground speed in the simulations being 100mph (44.7m/s) and forces are reported in Newtons, N (divide N by 4.459 to obtain pounds, lb). The CFD simulations included mesh refinements around the wings and wheels for improved capture of flow separations; the K-epsilon turbulence model; moving ground; and rotating wheels. Each simulation was run until calculated forces were acceptably steady.

Wing data

It's common to see wings characterised by analysis in isolation, a useful means of providing information



CAD Figure 1: The datum CAD model with single element, 1000mm span, 300mm chord rear wing. The racecar has been 'modified' for the purposes of this aerodynamic study



CFD plots1 and 2: Rear wings operate in a highly compromised environment

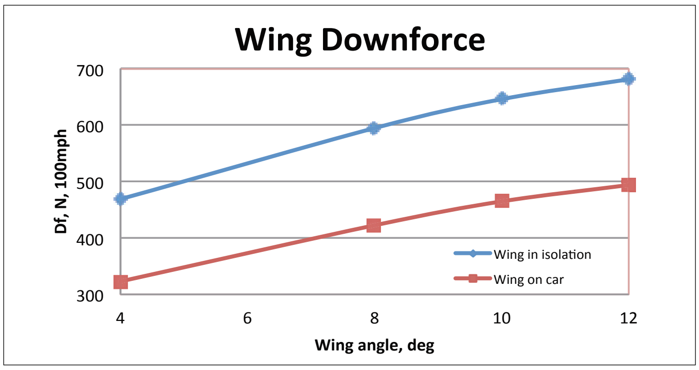


Figure 2: Wing downforce in isolation versus the performance when fixed on the car

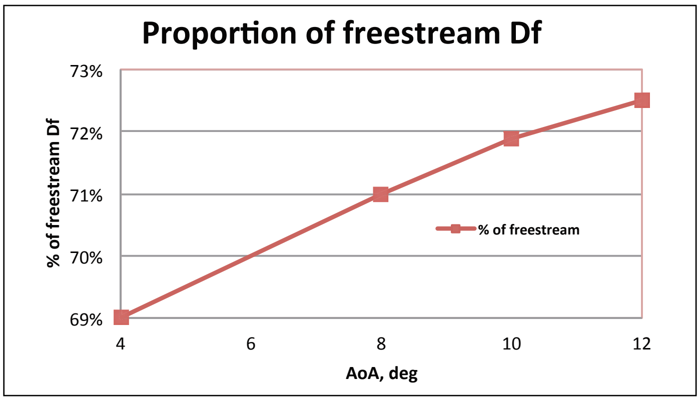


Figure 3: Rear wing made less downforce fitted to the car, but lost less at steeper angles

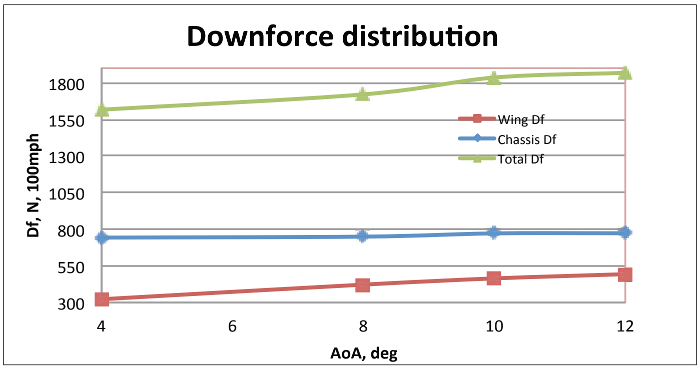


Figure 4: Not only the rear wing downforce increased as its angle was steepened

on a given wing's performance across an operating range, whether the information has been divined in a wind tunnel or numerically (generally CFD nowadays). Comparisons between wings can also be done if the methodology and conditions are identical. However, the performance of a wing changes once it is affixed to a racecar, whatever type of car that may be, and that change in performance is obviously very apparent when the car is a single seater. We saw in our April 2014 study how front wing performance was significantly altered by the presence of wheels and the rest of the car downwind. Clearly then we should expect that rear wing performance will be much affected by the presence of most of the car and all four wheels upwind. However, it is also well-known that the rear wing can influence the aerodynamic performance of the upwind car. In essence then, this article explores how this rear wing was affected by its deployment on our single seater model, and in turn how the car was affected by the wing's deployment. **[CFD plots 1 and 2]**

The wing itself was a high downforce 300mm chord single element design with a relatively thin section and quite high camber. Chord remained fixed at 300mm in this study, purely on the basis that, in real-world practical terms, parameters like span and location are much more easily altered than section profile. It is hoped to continue with further on-car studies on variable wing chord and profile as well as dual- and multi-element designs in a future issue.

Angles

Generally the first means of characterising a wing is to carry out an 'alpha sweep', by mapping downforce versus angle of attack (AoA). So the wing was mapped in isolation across a working range, and the same sweep was repeated on the car. Span was 1000mm in each case. **Figure 2** plots wing downforce versus angle and, as would be expected, the downforce the wing made on the car was less than it made in isolation across the angle range. The shape of the downforce curve was very similar in both cases, with gains tailing off at the steeper angles. And although the gap between the two curves superficially appeared to grow with each steeper angle, in reality the proportion of freestream downforce that the wing made on the car (at this wing span and location) actually increased with angle, as shown by **Figure 3**.

Looking at the overall aerodynamic performance of the car across the wing angle range, **Figure 4** plots total downforce along with wing downforce and 'chassis' downforce. The latter included the chassis, bodywork, suspension, and importantly, the underbody, but excluded the wheels and the front wing. Total downforce, as would have been measured in a wind tunnel, increased with each wing angle

The performance of a wing changes once it is affixed to a racecar

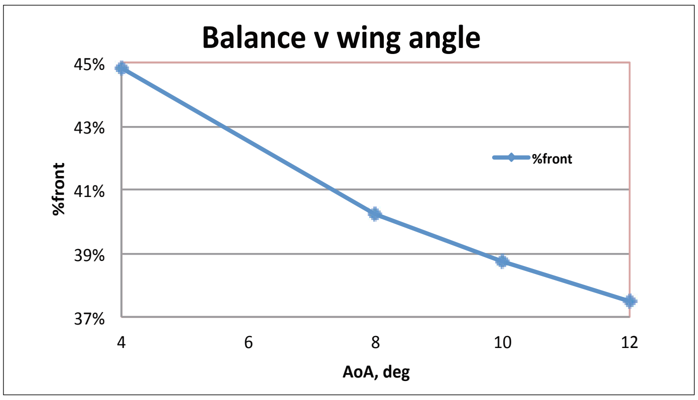


Figure 5: The balance responded to the rear wing angle change, as was expected

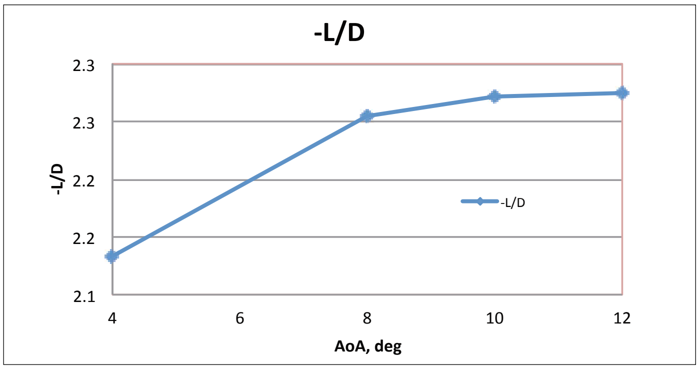
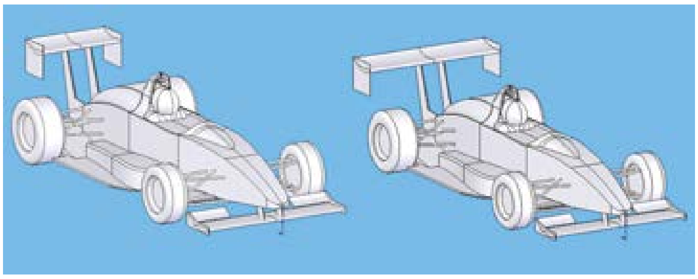


Figure 6: This shows that efficiency increases tailed off with increasing wing angle

Table 1 – the car's data across the rear wing angle range, forces in Newtons at 100mph

AoA, degrees	Drag	Downforce	%front	L/D
4	757.56	1615.60	44.81%	2.133
8	763.32	1720.91	40.24%	2.255
10	808.32	1836.01	38.74%	2.271
12	821.53	1868.22	37.48%	2.274



CAD-2: Rear wing spans from 800mm to 1400mm were evaluated on the racecar model

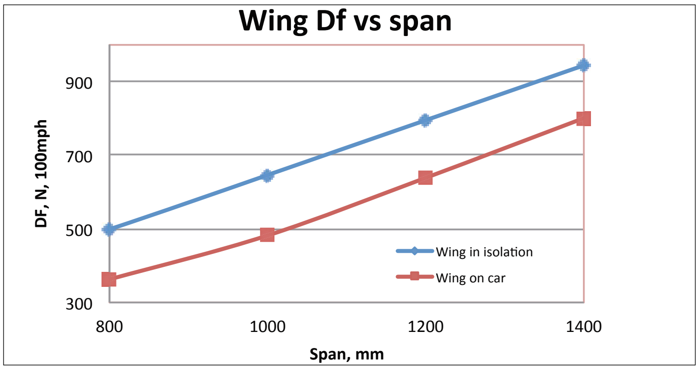


Figure 7: The wing's downforce gains as span was increased were greater on the car than on the wing in isolation – because of the driver etc., upstream of the centre section

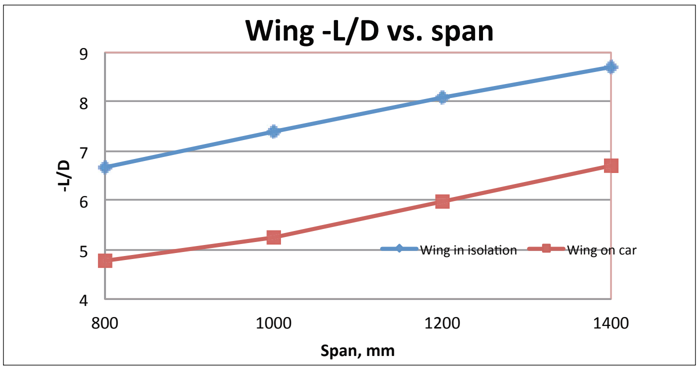


Figure 8: The wing's –L/D also improved more with span increases when on the car

increase, but notice the upwards step at 10 degrees. Exploiting the CFD to quantify the force contributions of individual component groups, it was evident that the chassis/underbody showed a modest step increase in downforce at 10-degree angle too. And not shown on this plot but which made a contribution here, wheel lift also appeared to reduce at the steeper wing angles, demonstrating simulated interactions that would not have been individually discernible in a wind tunnel that simply measured wheel contact forces (although a wind tunnel that supported the wheels separately from the chassis would pick that component up). The key point here is that yes, the rear wing's downforce contribution increased with increasing angle, as would be expected, but there were also other interactions, albeit it modest ones, in this opening example, that demonstrated the picture is rarely simple.

Figure 5 plots the car's aerodynamic balance (as '%front') versus wing angle and clearly showed the expected rearwards shift in balance with increasing rear wing angle. **Figure 6** plots –L/D (aerodynamic efficiency) versus wing angle, and shows that efficiency flattened off at the steeper wing angles. Together with the tailing off 'alpha sweep' plot, this suggested that the wing was approaching its maximum useful angle, in this application and configuration, at 10 degrees. **Table 1** summarises the data over the wing angle range tested.

Span decks

The baseline wing on which the alpha sweep was conducted had a span of 1000mm. It was decided to test some different spans at just one angle of attack, and the 10 degree AoA model from above was modified to spans of 800mm, 1200mm and 1400mm. The datum of 1000mm was chosen to represent the rear wing width limit seen in many a circuit racing category, while 1400mm is the UK's hillclimb maximum rear wing width. The narrower span of 800mm was chosen to see how narrow wings such as Formula 1 use would fare on the back of a 'regular' single seater. The wings were again tested in isolation and on the car. **(CAD Figure 2)**

When tested in isolation, the wing's downforce and drag both showed linear increases over the range of spans tested. Efficiency, as defined by –L/D (or downforce divided by drag) also increased linearly across this span range, too, which fitted with the accepted wisdom that efficiency improves as 'aspect ratio' (span divided by chord) is increased.

However, when the wing was located on the car the downforce gains that accrued with each span increment increased each time, the curve 'accelerating' slightly as span was increased **(see Figure 7)**. This reflects the fact that the central section of the wing was the most adversely affected when the wing was placed on the car, being behind the upstream obstruction of driver, roll hoop and so forth, whereas the additional outer widths are always in 'cleaner' air. The –L/D plot of the wing in isolation versus on the car **(Figure 8)** shows a similar picture. The wing clearly had a lower -L/D when on the car, but the gains with each span increase got bigger each time, reflected in the proportion of freestream downforce that the wing made on the car at this angle and location, seen in **Figure 9**.

The global picture is equally interesting. Overall downforce (and drag) increased with increasing rear wing span, of course, but the gains tailed off at the top end of the span range, in contrast with the gains from the rear wing itself and from the chassis/underbody **(see Figure 10)**, both of which actually saw slightly 'accelerated' gain at the widest span. This reflected an increase in wheel lift at the widest span (reversing what was a decline in wheel lift with each previous span increase), which coincided with the rear wing now

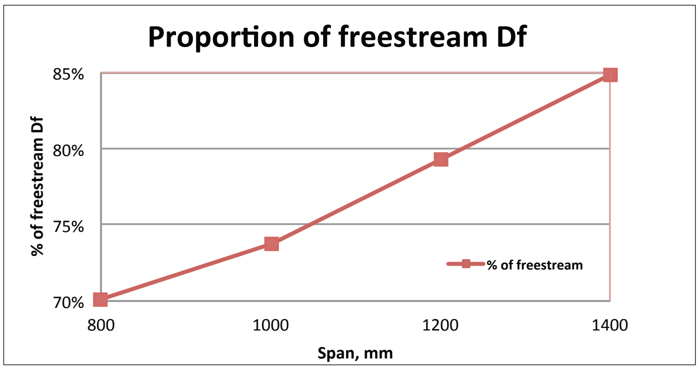


Figure 9: The wing lost a lot less of its 'in isolation' downforce at the larger spans

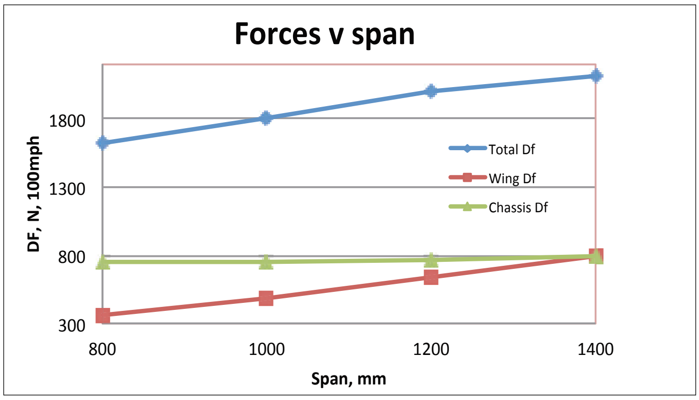
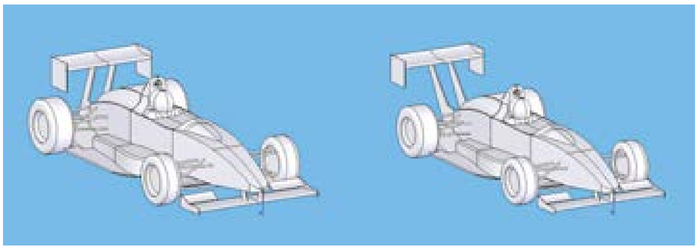


Figure 10: The increase in total downforce tailed off as the span was increased, this was despite wing and underbody downforce increases that did not tail off

Table 2 - the car's data across the rear wing span range, forces in Newtons at 100mph

Span, mm	Drag	Downforce	%front	L/D
800	762.32	1621.75	43.40%	2.127
1000	797.60	1804.91	38.34%	2.263
1200	824.52	1999.35	33.07%	2.425
1400	845.08	2111.40	28.01%	2.498



CAD-3: A range of fore/aft locations for the model's rear wing was also evaluated

Table 3 – the car's data at different rear wing fore/aft locations, forces in Newtons at 100mph

x, m	Drag	Downforce	%front	L/D
3.15	833.30	1741.75	42.56%	2.090
3.35	820.24	1804.94	40.61%	2.201
3.55	821.53	1868.22	37.48%	2.274
3.75	807.65	1815.50	35.90%	2.248

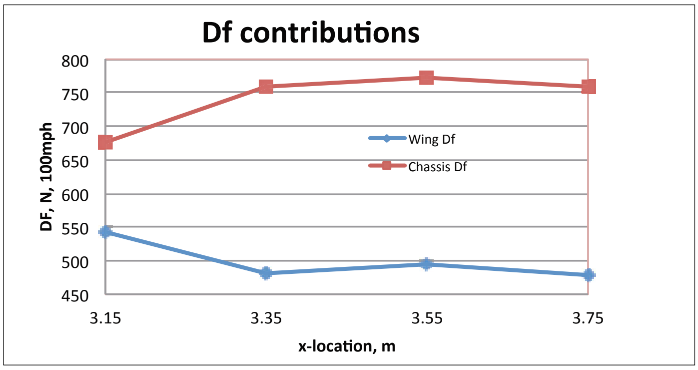
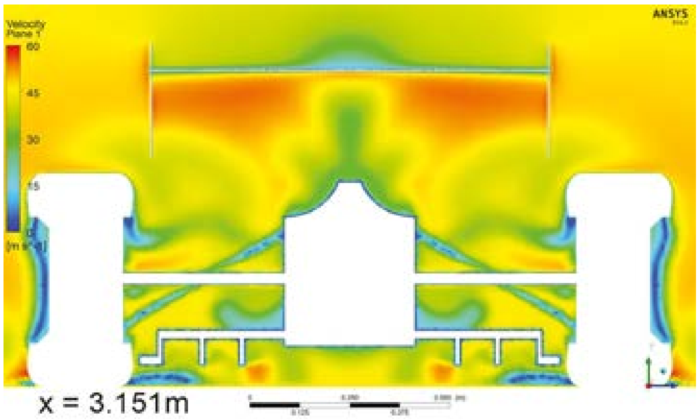
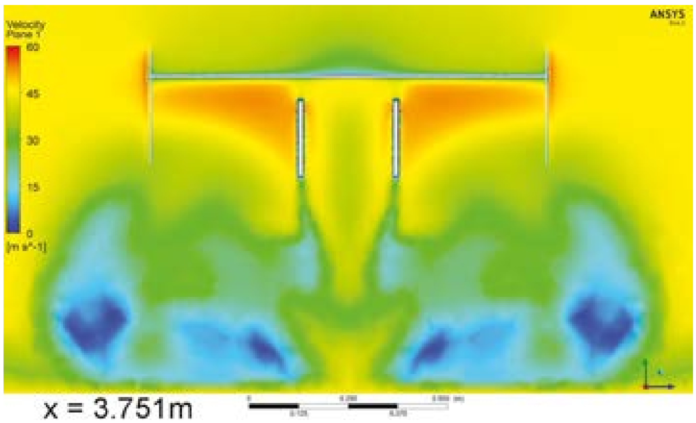


Figure 11: This shows the downforce contributions of the rear wing and chassis/underbody at varying wing fore/aft positions – and some interesting interactions



CFD-3: The velocity plot on the plane at the wing's leading edge at location x=3.15m shows 'freestream velocity plus' across most of the span



CFD-4: The velocity plot on the plane at the wing's leading edge at location x=3.75m shows lower velocities approaching the wing's all-important underside region

being wider than the inside of the wheels and as such accelerating the airflow (and thus reducing the static pressure) over the tops of the tyres both front and rear. Balance not unexpectedly showed a marked and linear shift to the rear with each extra increment of rear wing span. **Table 2** summarises the data over the span range tested. Nevertheless, the downforce and efficiency gains certainly point towards using the maximum permitted span.

Fore/aft location

The datum fore/aft, or x-location in the forgoing sections, put the wing's leading edge at x=3.55m, where x=0 coincided with the tip of the car's nose. Three other x-locations for the wing were evaluated on the car, at 3.75m, 3.35m and 3.15m, the last of which put the wing's leading edge directly above the rear axle. These runs were with wing at 12 degrees, and **Table 3** summarises the data. **(CAD 3)**

Superficially this all looks fairly straightforward, with downforce and –L/D peaking at the datum fore/aft location of x = 3.55m, which we might naturally assume was where the wing interacted best (at this height) with the car's underbody. Balance, however, changed in an essentially linear fashion with the wing's fore/aft location, and we might simply assume that this was just down to the wing's location. However, check out **Figure 11** showing the downforce contributions of the rear wing and the chassis/underbody and it becomes clear that the picture is not that simple. Wing downforce actually peaked at the furthest forward location, which initially seemed curious but can be explained by **CFD plot 3 and 4** showing generally higher velocity in the airflow approaching the underside of the wing at x=3.15m. At the other locations the wing's

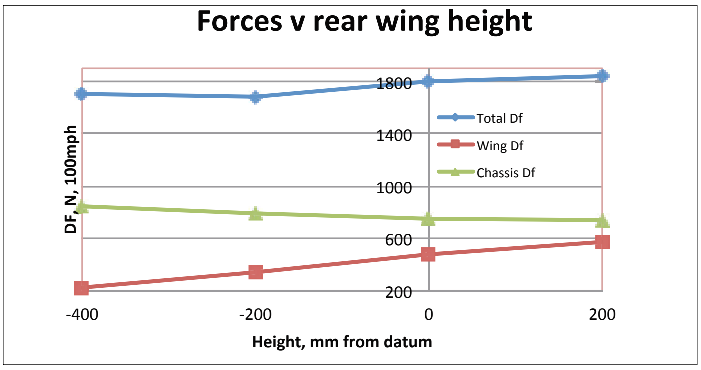
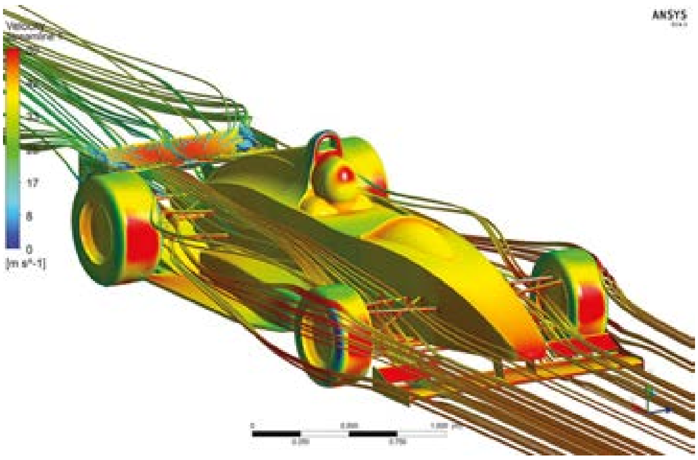


Fig 12: Adjusting rear wing height once again showed that interactions were taking place. The racecar model was tested at three additional wing heights

Table 4 – the car's data at different rear wing heights, forces in Newtons at 100mph

Delta y, mm	Drag	Downforce	%front	L/D
200	792.49	1835.17	35.17%	2.316
0	797.60	1804.91	38.34%	2.263
-200	757.51	1683.35	44.25%	2.222
-400	730.02	1699.86	48.06%	2.329



CFD-5: The rear wing's operating environment is much compromised at reduced height, but the car's overall aerodynamic performance didn't necessarily suffer

Table 5 – the car's data at different rear wing dual tier spacings

Tier spacing, mm	Drag	Downforce	%front	L/D
0	816.11	2033.74	33.78%	2.492
150	896.50	2248.07	28.02%	2.508
300	906.72	2211.00	28.59%	2.438
450	875.05	2209.92	33.84%	2.525

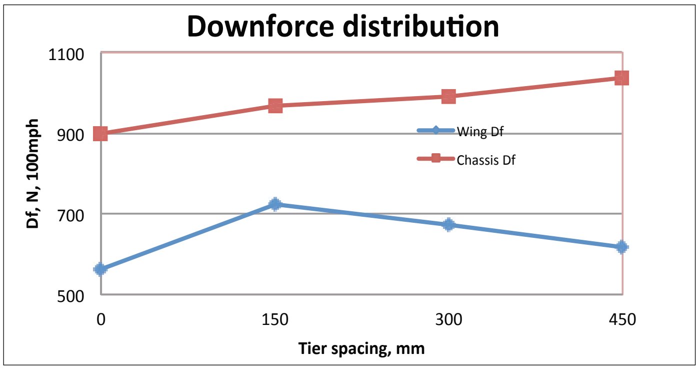


Figure 13: Downforce distribution with a dual tier rear wing fitted to the racecar model, and varying heights of the lower tier, again showed wing/underbody interactions

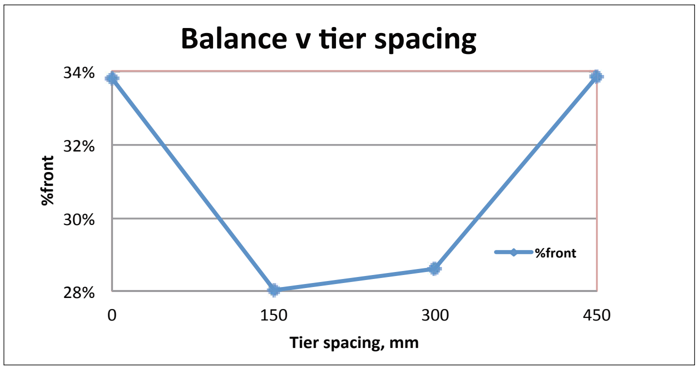


Figure 14: The balance was the same at the lowest second tier height as it was with no second tier, but the total downforce was greater in this configuration

downforce was somewhat lower and altered little. Conversely, the chassis/underbody's downforce contribution increased significantly when the wing was moved from its furthest forward location and continued to increase to the datum position of x = 3.55m. So, while our initial assumption about interaction with the underbody looks correct, once more the detail shows a more complex situation.

Height

The datum height of the wing was initially set so that the top of the end plate, which was just clear of the top of the wing's trailing edge, was 900mm above ground, a typical maximum height in many single seater categories. Using the datum x-location of 3.55mm and AoA of 10 degrees the car was re-tested at three additional heights of +200mm, -200mm and -400mm relative to datum height. Overall drag and downforce, plus rear wing and chassis downforce are plotted in **Figure 12** and **Table 4** summarises overall data.

Overall drag was roughly the same at +200mm and datum height, but dropped fairly linearly by a modest amount at each of the next two lower heights. Overall downforce peaked with the rear wing at +200mm but recovered slightly when the wing was set at -400mm despite the initial decline with reducing height. Rear wing downforce showed a more or less linear decrease with each reduction in height, while conversely chassis/underbody downforce showed a more or less linear increase as wing height reduced. Not shown here, rear wheel lift also decreased with this last rear wing height reduction, this also contributing to the recovery in total downforce at this lowest wing height.

Once more our immediate conclusion must be that the rear wing, despite generating less downforce itself, was interacting with the underbody more at lower heights and helping to increase the downforce of the latter **(CFD plot 5)**.

The –L/D shows that the initial decline with reducing wing height also sharply reversed at the lowest wing height, reflecting the relative efficiency of underbody generated downforce and also that overall drag had declined at the two lowest wing heights evaluated.

Multiple tiers

Additional tiers are a common sight on rear wings across a multitude of categories, although generally speaking the maximum is two tiers. Joseph Katz showed us in *Race Car Aerodynamics* (1st Ed.) that, in isolation, up to four tiers incrementally increased downforce potential but that the –L/D also incrementally reduced. So more than two tiers was not recommended unless maximum downforce was sought and drag penalties were to be disregarded. Part of the problem is that space on the back of a racecar is usually limited by: regulatory maximum height; locating the lower tier to interact favourably with the diffuser exit; and physical space. Furthermore, Katz showed that putting one wing below or above another saw them interact unfavourably with each other and reduce the downforce of each element, although the potential combined downforce could still be greater than a single wing on its own as long as vertical spacing between them was approximately 50 per cent of chord or more.

With all the above in mind, dual-tier configurations were evaluated initially on our single seater model at three different tier spacings; the lowest second tier position was 450mm below the datum height, which put the lower tier nicely above the diffuser exit; the intermediate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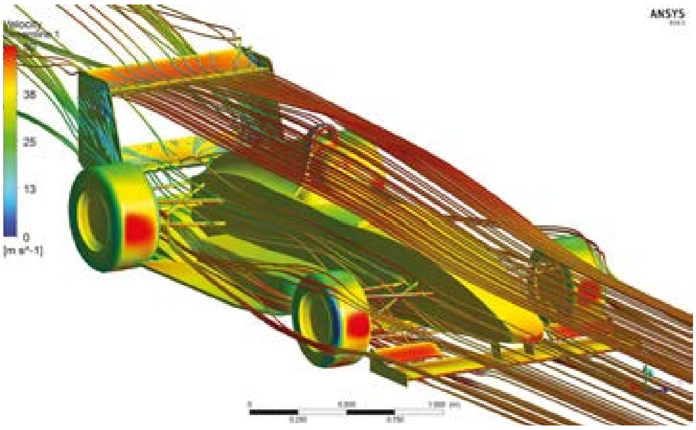

CFD-6: The dual-tier rear wing configuration worked well on our racecar model

Table 6 – the car's data with one to four wing tiers

No. of tiers	Drag	Downforce	%front	L/D
1	816.11	2033.74	33.78%	2.492
2	875.05	2209.92	33.84%	2.525
3	959.52	2362.89	26.47%	2.463
4	1008.76	2487.99	24.50%	2.466

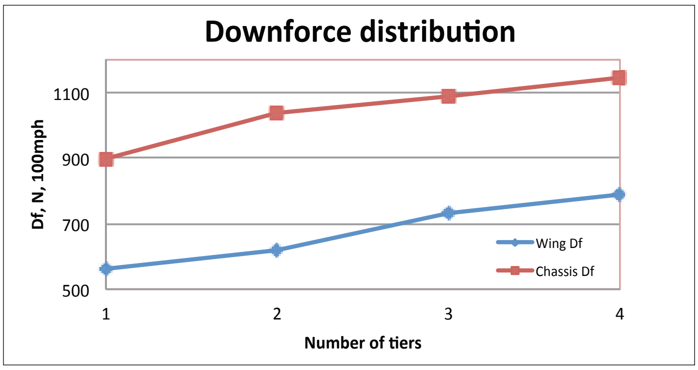


Figure 15: This graphic shows that the wing and the chassis/underbody downforce increased as the rear wing tiers were added to our racecar model

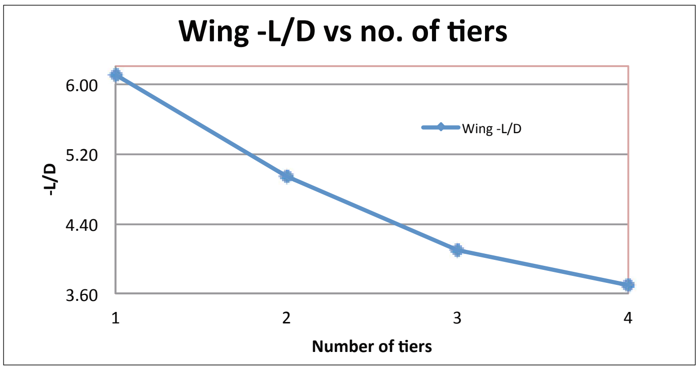
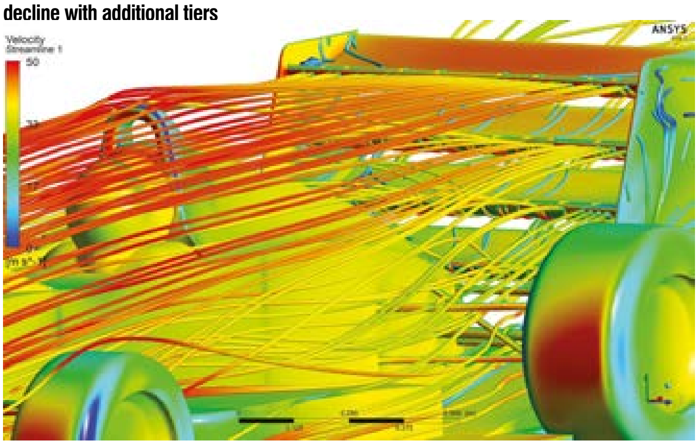


Figure 16: The –L/D of the wing assembly on the car showed an exponential decline with additional tiers


CFD-7: The airflow to each successive lower tier can be seen here to be compromised more than the one above. Yet multiple tiers can offer potential performance advantages, though that depends very much on the application. This is similar to the Katz plot

spacing was 300mm below the datum (= one chord's distance) and the highest position was 150mm below datum height. The upper tier was fixed at datum height, 10 degree AoA and x=3.55m in all cases. The second tier was set at the same angle and x-location. To connect the tiers the central mountings were replaced with end plate mountings that attached to the outside of the diffuser.

The overall results are shown in **Table 5**, and where the tier spacing is stated as 0mm only one tier was present, in the datum location, with end plate mountings.

Adding the second tier at 150mm (half a chord's distance) below the datum wing added slightly more than 10 per cent total downforce and also added just under 10 per cent more drag, which saw the –L/D value increase very slightly. Balance shifted rearwards fairly significantly.

However as the second tier's height was reduced, drag initially climbed slightly further but then reduced again, while downforce dropped and then stabilised over the next two spacings. Interestingly, but not entirely surprisingly given what we saw above when the single rear wing was lowered in height, when the second tier was put 450mm below the top tier the balance shifted forwards again and –L/D reached its maximum. The plots in **Figures 13 and 14** illustrate how the wing and chassis/underbody individually fared, and how balance changed. **Figure 13** shows the initial (29 per cent) jump in the wing assembly's downforce with the addition of the second tier, which then decreased at the next two lower positions as the lower wing tier was moved into what we know from the previous section was a less favourable environment. Chassis/underbody downforce, however, increased with the initial fitment of the second tier and continued to increase as that tier was lowered in height.

So locating a second wing tier 1.5 chord's distance below the upper tier increased total downforce by 8.7% and –L/D by 1.3% without changing the aerodynamic balance. On the downside drag increased by 7.2%, so the suitability of this configuration would obviously depend on the specific application **(CFD plot 6)**.

If placing the second tier 450mm below the first tier was the best solution from the above trial, and 450mm was accepted as the lowest practical location here, what would happen if one or two more tiers were fitted in between the top and bottom tiers? While this might be less practical if deeper section (for example multi-element) wing tiers were being used, with the relatively thin section single element wing here it was a simple thing to try. So one and two additional tiers were installed at even spacings between the top and bottom tiers, and the overall results are in **Table 6**.

A glance at **Table 6** shows that both downforce and drag increased roughly linearly with each additional tier and balance shifted rearwards with tiers three and four. It might be tempting to think that the extra intermediate tiers added drag and rear wing downforce only, but **Figure 15** shows that chassis/underbody downforce did respond to these intermediate tiers and contributed to the incremental downforce increases, just not by enough to prevent the balance shifting rearwards. Interestingly, the decrease in the car's –L/D with each extra tier was very modest in the context of the whole car, although plotting the –L/D of the wing assembly only versus the number of tiers **(see Figure 16)** produced a generically similar plot to that published by Katz. **(CFD plot 7)**

Summary

This brief look of some of the rudiments of rear wings has highlighted that simple assumptions can hide some of the detail of what is actually going on. But CFD can reveal useful and fascinating insights into the underlying interactions.

Many thanks to ANSYS UK for providing the CFD software.

Simple assumptions can hide some of the detail of what is going on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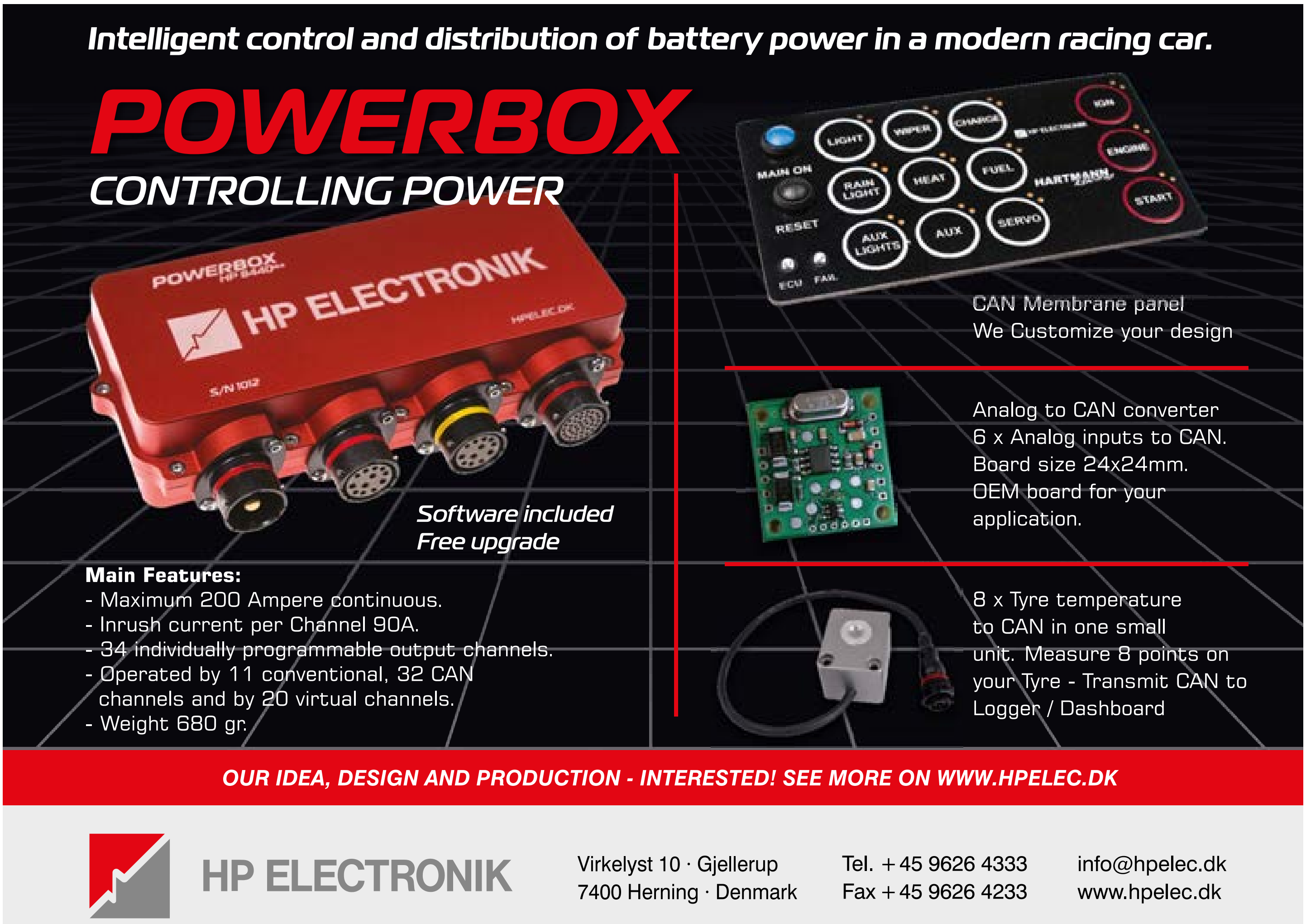
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Practical magic

Our maths wizard conjures up a practical approach to generating aero maps from track data, a trick well worth having up your sleeve

By DANNY NOWLAN

One of the first articles I ever wrote for *Racecar Engineering* was about aero map generation from race data. In that piece and subsequent articles I laid down the theoretical basis for this and some tips and tricks I've learnt on the way. The goal of this article is to tie these techniques together, so that if you ever need to do this you can roll this out at a moment's notice.

The motivation for this article is that if you are working as a data or performance engineer you are going to have to do this at some point. Don't get me wrong, I am not trying to do a disservice to wind tunnels or CFD. They are valuable tools and you would be mad not too make use of them. As a case in point the quality of the work done by TotalSim (CFD) and the A2 Wind Tunnel are totally first class. That said, the final validation point must always be on the track. Also, there will be times when you won't have access to these tools so you will have to make do with what you have.

Also the technique we are about to discuss here is not theory. It has been validated in categories as diverse as open wheelers, sportscars, GT cars and touring cars. If truth be told I have lost count of the number of times I have done this. If anything, this was the thing that motivated the creation and employment of the ChassisSim aero modelling toolbox. It has saved my neck on more occasions then I care to remember. I will also be talking about how to use the ChassisSim aero toolbox – and for this I make zero apologies.

Stick to pogo

The theoretical background of all this is that every damper pot on the racecar is a load cell. If we know that then all we need to do is figure out the forces from the spring rates, bump rubber and motion ratio information. The why of this, as always, is provided by the beam pogo stick visualisation of the racecar presented in **Figure 1**. As I have stated in previous articles, something needs to support the racecar. As we can see from the beam pogo stick visualisation, that comes from the springs.

To prepare for the test we need to discuss some preparation points. To begin with, in terms of set-up you want the car as soft as possible. In any aero test we want as much ride height variation as possible. The key reason for this is when ever we run a car we get a thin sliver of the aero map back, as illustrated in **Figure 2**. What is shown here is an overlaid plot of the ride height envelope we are in, shown on top of the aero map. The softer the car the better because it means that sliver is as big as possible. Also, where you can just run springs you want the car as linear as possible so you don't have any hysteresis effects spoiling the party.

Secondly, you must have well calibrated and reliable damper pots. If you don't have that don't even bother turning up. The other key thing is zero them on the ground. My favourite place to do this is with the car trundling out of the pits. This is illustrated in **Figure 3**.

The reason we want to zero our dampers on

The car trundling out of the pits is in an ideal state for zeroing your damper pots

XPB

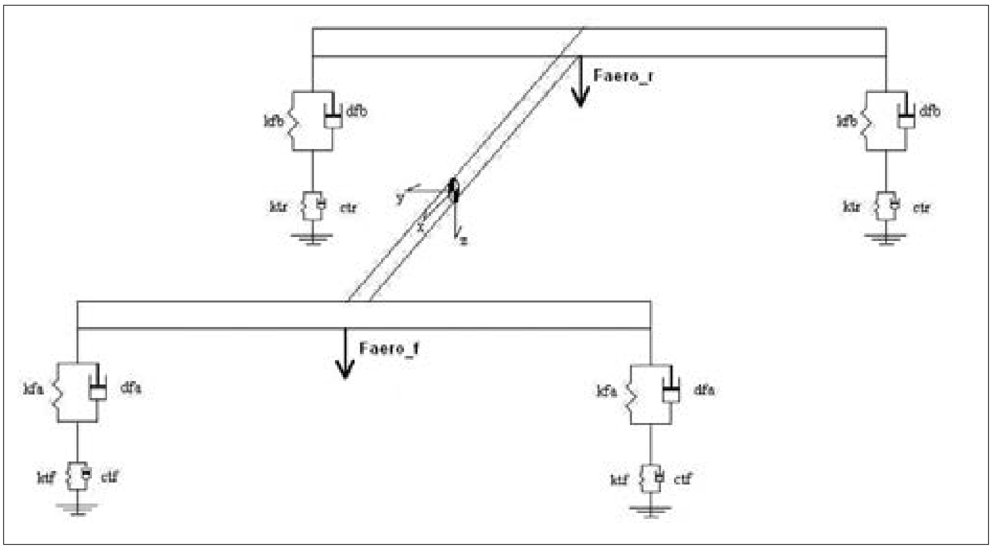

Figure 1: The trusty beam pogo stick approximation, which shows how the springs support the racecar

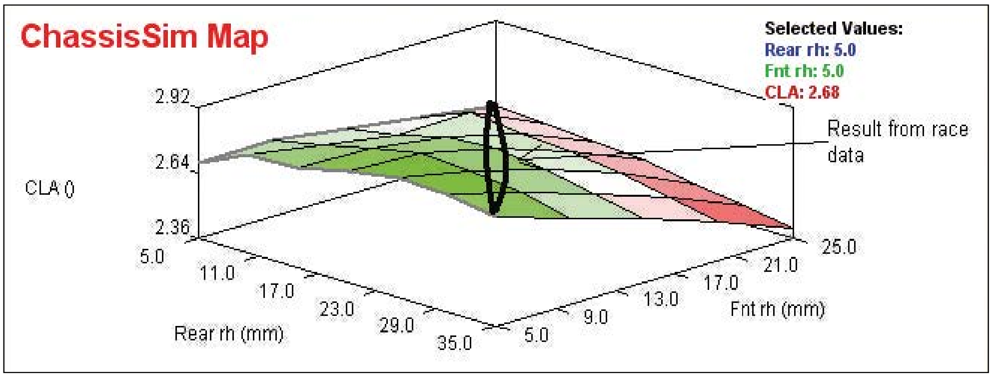

Figure 2: You will only ever get a small amount of the data back, as shown, so it's best to run the car soft

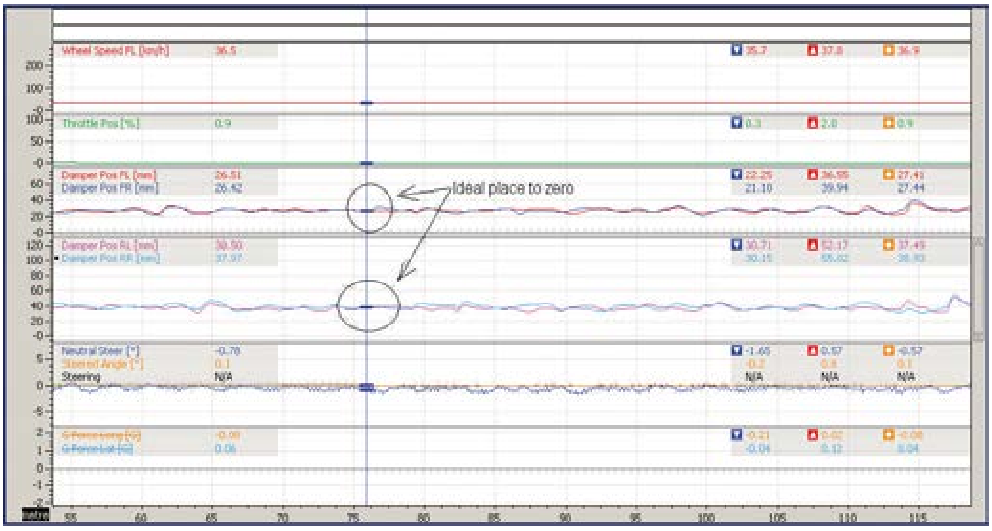

Figure 3: Damper zeroing procedure – this really needs to be done on the ground

You must have well calibrated and reliable damper pots. If you don't have these then don't even bother turning up

the ground is that in my experience it's a really handy tool to validate what you are doing. Just for the record, the ChassisSim aero toolbox can do both, but I have found that zeroing on the ground delivers more consistent results.

Also, while load cells and laser ride height sensors are great, they are not a show stopper if you don't have them. Don't get me wrong, if you have them and they are working properly you would be crazy not to use them. That being said I have found that these sensors are a bit like fish and chips or romantic movies. They are either really good or really bad and there is no in between. Loads can be approximated by your damper pots and if you have good tyre spring rate data you can fill in the blanks with tyre deflection. It's what the ChassisSim aero modelling toolbox does.

The test matrix we'll adopt will be a ride height sweep followed by wing runs. This is illustrated in **Table 1**.

Flat on flat

The deltas you choose will depend on the type of racecar you have. For example, for an open wheeler or sportscar these might only be in the order of 2 to 5mm. For a touring car these deltas might be in the order of 10mm. As a rough rule of thumb, choose the delta where you know it will have an effect on the car. The goal of tests 1 to 6 is to establish the pitch sensitivity map. The goal of tests 7 to 9 is to assess the variation in downforce levels.

In terms of the mechanics of the test you are better off using straight-line, full throttle tests. A smooth airport is ideal but it can work on a race track. I had to approximate this once at a roval when I was doing work in Star Mazda. But the key thing is to ensure that your test track is as flat as possible. Again the reason you are doing full throttle tests is to get as much ride height variation as you can and given the engine is at full power that is one less variable to worry about.

Just a quick word on coast down and single point tests, because I realise for some it is an article of faith. I would certainly do a coast down test and I would certainly run some single point tests for validation. That being said, I wouldn't be losing too much sleep if you didn't do it. This is just based on the volume of aero testing I have done with full throttle runs.

Also, when doing the pitch sensitivity, make sure you have the car in the representative configuration you run in. I once had a customer run a test on an open wheeler where they set the front wing to minimum settings and negligible aero at the rear. Anyone familiar with the aero of high downforce open wheelers will know the front wing and rear wing configuration have a big effect on the pitch sensitivity of the racecar, since these dictate the flow conditions under the car. Fortunately in this case we just got away with it. However, the telling word here is *just*.

Table 1: Aero test procedure for a sportscar

Run No	Set-up
1	frh_0 and rrh_0 + baseline rear wing
2	frh_0 and rrh_0 + d_rrh + baseline rear wing
3	frh_0 and rrh_0 + 2*d_rrh + baseline rear wing
4	frh_0 and rrh_0 + 3*d_rrh + baseline rear wing
5	frh_0 – d_rrh and rrh_0 + baseline rear wing
6	frh_0 + d_rrh and rrh_0 + baseline rear wing
7	frh_0 and rrh_0 + baseline rear wing
8	frh_0 and rrh_0 + baseline rear wing + 2 holes
9	frh_0 and rrh_0+ baseline rear wing + 3 holes

The nomenclature we have:
frh_0 = Baseline front ride height as specified in the starting set-up.
rrh_0 = Baseline front ride height as specified in the starting set-up.
d_rrh = delta rear ride height.
d_frh = delta front ride height.

Table 2: Noting down the average results

Wing configuration	C_LA_{AVGE}	C_DA_{AVGE}	Ab_avge
Baseline	3.6	1.1	40
Rear wing + 2 holes	3.62	1.12	38
Rear wing + 3 holes	3.63	1.13	36

Table 3: Example database of what you enter in ChassisSim

Wing configuration	C_LA_{max}	C_DA_{max}	Ab_offset
Baseline	3.7	1.2	0
Rear wing + 2 holes	3.72	1.22	-0.02
Rear wing + 3 holes	3.73	1.23	-0.04

EQUATIONS

EQUATION 1

$$Z = A\cdot x^2 + B\cdot y^2 + C\cdot x\cdot y + D\cdot x + E\cdot y + F$$

EQUATION 2

$$C_LA_{MAX}\_new = C_LA_{MAX}\_bline + (C_LA\_new - C_LA\_bline)$$
$$C_DA_{MAX}\_new = C_DA_{MAX}\_bline + (C_DA\_new - C_DA\_bline)$$
$$ab\_offset = (ab\_new - ab\_bline)/100$$

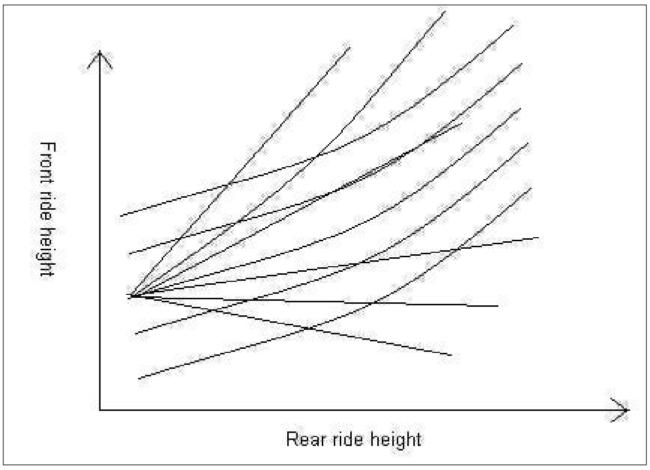

Figure 4: Plot of front *vs* rear ride height – this needs to be as 'fat' as possible

As a further note the techniques we are discussing work fine for small wing changes. You have to redo the process when you make big changes that will effect the under body flow of the car. Big changes in front wing configurations for an open wheeler are a good case in point. Once the tests are completed your analysis will split into two sections.

Step one

The first step is constructing the ride height sensitivity map. In that regards the ChassisSim monster file export system and the aero toolbox are going to be your best friend. For the uninitiated, the monster file is an ASCII export of your data at 50Hz of distance, RPM, acceleration, damper pots speed steer and throttle. You enter this into the ChassisSim aero toolbox and what it returns is the downforce, drag and aero balance sliver we discussed in **Figure 1**. The format of this is the following: Front ride height (m), Rear ride height (m) C_LA, C_DA, aero balance/100.

You run this for each data set saving the name of the output file. For example ChassisSim will create a file called 'aero_analysis_results.dat', so you rename this for each one. As an example for Run 1, you would rename the file 'aero_analysis_results_run1.dat', and so on.

Once you have done this you concatenate the files into a single big file and do a 3D curve fit to generate the ride height sensitive aero maps. ChassisSim has a number of inbuilt tools to help you do this but since it's an ASCII file you can import this into packages such as Matlab to do your own analysis. The curve fitting algorithm you choose is up to you. That being said, in my experience the most stable is a second order curve fit that looks like **Equation 1**.

Here *Z* can be C_LA, C_DA or aero balance and *x* and *y* are the front and rear ride heights. *A* to *F* are constants. There are also other algorithms you can use such as the parabolic front ride height fit method used in ChassisSim but a detailed discussion of this can be left for another time.

The plot fattens

One thing I will highlight is to have a good look at the returned plot of front and rear ride height. If you plot front and rear ride height as a function of each other you will have a plot that looks like that shown in **Figure 4**. You want **Figure 4** to be as fat and as big as possible, because this will then give you plenty of data to work with.

Once you have established this, your next job is to establish what the wing adjustments do. You'll notice that in the test procedure we outlined in **Table 1** that we reset the ride heights back to their initial condition for the wing sweeps. The reason we do this is to re-establish our baseline condition so we know what does what.

As was the case with the ride height sweeps, you export the monster file and run the aero toolbox in ChassisSim. This time around, though, you are looking at the averages ChassisSim returns. You want to note this down in a table similar to the one shown in **Table 2**.

The finishing touch is to look at the ride height map you just generated and tie it together with what has been generated in **Table 2**. This will vary from simulation package to simulation package but in ChassisSim the front wing dictates the pitch sensitivity and the rear wing controls the scale of the downforce and drag maps and the aero balance offset. What you need to note is the maximum C_LA and C_DA of the pitch sensitivity map we created for the baseline configuration. Let's denote these C_LA_{MAX}_bline and C_DA_{MAX}_bline respectively. Then to figure out the new maximum C_LA and C_DA and aero balance offset the equations become those seen in **Equation 2**.

Here C_LA_bline, C_DA_bline and ab_bline are the average values of our baseline configuration in **Table 2**. The terms C_LA_new, C_DA_new and ab_new refer to the subsequent entries in **Table 2** and the terms C_LA_{MAX}_new, C_DA_{MAX}_new and ab_offset is what you put into the rear wing of ChassisSim. When you are done you'll have something that looks like **Table 3**.

That is the general game plan for generating aero maps from race data, then. That said, there are a few tips and tricks worth noting.

The first tip I would give is to validate the pitch sensitivity map. Since this is inherently a curve fit there will be some errors that creep in. My preferred method is that I will construct a bump profile and curvature file of the test track

Using a few simple steps you can come up with a map that is very close

and replay it using the lap time simulation for the pitch sensitivity runs I did. Then what I will do is change the C_LA_bline, C_DA_bline and ab_bline to best suit the data. This will take a bit of time for you to develop your instincts and refine the results, but as a rough rule of thumb for open wheelers and sportscars if you have your pitches within a mm then you are doing okay.

The second step is to validate the wing level changes. Again what I do is run the lap time simulation to see the changes make sense and then adjust the delta wing changes accordingly.

In both cases, when you are validating the places to concentrate on are the ends of the straights. Being from race data, and remembering that the lap time simulation does not know fear, this is not going to be perfect everywhere.

The pay-off at the end of this process will be an aero map and configuration you can use in anger at the race track. An example of the correlation you can expect is shown in **Figure 5**.

As always, actual data is red and simulated is black. This particular example came from a Star Mazda car I did some work on back in 2009. As can be seen, while not perfect everywhere, as we can tell from the front and rear pitch traces (third and fourth plot) respectively, we have pretty much nailed down both the downforce levels and the pitch sensitivity. Just to be clear, front pitch is the average value of the two front dampers and rear pitch is the average value of the two rear dampers. If you have something that looks like this, start using it in anger.

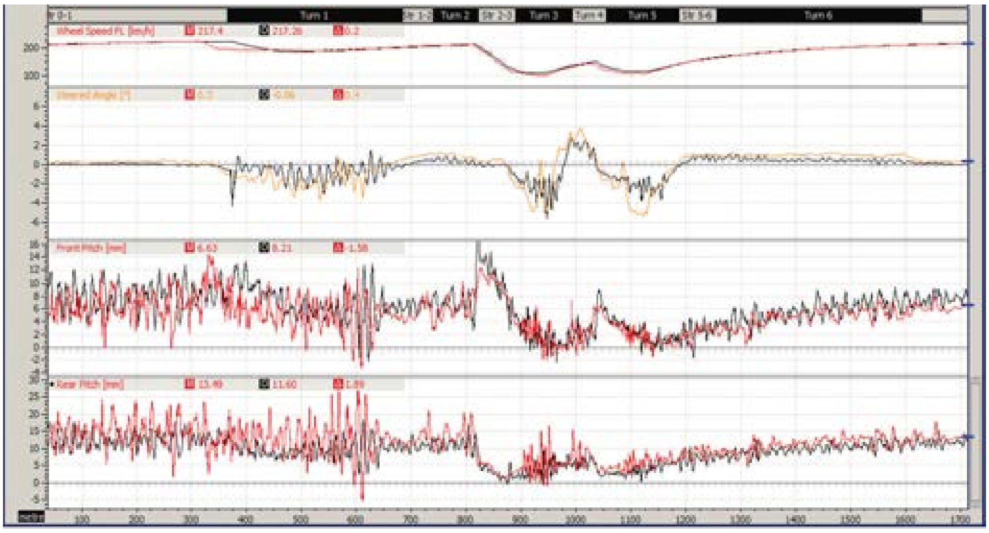

Figure 5: Comparison of actual *vs* simulated data using an aero map generated from the track data of a Star Mazda racecar

The edge

In closing generating an aero map from race data isn't just necessary it's actually also quite doable. Using a few simple steps you can come up with an aero map that is very close. The keys to making this a success is to use a soft set-up, do full throttle runs and break the test down into a pitch sensitivity and wing sweep section. If you do that and then apply the tweaks we discussed you'll not only have an aero map that you can not use to determine the set-up, but you will have also learnt a lot about the racecar in the process. This will give you that crucial edge when it come to race day.

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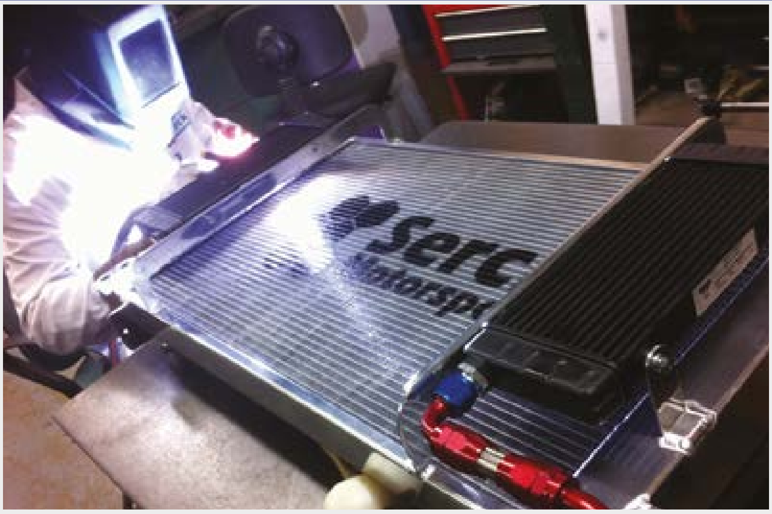

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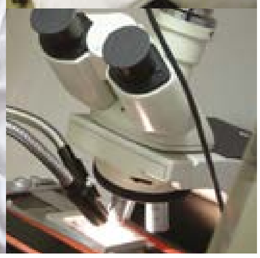

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Where Eagles dare

A mechanical issue may have scuppered the North American Eagle team's first attempt to make history but it is confident it's still on course to smash the Land Speed Record

By LEIGH O'GORMAN

First featured in *Racecar Engineering* in January 2012 (V22N1) the jet-powered North American Eagle machine has been through much since then. But before we update you on its trials and triumphs, here's a reminder of what's at the heart of this US Land Speed Record project.

It will not surprise you to learn that the North American Eagle did not begin life as a Land Speed Record machine at all, but rather as an abandoned fuselage from a jet fighter that had had its wings clipped, bought by owner and driver, and former US Air Force man, Ed Shadle, in 1999 for $25,000.

The fuselage, which once made up a large part of a Lockheed F-104 Starfighter, formed the basis of a project that took some years to kick into life. Initially set for scrap, the unit came with a significant amount of structural damage after the airframe had been demilitarised. 'There were certain things that were cut and damaged purposely, so we had to repair those things before we could even start building the car,' Shadle says. 'We had to start off with scanning the fuselage, take that data, using software to convert it into surfaces and we could use other software to do the analysis work. But in the end it is already designed for supersonic speeds – it is designed to go very fast.'

The build process for the North American Eagle involved not only resurrecting the fuselage, but also designing elements such as brakes and suspension – neither of which had been part of the original machine – in addition to building an engine. There was also a need to consider material applications; properties and treatment, before they could even begin manufacturing the ancillary components.

'The nose wheel, the middle wheel and rear wheel have three separate types of application,' says Shadle. 'The nose wheel has to be substantial enough laterally to take any forces from turning the car; the middle ones are smaller to run at high RPMs – at 800mph, they will turn 15,000rpm – then there's the rears, the larger ones which also have the magnetic brakes attached to them, so there are three different applications that they have been designed for.'

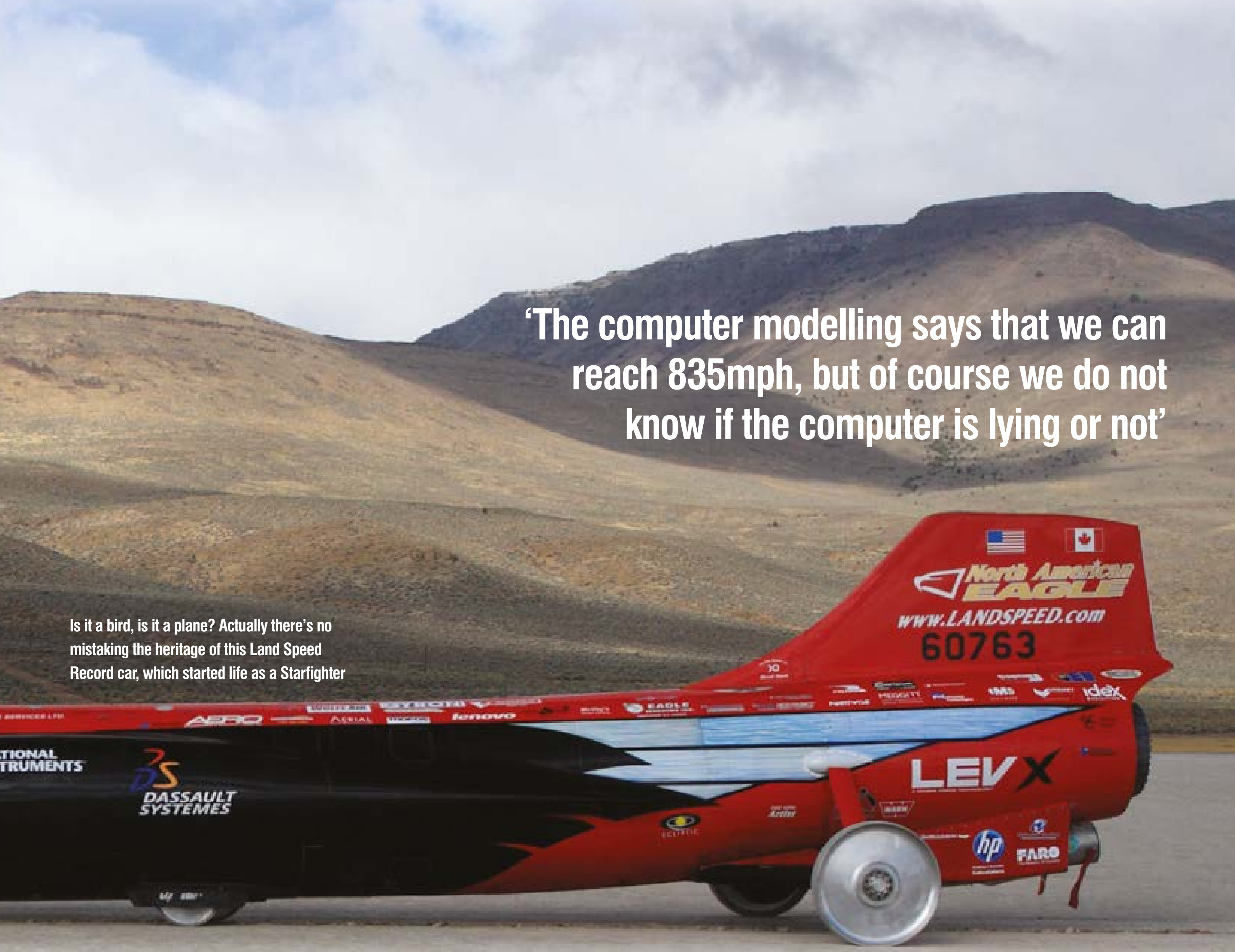
Groundwork

There was also extensive fluid dynamic analysis on the design work prior to production. Director of operations Keith Zanghi says: 'We went through around one year of engineering before we even got a final design, so there was lots and lots of FDA to identify stress points, because at $20,000 per wheel we didn't want to start until we had a design that was going to work.'

Thereafter the team brought the North American Eagle to Victor Aviation in Palo Alto to cryo-treat the nose wheel. Meanwhile, CMOS X-Ray conducted in-the-field scans of the equipment to search for possible internal cracks within the structure.

The braking technology on the North American Eagle was an element that Shadle admits 'came to us by accident'. In an unusual circumstance, Shadle became connected to a company called Lev-X, of which he had become aware when an IBM work colleague informed him of a son-in-law who worked for the Port Angeles company, who then put him in to contact with owner, Jerry Lamb. Shadle says: 'I explained to [Lamb] what we were trying to do with the Land Speed project. He stepped up and said he would like to help with the brakes and that's where we came upon the idea of using magnet-braking technology.'

A hydraulic system activates the brake rotors in the rear wheel, which are 24 inches in diameter. The rotors contain 27 neodymium iron bar magnets inside each brake pack and the brake rotors are mounted to the wheels, which when closed creates approximately 1570lbs of resistance torque on each wheel. According to Shadle, it is a technology that greatly moved the project forward. 'The good thing about it is that



‘The computer modelling says that we can reach 835mph, but of course we do not know if the computer is lying or not’

Is it a bird, is it a plane? Actually there’s no mistaking the heritage of this Land Speed Record car, which started life as a Starfighter

it is not only a wonderful brake, but also they do not wear out, because they never touch and they won’t skid, because as the rotation slows down, the eddy-force currents diminish, so we have a non-skid, non-wear type of brake.’

Stopping power

The brakes are kept cool during runs by dumping pressurised water on to the rotors, via a switch in the cockpit. Shadle adds that braking temperature has not been a significant issue: ‘I’ve done a stop from over 500mph and the brake rotors only got up to 175degF, and we are really tickled by that.’ In addition to the Lev-X brakes, the North American Eagle possesses air brakes that came with the aircraft, as well as parachutes that were developed in conjunction with Drumheller Engineering of Kent, Washington, for the purpose of stopping from extremely high speeds.

Powering the North American Eagle is a General Electric LM-1500 turbojet, modified from the J79-19 jet engine, originally developed for the Starfighter, which runs with a military-style afterburner. In-depth care of the GE LM-1500 is monitored by S&S Turbine Services – a family-owned turbine maintenance company, based in Fort St John in Canada, headed by Robin Sipe. It was a relationship born when a fault on a previous engine module spat turbine blades out of the back, prompting S&S to rebuild the unit with a new ‘hot’ section. According to Shadle, in the time since, the GE LM-1500 ‘has not had any issues that are significant. We are pretty darn happy with that engine – it performs how we want it to’.

Shadle feels that in its current format, the North American Eagle could produce close to its maximum when allowed to stretch its legs. ‘In crude configurations, the computer modelling says that we can reach 835mph, but of course we do not know if the computer is lying or not – the only way to prove it is to do the actual runs.’ Hitting that marker would take the North American Eagle well beyond the current Land Speed Record of 763.035mph, as set by Andy Green in the Thrust SSC in 1997.

Yet despite the confidence in the project, recent testing at Alvord Desert in Harney County, Oregon, ended prematurely when the NAE began pulling to the left during its initial run. According to Shadle a combination of hydraulics and structural engineering led to the problem: ‘It took sitting down and analysing all of our runs throughout the years to come up with the common denominator. We decided that it was prudent to do the next step, which was come home, analyse the problem, fix it and come back. That was the only technical issue we had to overcome. Everything else worked wonderfully.’

The fault curtailed Jessi Combs attempt to break the record for world’s fastest woman, but Shadle was quick to commend the professionalism of both Combs and the team given the circumstances. ‘[Jessi] has been in many races where things didn’t work out and she just says, “Okay, we’ll get them next time,” and that is the attitude of the entire team.’

Cloud and clear

While the North American Eagle may be close to reaching its maximum potential on the ground, there are plenty of developments behind the scenes that are revolutionising the project, including a relatively new partnership with Microsoft. ‘In the session, we did have a test of our overall data acquisition system and that went really well,’ Zanghi says. ‘We set up an area for a broadband network and had full coverage over the entire lakebed and had full data stream over the lakebed, so that worked really well.’

Commencing last year, the computing giant brought cloud storage technology to the team – an addition that has changed the way the team operates. ‘This has really changed the project quite a bit.’ Zanghi continues. ‘Prior to our last

Dust is just one of the difficulties an LSR team faces in desert locations. NAE is looking for new location for next run in 2016

The point of the Eagle is to reclaim the LSR for USA

Former US Air Force man Ed Shadle is at home in the cockpit of the North American Eagle; he bought the fuselage for $25,000

Amongst the stand-out technology the Eagle uses is its magnetic brakes, which can't lock and won't wear out

set of test runs, we would gather the data, take it back to our hangar back in the Seattle area, send it out to be analysed and it would take about a week or two [to examine]. Now what we do is after a run, we take that data, we send it up through satellite to the cloud and using 300 Microsoft servers we can data crunch this gigantic programme in about 10 minutes or less.'

Previously the project used numerous solid-state drives to hold data collected from runs, but the length of time that was required to transfer data made on-site set-up changes impossible. Zanghi continues: 'Now that we are going a lot faster, this has turned the whole project into a much better place. We are getting a lot of great information. We have got Microsoft engineers that came with us for a week down at the lakebed and they sit there and analyse the data. It is a unique and great partnership.'

Upon a run, the car is divided into 20 million cells, during which the airflow of each cell location is measured approximately 1000 times. The data is then compared to the actuals that are retrieved from a run to see if the model maintains a similar attitude. 'You could take a cup of coffee and lay it on one of the axles and we can measure the amount of downforce, so we are getting very, very accurate information,' Zanghi says. 'It is really quite amazing. At every mph mark, we can tell you how much downforce or lift is being generated. It has changed the project immensely.'

Supersonic shock

The move to cloud technology has delivered other benefits, including the ability to monitor transonic shockwaves around the vehicle, which at sea level occur just below the Mach 1.0 range. Depending on the speed and the temperature of the airflow around the vehicle, such pressures can significantly increase drag. Zanghi says: 'We start generating localised transonic shockwaves at about 630mph and so the airflow around the vehicle starts changing.

'We are not too concerned about the pressure waves that are generating above or into the side of the vehicle, but we are really concerned about the pressure waves generated under the vehicle. So the whole use of the Cloud and the Microsoft product to analyse it has taken us to areas we have never been able to achieve in the past.'

Shadle is determined to give the North American Eagle another run next year, although it us unlikely the team will return to Alvord Desert. 'We can still only get eight miles [at Alvord]; it is okay for going out and doing tests, but it is a lot of expense and we are not as well [off] as the British team [Bloodhound], so for us to do that, it is a pretty significant expense compared to our income, so I think we will be going to another lakebed in Nevada.

'As of this year, we have pretty much dialled in all of the technology angles that we need to do to go fast. We have been solving the issues that we had and we are looking at our plan for going after some records, starting hopefully in May of 2016.'

Much of what happens next year will depend on funding and obtaining permits, but don't bet against this determined North American Eagle LSR attempt.

'We are concerned about the pressure waves generated under the vehicle'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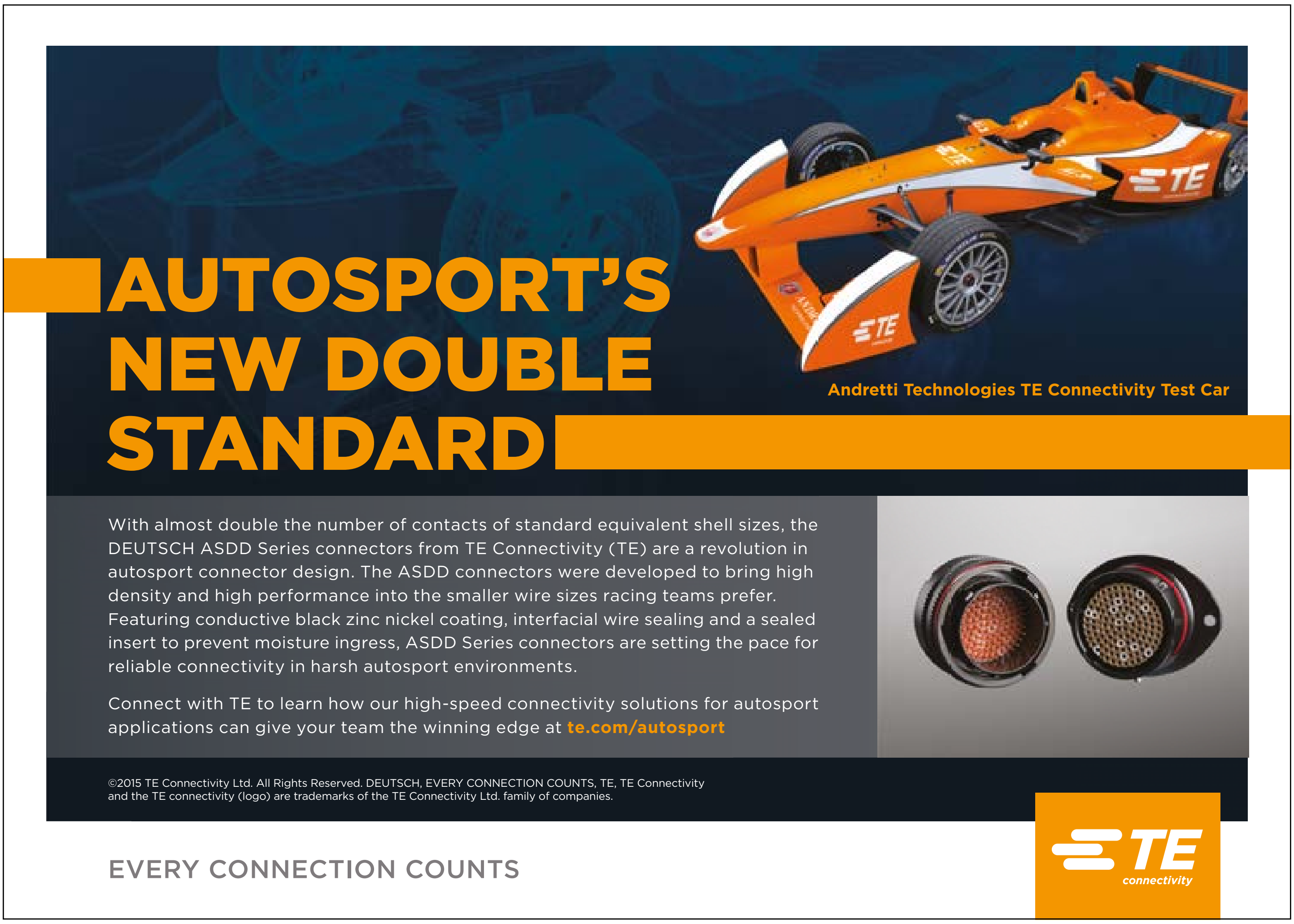
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To the power of 3

While the Dallara has almost reached the limit of its development there have been some changes in F3, including a new Russian car

By LEIGH O'GORMAN

Russian-based Formula 3 team ArtLine Engineering made its return to the category at the Nurburgring in September, following an absence of almost four years.

The team, headed by team owner and manager Shota Apkhazava, was due to return at the Spa round of the European Championship in June. However, questions over the design of the all-new ArtTech F24 delayed its entry. These question hinged around the definitions of articles 2.7.5-2.8 in the F3 Technical Regulations (see RCEV25 N4), which govern homologation of elements including the exhaust, for which the F24 fell foul of the series technical delegate.

Unlike the rest of the field, which is supplied by Dallara, the F24 featured a central-exhaust system – something that had not been used in top-level Formula 3 since the last of the Dallara F399s ran in 2002. But the programme hit a problem when ArtLine revealed that it was to use engines by Neil Brown Engineering (NBE), a move which would have required NBE to homologate a second exhaust unit.

According to the FIA's technical delegate Robert Maas: 'The Formula 3 regulations clearly say that "homologated parts may be changed for the purpose of installing the engine into a new chassis, but it may not have any performance influence." In the homologation paper, we have the exhaust from [NBE]; we have the data, the drawings, the pictures and it is a homologated part, so it is part of the complete engine parameter.'

Advantage gain?

Studies by NBE at the beginning of the year showed that the exhaust would have delivered no performance boost, but the FIA remained unconvinced by this. Maas says: 'Clearly the central exhaust has some performance influence, so we said "you can't change the primary line". Changing the exhaust line, even if it is just the tailpipe, has a clear performance influence and is not allowed in the regulations. From our side, it was pretty simple. You have a homologated exhaust – in their case, it was Neil Brown [Engineering].'

However, Vasily Antipov, director of engineering with the Russian squad, disagrees with Maas, arguing: 'The confusion was in the rules, article 2.75. It was not clear to us – a new technical delegate, when he read the rules, he thinks that we cannot use [this exhaust]. When we read it, we think that we can, but now we have cancelled this idea.'

Antipov has not completely given up on the possibility of the team using the exhaust, but the solution he has may not be the easiest or most cost effective. 'One possibility to use it, we need to work with a new engine manufacturer and homologate a new exhaust,' he says. 'It is big money. For example, we cannot homologate two exhausts for one engine; manufacturers would need to prepare a new homologation and this is homologated with a tailpipe exhaust. It is so expensive to do. We do have [original] exhaust still with the tailpipe [now fitted], but we have not had time to test it.'

Beyond the exhaust issue, Antipov has been pleased with ArtLine's new effort, but is keen to state that the project is very much in its early

The Russian ArtLine Engineering squad finally returned to Formula 3 in September, after technical wrangles held up the debut of its ArtTech F24

The ArtTech F24 F3 car has a distinctly stubby nose, below which two vertical flaps on the front wing direct air under the floor to the diffuser. The team behind the new car was keen to stress that it is still in the early stages of its development

Carlin and Prema Powerteam arrived at the Red Bull Ring round with what might be best described as a pair of diveplanes on the lower reaches of their barge boards. Carlin says they do little other than providing a small improvement in balance

The early rounds of the European Formula 3 Championship were marred by a series of accidents and the situation was so bad at Monza that a race was abandoned. F3 cars now have to run with these cameras to help the stewards police the driving standards

There is evidence that the ceiling of development is closing in on these four-year-old regulations

stages. 'This is a first generation car. The previous car had torsion bar suspension on the front and the rear and we brought our experience to this new generation of car. We were interested in using a pullrod system, because we analysed situations in Formula 1 and this is motivation for [us as a] general constructor and we really started to think about it.'

Unlike the existing Dallara, the ArtLine machine possesses what can be best described as a 'stub nose' and two vertical flaps on the front wing directing air under the floor and a diffuser with three downward vanes. The bodywork from the top of the sidepods and over the engine cover is rather 'boxy' in nature – a feature in common with much of ArtLine's approach to the F24. 'Because this is the first car that we are preparing it is very simple, but when we started to make aero tests, we found our results,' says Antipov.

Of the front wing and diffuser, Antipov commented: 'It is another result of our analytics and our work with TotalSim. We decided that this is better. We try to take some air and force it down [under the floor] and this was optimum for us. We made our first preparations and made the first generation of carbon fibre cars and work together with TotalSim who support us with aero. We also work with a new Russian composite company, which we are planning to produce body parts and monocoque.'

The ArtLine machine enjoyed a reasonably good first two weekends in the hands of Harald Schlegelmich and new ADAC F4 champion Marvin Dienst. After its debut at the Nurburgring, the F24 closed the gap to the front significantly, with the gap in qualifying shrinking from 4.76s to 2.46s at the series finale at Hockenheim. Antipov: 'This is step-by-step. I am happy our car is fixed and produced ourselves and we had to start with the big championship, because Formula 3 is my dream. Now we are here, I'm happy when the cars run, start and finish. You can see we are running second stage and the gaps are getting smaller and smaller. We have a good dynamic.'

Ridge racers

Meanwhile, at the Red Bull Ring earlier this season both Carlin and Prema Powerteam debut what could be best described as a pair of diveplanes, vanes on the lower reaches of their barge boards, and although the elements bring some improvement in balance and movement of air toward the rear of the F312, team boss Trevor Carlin was quick to discount the strength of their effectiveness. 'They change, slightly, the balance of the car. It is a tiny, tiny gain. If you knocked them off, you wouldn't really be able to tell the difference. You know they are better, but it is probably immeasurable. The drivers would never notice. It is a tiny part of a big package in what is already a finely tuned [car].'

As Carlin said, these gains may be only noticeable by the engineers, but they do represent evidence that the ceiling of development is closing in on these four-year-old regulations. 'To be fair, it has been dumbed back,' notes Carlin. 'Originally in 2012, we could do quite a lot to it; we could do a little less in '13 and in '14; in '15 we can't do anything to it. There are only certain areas that you can do anything at all and that window on the bargeboards is one of those areas – what we do is look at


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The bodywork along the top of the F24 appears rather boxy but this is part of a 'keep it simple' approach, the team says. ArtLine is planning on linking up with a Russian composite manufacturer to make its own monocoque and body parts

Despite the exhaust issue and the long dispute this entailed, which held back its debut, the purposeful-looking F24's first two events saw it put up a reasonable performance against the massed Dallaras in the European Formula 3 Championship

Several drivers and engineers have noted that the access to HD onboard footage that is directly linked to the data logging system has greatly improved the ability of the teams and the series to educate drivers

the areas where you are allowed to change something and play around. It's just fine-tuning for the conditions. It's all we're doing really.'

One interesting addition to the European F3 car this year was the implementation of onboard cameras following a spate of crashes. The cameras, manufactured and supplied by Memotec, were introduced to have onboard video footage from every car, in order to capture perfect footage for any incident.

The footage, which covers a 120-degree angle, is recorded in HD on to a memory card which is uploaded by the stewards post-race. It is time-coded and matched to the data logging system of each car, allowing stewards and the teams to see exactly what the driver does in any given situation. The recorded footage also contains data overlays, which measure how a driver is braking and accelerating and what gear the car is in. The on-screen logger also has a G-force indicator.

Driver development

An interesting side-effect of the introduction of the onboard cameras has been driver education. With drivers making earlier and earlier steps to Formula 3, numerous pilots have struggled to adapt to the large amount of data that they are expected to absorb in short order.

While not a perfect solution, several drivers and engineers have noted that the access to HD onboard footage that is directly linked to the data logging system has greatly improved the ability of the teams and series to educate drivers, who would otherwise have been overwhelmed by a flood of information.

Maas says: 'Data in lower categories is a nice tool, but you do need some experience to understand what you are doing. It was clear to us that it was a benefit for the teams as well. We had been running cameras in free practice, but there was a request from teams to use cameras for driver education.

'It was a longer term plan,' continues Maas. 'It was introduced in DTM some years ago. We have it in other championships – in Formula 4, for example, the cameras are already delivered with the car – but [in F3] it was just speeded up by the incidents. The chassis manufacturers in Formula 4 had it in their plans from the very beginning, so Formula 4 was first and then F3.'

Although the footage is currently available to stewards and teams, there are no immediate plans to use it in live television feeds. Maas says that for this to happen the camera system would need some modification: 'That's something for the next two or three years. You need to have a transmitter for it to go live into race control. You would need connection devices to get the video stream out of the system and then transmitted into the television production. There were ideas that could not be introduced in the short term.' Maas concluded that: 'For the moment, the video footage is already used for Eurosport Magazine, but no live coverage.'


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Diesel in the dock

The Volkswagen emissions scandal has shaken the car industry and the wider world – but what will it mean for the future of diesel racecars and VW's motorsport programmes?

By PETER WRIGHT

Volkswagen, the largest automobile manufacturer in the world, is in trouble. In mid-September it admitted to having evaded US EPA Tier 2 and California LEV-II ULEV emissions regulations with a 'defeat device' embedded in its 4-cylinder TDI ECU software. The device consisted of an algorithm that enabled emission controls during laboratory testing, and disabled them when the car was on the road.

In the USA just under half a million cars are involved and Volkswagen has now admitted that 11 million cars worldwide have this code. The CEO, Martin Winterkorn, has gone, protesting that he had no knowledge of the device; Matthias Mueller has been moved over from Porsche to take his place and to steer VW through this storm; and the blame has been laid at the doors of '100 rogue engineers'. The rest of the motor industry, especially in Germany, is now under suspicion of falsifying emission results, and it is nervously protesting its innocence.

But it is not just VW in the dock, awaiting sentence. Joining it on trial is the diesel engine, the internal combustion engine, and the automobile itself. The way society views and treats these devices will never be the same again, and motorsport will surely feel the fallout from this massive destruction of trust.

Guilty secret

The VW management has known for over a year that they were in trouble, but the sequence of events that led up to the climax of VW's guilty plea started in 1999. The US EPA announced new Tier 2 NOx limits of 0.07gm per mile to replace the existing Tier 1 limits of 1.0gm per mile, to be phased in from 2004 to 2009. In 2007 VW stopped selling its existing line of diesel-engine cars in the US, pending the development of clean, TDI technology. In 2009 the new range was launched amid acclaim, and VW and Audi sales started to rebound. Low emissions levels of Volkswagen vehicles enabled the company to avail itself of green car subsidies and tax exemptions in the USA. Volkswagen and Audi had struggled in the US and believed that the 1.6 to 2.0-litre range of four-cylinder TDI Jettas, Golfs, Beetles, and the Audi A3, with their impressive low fuel consumption, would enable them to gain ground against the gas guzzling American cars – US emission regulations do not even mention CO2!

Meanwhile, in 2006 Audi replaced its hugely successful R8 LMP1 car with the R10 TDI and, with a little help from the ACO, diesels have dominated Le Mans until this year. In 2015, the FIA's EoT equivalency formula finally caused the greater weight of the diesel to be

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Audi's diesel Le Mans programme looks doomed and the VW board may not be able to justify an F1 programme while it is faced with such eye-watering fines

Audi's LMP1 project has played a starring role in the VW Group's diesel marketing – but will it survive in the wake of the Volkswagen emissions scandal?

a disadvantage in determining the size of the energy store that could be used by the new hybrids. Porsche took up the VW Group baton at Le Mans with a gasoline-engine car again, after nine years of diesel wins.

Then, out of the blue as far as an unsuspecting public was concerned, VW admitted to having inserted, and in some cases used, software configured to be able to fraudulently pass EPA Tier 2, California LEV-11 ULEV, and European emissions tests on 11 million diesel engine VWs, Audis, SEATs and Skodas. Software was able to detect when the car was in the laboratory being tested and switched on emission control systems that were inactive when the car was driven on the road.

Attempts to fool the emission test have been a long tradition since regulations were first introduced in the 1970s. Early systems detected whether the under bonnet light was on, indicating that the bonnet was open, and so the car was not being driven on the road.

Road to nowhere

Exactly how VW detected that the cars were being tested has not been confirmed, but there are many indications that a car is not being driven on the road – for example only one axle rotating on the single-drum, rolling-road dynamometer (there would be a need to turn off traction control), steering wheel inactivity, and the uniformity of the temperature throughout the period the car is tested, which is closely controlled in the test laboratory.

In order to meet the Tier 2 NOx and particulate standards, VW's TDI engine deployed tiny turbos and common-rail injection systems. These technologies and their precise computer management enable engineers to take control over the diesel's combustion, refining it for quiet operation and efficiency, and giving the diesel an advantage over the gasoline engine in the race for lower fuel consumption and CO2 emissions. The US motor industry did not have this technology. It is likely they also did not want the Europeans to succeed in the energy efficient segment of the market.

School of hard NOx

The main problems associated with diesels are NOx and particulates, and they are fundamental to the diesel cycle. Efficiency in a thermal engine comes from increasing the temperature of combustion, achieved by higher pressure (boost and compression ratio) and leaner mixtures. Diesels exceed gasoline engines in both of these and in the way the fuel is burnt. Volatile gasoline will detonate if pressure and temperature exceeds certain limits, while diesel droplets burn progressively from the surface to the centre of the droplet. High pressure, common-rail injection reduces the size and perfects the distribution of the droplets, but these still leave a tiny, unburned particle of carbon. In addition, if the temperatures exceed around 1600degC, they cause the nitrogen in the charge air to combine with residual oxygen to form nitrogen oxides, or NOx.

Vehicle manufacturers with large cars and trucks powered by diesel engines can afford to fit after-treatment for the NOx: urea injection SCR (Selective Catalytic Reduction), and particulate filters, which must be periodically burnt off at a fuel consumption penalty. Mercedes and BMW, and most US truck manufacturers, fit this costly, heavy, and bulky equipment, but much to the surprise of the industry VW claimed not to require it on their small diesel engines. In fact, they did! Instead, VW turned off the emission controls employed for passing the test when the car is 'driven' through a comparatively light duty cycle, and provided its customers with good performance and drivability on the road, at the same time yielding low fuel consumption and CO2 emissions.

Coming clean

European Euro 5 emission standards (2010 to 2014) require a NOx of no more than 0.29gm per mile and Euro 6 (2015 onwards) of 0.13gm per mile – far less onerous than the US standard of 0.07gm per mile. How VW passed these tests and planned to pass the more stringent future tests is not yet clear, but what is evident is that when the EPA tested emissions under real-world driving in 2014, the VW TDI engine emitted up to 35 times the legal limit of NOx.

It took a year to persuade VW to come clean and admit its deception. It now faces fines, recalls, regulatory investigations, legal proceedings and lawsuits across the world. The group has set aside $6.5bn for this, but estimates of the final cost go as high as $25bn. The cost to VW's reputation may be even higher.

Whether the Volkswagen Group feels motorsport is useful in re-establishing its brand image will become clear in time

There have been many scandals of similar proportion in the motor industry in the past. But all the past scenarios have involved safety: the manufacturer versus the customer. In VW's case, the manufacturer has put the customer before the rest of society, offering a better driving car that was cheaper to buy and run, while deceiving the rest of society about how much NOx and particulates they were emitting. That is a completely different sort of dispute.

Bin diesel?

I doubt that this is the death knell of the diesel, and certainly not the internal combustion engine, but it could be the end of diesel engines in cars. Perhaps the VW Group already saw the writing on the wall and was facing the error of its stand against hybrids and EVs; maybe this is why it put Porsche into bat at Le Mans with a small hybrid gasoline engine? However, it should be born in mind that a 42 US gallon barrel of oil yields only 20-something US gallons of gasoline and, without bio-ethanol and synthetic-ethanol, the oil barrel cannot be cut to supply an all-gasoline car park.

VW has never been an iconic motorsport name, although some of its brands – Porsche, Audi, Bugatti, and Bentley – have built a large part of their image through motor racing. VW has always portrayed itself as a car of the people and has not depended on motorsport to create loyalty. What happens to the Group's motorsport activities is not yet decided, although one so-called 'analyst' has called for an immediate cessation of all its motorsport programmes in the wake of the scandal. Audi's diesel Le Mans programme looks doomed (if it wasn't already so) and the VW Group board may not be able to justify an F1 programme while it is faced by such eye-watering fines, legal settlements, and recalls. I suspect the Porsche Le Mans programme will survive based on its success, Porsche's history in the category, and the company's profitability. WRC and DTM? We will have to wait and see.

Blame game

Who gets the blame within VW is not yet clear. As mentioned, to date it has been claimed that '100 rogue engineers' acted independently, with senior management ignorant of what was going on. With industry amazed by VW's ability to produce such clean, efficient, small diesels, management must have been extremely proud of its engineers, but surprisingly uninterested in how they had achieved the impossible. Bosch has admitted that it wrote the algorithm for detecting whether the car was being tested or driven on the road, but has stated that in 2007 it informed Volkswagen management that this was solely for test purposes and could not be used legally in production.

Two members of the senior technical management have allegedly already been suspended: Wolfgang Hatz, who served as head of Engines and Transmissions Development of Volkswagen AG since December 2010, and also as its head of Powertrain Development, and has been executive vice president of Research and Development and member of the Management Board at Porsche Automobil Holding SE since February 1, 2011, and Ulrich Hackenberg, who was appointed Member of Volkswagen's Brand Board for Development in February 2007, and since July 1, 2013, has been a member of the Board of Management at Audi with responsibility for its technical development. Worryingly, these executives have been two of the strongest advocates for motorsport activity within the VW Group.

Of course, this story has many parallels in motorsport history: hidden algorithms that may or may not have been activated (Benetton and traction control, for instance); or rogue engineers intentionally skirting the regulations without telling senior management (Toyota WRC intake orifice device). But then racing engineers will always reach for the rulebook and look for ambiguities and ways to pass the compliance test to gain an advantage. We only know about the cases where they were caught and, where real deception has occurred and been discovered, the damage to the organisation is often severe.

Damage control

VW is going to suffer a great deal of damage, not only financial, which it can probably survive, but also to its reputation. Whether it feels motorsport is useful in re-establishing its brand image will become clear in time. The problem it faces is that it is as much the non-motoring members of society it is up against and has to convince as its potential customers. The latter are going to be offered more expensive, less effective cars, and there may be a decline in the practice of giving cars a performance image. The non-motoring members of society do not generally care much for motorsport.

But what really baffles me is why Americans mind so much. Why worry about the small amounts of NOx emitted by the smaller diesel cars when their preferred transportation is gas-guzzling pickup trucks and SUVs, which manage to avoid emissions, fuel consumption and safety regulations, thanks to carefully crafted official definitions?

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Volkswagen has been flying high in the WRC with its Polo but can it justify such a programme with the scandal now set to cost the group so much?


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Formula 1 teams make official EU complaint over team payments

Sauber and Force India have filed an official complaint with the competition commission of the European Union in which it raises concerns about the payment structure in F1 and the way the rules in the sport are determined.

The two teams argue that there is a distinct bias in the sport, and that the five biggest teams not only take the largest slice of F1's revenue, but through their membership of the F1 Strategy Group they also have a disproportionate say in the formulation of regulations.

Earlier this year a UK member of the European parliament, Anneliese Dodds, approached the commission on behalf of Caterham and Manor, but the competitions commissioner, Margrethe Vestager, was unable to act because a formal complaint was not made. Sauber and Force India's action constitutes a formal complaint, but thus far there has been no word on what action, if any, the EU will take.

Sauber and Force India get together at the Russian GP in Sochi – they have also teamed up in a more positive fashion to make a formal complaint to the European Union's competition commission concerning team payments and F1's governance

Sauber team principal Monisha Kaltenborn said of the matter: 'I can't tell you details about the complaint because now it's an ongoing procedure and we have to adhere to all the steps there. What we have basically requested or asked the commission to do is to investigate why these, in our view, unfair terms regarding the voting rights, the rule-making on one side and on the other side the distribution of revenues have been imposed.

'We have asked the commission to [look at the], as we see, abuse of dominance arising from the way these privileges have been granted in these two areas. So we have our position on that, we don't consider it to be fair and based on that, we have submitted our complaint which is, to be also clear about it, against the commercial rights holder.'

Force India is actually in the Strategy Group, by dint of its fifth-place finish in the constructors' championship last year, along with the big five of McLaren, Williams, Mercedes, Ferrari and Red Bull.

The top five teams received bonus payments from the commercial rights holder in 2014, not including constructors' championship prize money, of $249m in total. Ferrari took the largest slice last year, with $97m, which is some $30m more than it pocketed for its fourth place in the 2014 constructor's championship.

Pirelli seals Formula 1 tyre deal for three more seasons

Pirelli has held on to its Formula 1 supply deal until 2019 after seeing off a challenge by rival tyre manufacturer Michelin.

While an official announcement had not been made at the time of writing Pirelli Motorsport director Paul Hembery told *Racecar* the final signing off of the deal by the FIA was now little more than a formality.

XPB

Pirelli will remain a feature of the Formula 1 paddock until the end of the 2019 season at least after a new tyre supply deal was agreed

'We've agreed the commercial deal,' Hembery said. 'There's different phases of the F1 renewal process; the first part of the tender was to get technical approval from the FIA, which was passed, we were approved. Then you're allowed to go forward and talk to the commercial rights holder, which is where we've made an agreement, and now it's just up to the FIA to nominate us as the official supplier … But obviously if you've passed the FIA approval process and you've passed the commercial rights holder, there aren't any other formal steps, although there are elements of contractual detail to be confirmed.'

The deal is for the 2017, 2018 and 2019 seasons – as incumbent supplier it is already on board for next year – and it will include supplying new wider rubber for the new formula in 2017.

Michelin was also in contention for the contract and when asked why Formula 1 chose Pirelli over its French rival, Hembery said: 'I think we've been a great partner to the sport for five years. We've tried to provide F1 with what they've asked us to provide. We work as a partner; we try to be active in assisting the sport in achieving its goals and I think we've given them stability, which is important in motorsport because a lot of people come and go; be it sponsors, teams or drivers.'

Hembery also told us that Pirelli's budget for Formula 1 is on a par with that of an F1 team, and this does not include branded signage to actuate sponsorship at the racetrack, though he would not be drawn on the figures. Pirelli can certainly afford its Formula 1 presence, though, with its most up to date figures (2013) showing retail sales of over €6bn, operating income of €791m, and total assets of €7.3bn.

Volvo to compete in World Touring Cars from next season

Volvo works team Cyan is to campaign a brace of S60 Polestar TC1s in the World Touring Car Championship

Volvo is to enter the World Touring Car Championship from 2016 in a campaign fronted by its Polestar performance brand and run by motorsport partner Cyan racing.

Operating as Polestar Cyan Racing in deference to Volvo's acquisition earlier this year of Polestar Performance AB – the Swedish tuning firm – and Polestar's official motorsport partner, Cyan Racing, Volvo will field two race versions of its flagship S60 model – the racecar is to be called the Volvo S60 Polestar TC1.

Volvo will see the WTCC as a chance to bolster the image of its performance brand in some of its key markets, such as China, Germany and Russia – all of which are visited by the championship – and it is particularly interested in increasing and consolidating its sales in China.

Earlier this year Volvo's president and chief executive, Hakan Samuelsson, said the company would need to work hard to continue the success it's had in China in recent years, as the China car market is now showing signs of slowing down: 'It is going to be tougher, there's no doubt about that. But there is still solid growth to be had, especially in the premium sector,' Samuelsson said. China was Volvo's largest individual market in 2014, with 81,000 cars sold, 17.4 per cent of Volvo's total retail sales across the world, while the Swedish company, which has been owned by Chinese firm Geely since 2010, posted an operating profit of $265m for 2014, up 17.5 per cent on the previous year.

Polestar Cyan Racing currently runs five cars in the Scandinavian Touring Car Championship and also prepares the Garry Rogers Motorsport entries for the V8 Supercars championship in Australia.

Alexander Murdzevski Schedvin, head of motorsport at Polestar, said: 'This is a great day for us to announce our assault on the FIA World Touring Car Championship, a programme that boils down to one thing; to bring the world title to Sweden. We have got respect for the task ahead of us that we take on with absolute commitment. This is a long-term effort and we have got an extensive testing programme during the winter that will continue alongside our first WTCC season in 2016, which is all about learning.'

The WTCC announcement came on the 30th anniversary of Volvo's 1985 European Touring Car Championship win. Polestar scored its first WTCC points in 2011 with the C30 model.

Mercedes pays the price for Formula 1 success in 2014

The Mercedes F1 team has put its £77m loss in 2014 partly down to its dominant season on track last year, saying the bonus payments it paid out as a result of its triumphs increased its spending significantly.

Mercedes recently filed its financial results for last year, the headline figures showing a turnover – the money it brings in from sponsors and prize money – of £146.9m, which is up £21.7m from £125.2m in 2013.

However, the team's operating costs rose from £190.7m to a whopping £240.2m in 2014 (up £49.5m), which Mercedes says is largely due to the higher bonus payments it's had to pay, as well as the investment needed to develop the car to meet the new regulations for 2014. It explained that the extra spend was due to, 'significantly higher bonuses payable as a consequence of the record-breaking level of sporting performance and also increased costs arising from regulation change'.

Meanwhile, the filings also reveal that the workforce at the Brackley-based team increased from 663 to 765 from 2013 to 2014, with a subsequent increase in salaries paid out of £15.8m (from £49.7m to £65.2m).

The team's executive director, Toto Wolff, who owns 30 per cent of the team, pocketed £6m in 2014, which is up by over £2m on 2013 (£3.9m).

While success in 2014 might have been partly responsible for its loss, Mercedes points out that due to its winning ways larger payments from F1 will have started this season: 'The agreement with the Commercial Rights Holder has provisions for significantly increased revenue flows based on sporting performance, some of which will be triggered in 2015 as a result of the team's performance in 2014,' Mercedes said.

XPB

The Mercedes domination of the 2014 Formula 1 World Championship led to big bonus payments throughout the organisation

UK motorsport engineering giant Prodrive back in profit

Famed motorsport and performance engineering company Prodrive has posted its accounts for 2014, which show it made an operating profit of £638,000 last year, a significant improvement on the £6.4m loss it made in 2013.

Prodrive was back in profit last year while the roof of its new headquarters in Banbury is now to be used to harvest solar power

The profit came from a turnover of £27m, which was actually just half a million up on the previous year, but Prodrive says that it has become profit making once again thanks to the 'introduction of incremental race programmes and product offerings, a significant improvement in operating processes and a consolidation of all race and rally activates to operate under one management team'. Prodrive added that the latter move was 'a significant reason for the reduction in costs in 2014'.

Prodrive's main motorsport programmes last year were its Aston Martin Racing WEC campaign, which it says it will reduce next year, plus the VW Golf SCRC rally car, which it developed for competition in China. While profits were up the average number of employees at the organisation fell from 193 in 2013 to 142 last year.

Meanwhile, the company has made room for a community-owned rooftop solar power installation on top of its new Banbury headquarters, which will go in to operation in 2016. The project, which has been conceived in collaboration with the Low Carbon Hub – an Oxfordshire-wide social enterprise – will generate green electricity for Prodrive while also delivering an annual financial benefit of approximately £20,000 to low carbon community projects in the local area.

David Richards, chairman of Prodrive, said: 'Renewable energy is vital for all our futures. Our new headquarters by the M40 has a large south facing roof and it made absolute sense to use it to generate clean electricity for us and to help fund similar renewable energy projects in our local community.'

The project will generate 636kW of renewable electricity when it is operational, the equivalent of that which is needed to power more than 150 houses. This will be used to help power Prodrive's headquarters, while surplus income from the initiative will fund community energy projects.

When completed it is likely to be the largest community owned rooftop solar power installation in the UK.

IN BRIEF

Prema primed for GP2

Crack Formula 3 outfit Prema Powerteam is to expand its operation to run cars in the GP2 Series from next year. The multi-European F3 Championship-winning squad will replace Lazarus on the GP2 grid, marking a return to this level of competition for the Italian team, which fielded cars in GP2's forerunner Formula 3000 back in 1998. Despite the step up Prema will continue to enter its four-car team in European F3 next year, while it will also carry on with its involvement in the Italian and German Formula 4 Championships.

Marc calls time

Belgian sportscar team Marc VDS is to quit car racing to concentrate on its efforts in MotoGP and Moto2 motorcycling. Marc van der Straten, the owner of the team which won this year's Spa 24 Hours with BMW, has said his 'passion for car racing has now gone'. Marc VDS has its roots in the VDS outfit of the 1970s and 1980s, which was run by Marc's father Count Rudi van der Straten. VDS competed in Formula 5000, Can-Am and CART, while the newer outfit raced in GTs.

DAMS to quit FR3.5

French single seater powerhouse DAMS is to walk away from Formula Renault 3.5 at the end of this season, choosing to switch to GP3 rather than stick with FR3.5, which has lost its Renault Sport backing for next year. Yet while DAMS did not feature on the list of entries for next year's series, which is to be on the GT Open bill for much of the 2016 season and continues to be promoted by RPM, all the other current teams have committed to it, plus one new outfit in the shape of Spirit of the Race, which has been set up by Amato Ferrari, the owner of sportscar squad AF Corse.

GT tyre deal

Pirelli has reached an agreement to supply rubber to the Blancpain GT Series for a further five years. The deal includes equipping the field at the prestigious Spa 24 Hours, and Pirelli says that this race is its biggest engagement in motorsport out of all the 300 or so championships that the Italian firm supplies worldwide, with approximately 9000 tyres taken to this one event alone. The 10-round 2016 calendar for the Blancpain GT series has also been announced. The sprint and endurance races will take place at classic European venues from Monza in April to Barcelona in October, showcasing more than 10 different manufacturers using a wide variety of engines and different vehicles architectures.

Silverstone's business park launches study into motorsport cluster

MEPC Silverstone Park, the industrial area around the British GP venue bought from Silverstone owner the BRDC by commercial property company MEPC in 2013, has commissioned a study in to the area's motorsport business base.

The aim of the study, or 'cluster report', is to help attract further investment and also government support for the companies operating in the high performance technology and motorsport (HMP&M) sector in the area.

SQW, a leading independent provider of research, analysis and advice in economic and social development, has been commissioned to carry out the study. This is already under way with the final cluster report document due for publication in March 2016.

Silverstone Park's commercial director, Roz Bird, said of the report: 'MEPC has been involved at Silverstone Park for two years now and in that time has had many discussions with occupiers and companies in the local area. Every business and individual has a story to tell about where they started, the people that influenced them and the businesses that they have been involved with, and this activity has been taking place in the area for over 50 years.

'I believe that this is why the Formula 1 teams are here and it is why we wanted to map the activity and consider whether the area is part of an HPT&M cluster where similar companies not only gravitate to the same area but interact with each other and in so doing benefit from being close to each other in many different ways including access to a specialist skills pool, machinery and expertise.'

Explaining why SQW was chosen for the project Bird said: 'SQW undertook the Cambridge Phenomenon Report back in the 1980s. The study put Cambridge on the global map as a key hi-tech cluster, bringing in venture capital and business angel investment and government backing. It is hoped that this study could bring similar benefits to this area.'


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F1 composites manufacturer expands into new facility

Crosby Composites, a supplier to Formula 1 and other high-end motorsport, has snapped up new manufacturing capacity in the heart of Motorsport Valley in the UK's Midlands, a move which could lead to 150 new jobs.

The company, which was founded over 30 years ago by former March F1 race engineer Paul Crosby, is based across two facilities in Brackley – totalling 25,000sq.ft – but has now also acquired additional premises in Wellingborough, Northamptonshire.

Crosby's new site was formerly the GEC Siemens building on the Dennington Industrial Estate. The property offers 63,000sq.ft on 3.83 acres of land. The company currently employs 90 people but because of the new property it could expand its workforce by an extra 150 over the next five years, it says.

Paul Field, managing director of Crosby Composites, said: 'Our existing buildings had become full to capacity which led to a search of the Midlands for additional premises. As well as providing a suitable property, Wellingborough offers a mix of skilled labour and candidates that we will train to a high level within the composite industry.'

The Borough Council of Wellingborough granted a change of use to the property to accommodate the business. Councillor Peter Morrall, chairman of the Planning Committee, said: 'This is excellent news for our Borough and we unanimously supported the company's planning application.'

Crosby Composites will soon begin a bespoke fit-out of its new facility. This will include CAD stations for design and conceptual work, CNC machines for tooling block patterns, aluminium moulds and machining components; plus laminating, and trim and fitting departments.

Field added that Crosby was not just about motorsport: 'As well as having a strong customer base within the automotive industry for customers such as Mercedes F1, Red Bull F1, McLaren F1 and Aston Martin, we also trade within the aerospace, sports and medical sectors.'

CAUGHT

Cole Pearn, the crew chief on the No.78 Furniture Row Racing Chevrolet in the NASCAR Sprint Cup, has been placed on probation until the end of the year after officials discovered a problem with a wheel faring before the start of the Dover International Speedway round of the series. The car was sent to the back of the 43-car field for the race as a result of the infraction.

PENALTY: Grid demotion

Billy Scott, the crew chief on the Michael Waltrip Racing (MWR) No.15 car in the NASCAR Sprint Cup, has been fined a whopping $75,000 and suspended for three races after the Toyota he tends was found to be running with incorrectly fitted suspension components at the Chicagoland round of the series.

The No.15 car's driver, Clint Bowyer, was hit with a 25 point penalty in the drivers' rankings while MWR co-owner Rob Kauffman has lost the same amount of points in the owners' championship. An appeal by MWR proved to be unsuccessful.

FINE: $75,000
PENALTY: 25 points

CSM set for US and Asian growth

The global motorsport, sports and entertainment business, CSM, has announced it is now setting its sights on investing in North America and Asia in the wake of the acquisition of its parent company, Chime, by Providence Equity Partners.

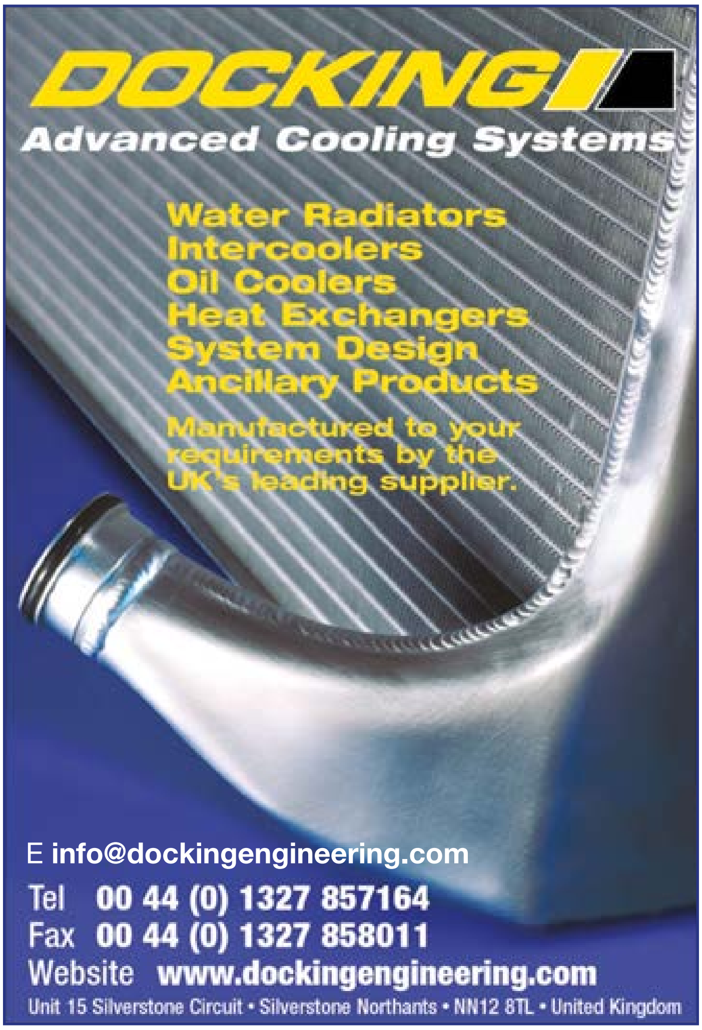
CSM says it has now started working with new owner Providence on a growth plan that will include both acquisitions and organic growth.

CSM Group CEO Zak Brown said: 'Providence has experience, knowledge, vision and funds that will enable us to invest in CSM's global business. It also has a great portfolio of businesses around the world in sport, entertainment, telecommunications and education. These businesses will provide new opportunities for both us and for them.'

Brown added that CSM is now looking to expand, beginning in North America and Asia: 'The global sponsorship market is strong and growing steadily. North America is the largest sponsorship market by region and the biggest sports market in the world, while Asia is the fastest growing so it makes sense that our investment focus is in these two regions.

'This is an exciting time for the world of sport,' Brown added. 'We will see many changes in sport, from governance and the role of sponsors to fan engagement and evolving sport formats. Through our presence in 19 countries, CSM is active in every sport with world-class services from strategy to execution. Beyond sports business experts and sports enthusiasts, our leadership team have also competed in sport at the top level from the Olympic Games to motor racing, international hockey and cricket. Using the insights and instincts from that competitor experience, we will be at the heart of this growing industry challenging the status quo and driving innovation, engagement and activation.'

While the investment focus in the short term is on North America and Asia, CSM says its European, Middle East and Latin America operations should continue to grow strongly, particularly on the back of the success of the Rugby World Cup. Meanwhile, following the soccer World Cup in Brazil last year, CSM Latin America is looking forward to 2016 and the Olympics, also in Brazil.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INTERVIEW – Joie Chitwood

Grandstand finish

With Daytona's $400m refurb now close to completion, the speedway's boss tells us why he believes the huge project has been worth every cent ISC has spent on it

By MIKE BRESLIN

'We have to ensure the experience at the venue lives up to the expectation'

Joie Chitwood knows a thing or two about putting on a good show. He should do; by the age of five he was performing in his family's famed stunt driving extravaganza, and at 16 he was standing on the side of a car while his father drove it – on two wheels. So when it comes to giving people what they want he knows the basics. Yet that's just half the equation, it's not just what they want to see, it's where they want to see it, and right now Chitwood, in his capacity as president at Daytona, is confident that when the show is NASCAR then the Florida speedway will be the best venue bar none when its mammoth refurbishment is finished come January.

It's worth taking a look at some of the numbers behind the Daytona Rising project before we get into the whys and wherefores. For instance, the new grandstand is nine tenths of a mile long. So long, in fact, that those building it had to take the curvature of the Earth into account (seven inches over that distance, we're told). Another eye-popping figure associated with the project is the one per cent of US steel output used in its construction during each year of the two and half year build. But the number which really jumps out is 400.

That's $400m; and $400m that has come directly from the coffers of the track's owner, the NASCAR-founded International Speedway Corporation (ISC). Even for a company like ISC, which owns 13 venues across the US, that's a great deal of money. Which begs the question: why?

'At the end of the day the customer needs to be entertained; whether it's the venue, whether it's the racing on track, whether it's the social aspect, people want to enjoy themselves when they attend events,' Chitwood explains. 'Right now people go to social events that include sports, they want to enjoy it with their friends; and they use football, or basketball, as the reason to congregate and have that experience. So we can't understate the importance of the social experience as part of any venue moving forward.'

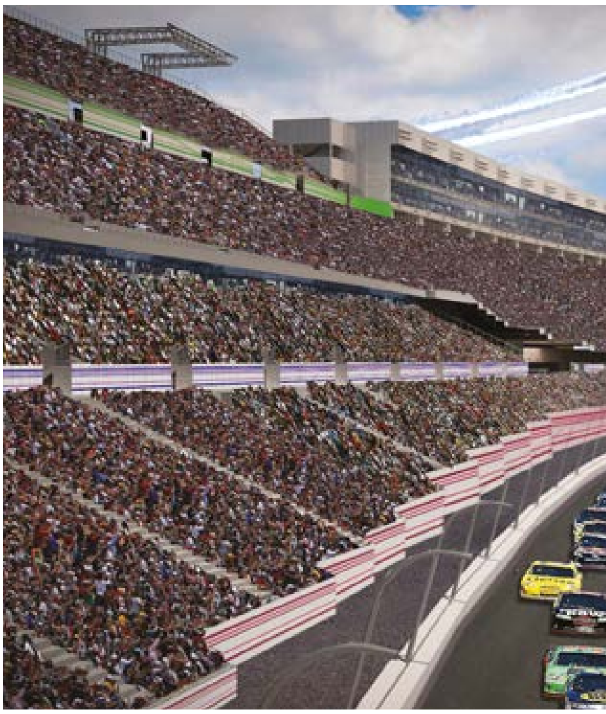
Historic track

And that's the crux of this project. It's not just about watching the racecars race anymore, it's much more than that. 'This is our flagship brand,' Chitwood says. 'This race track is in the same location it was when it was opened in 1959; but it's not living up to the experience the fans expect today. Here in America they're building new venues left and right for soccer, basketball and football; and we have to compete with that. So this was an opportunity to plant our flag in the ground for the next 50 years, and make this investment, because if we're going to be the world centre of racing, hosting NASCAR's biggest event, we have to make sure the experience at the venue lives up to the expectation.'

Yet in the above assertion is an interesting point: Daytona *is* historic, it is one of the most storied race tracks in the world. So isn't there a risk that with such a big change you might lose something very important along the way? 'I think the advantage we have is that the racing surface doesn't change. That start-finish line is in the same location that Lee Petty crossed in 1959 to win the very first Daytona 500; all we've changed is the grandstand and the experience around the race track … I think we've been able to balance both, to do the investment, with the historic race track.'

The main changes at Daytona revolve around the way the spectators enter the stadium area and also how they are seated. In the first case it's all about the 'Injectors', basically five banks of escalators (40 in total) and elevators (17), while in the second it's a combination of the fan neighbourhoods – 11 huge football field-sized areas with food, giant video screens, merchandise, connectivity and so on, that are integrated into the front-stretch stand area – and the grandstand itself. We say 'itself' because the new stand is contiguous, almost a mile of seating following the curve of the track. This will seat 101,500 – in new larger, more comfortable seats – yet overall the venue will lose capacity, as the grandstand on the back stretch has been consigned to history.

'We started with 101,000 seats on the front stretch. When we're done with the renovation we'll still have 101,000 seats there,' Chitwood says. 'But we have a separate grandstand on the back stretch and that's 46,000 seats. We're taking that down. It's our worst renewed grandstand, and candidly when we have all the new amenities and elements open in the new stand, we don't want to sell a sub-par experience. Why would we sell a seat on the back stretch if it had no elevators, no escalators, didn't have a good seat, didn't have a good sight



line? We would be doing ourselves and our fans a disservice.'

There's more to this, though, as the Daytona 500 has rarely been a sell out in recent times. 'We've had over 146,000 seats, we come close some years, but candidly I'm not sure if anyone can sell 146,000 seats in this day and age,' Chitwood says.

Such a project requires a huge workforce and at times there has been around 1000 people working on the site a day and ISC says it's created 6300 new jobs in total. On top of that the track brings much to the Florida economy. 'The beauty of our sport is that over 60 per cent of the crowd at the Daytona 500 comes from outside the state of Florida. On average they stay five nights when they're here. That's a huge economic impact to the central Florida region,' Chitwood says.

Yet the project has received no state or government backing, which is clearly a source of some frustration. 'A lot of other sports properties in the Florida area have something called a sales tax rebate; the football teams, the baseball teams, get a rebate back on their sales tax,' Chitwood says. 'We would like to be considered for that, but we're not. We're talking to legislators, but we decided [to do] the project, with or without the support. We believe that we deserve credit for it. We truly generate economic impact, but right now we do not receive any government support.'

Rising up

Another interesting aspect of this project is the name. It could be the first construction site in the world to be branded in its own right, as Daytona Rising. But that will all soon be in the past and the track's future will depend largely on attracting fans to the stadium, yet in recent years NASCAR has struggled with its gate. But Chitwood, who is also executive vice president at ISC, senses there's already change in the air. 'We're actually having a very good year [at ISC]. The Daytona 500 was up this year, and a number of our race tracks are up. Everything's cyclical. It does feel like the last year or so in America the stock market has done well, unemployment is down, gas prices are down, so maybe those things tell us that perhaps fans are willing to spend their disposable income a little bit more, and if that's the case I think we as an industry could benefit.'

With that in mind it will be interesting to see whether fans will be drawn to this new way of enjoying the motor racing experience. Or to put it another way, whether Daytona will keep rising once 'Rising' has risen.

Central to the $400m Daytona Rising development will be the new grandstand on the front stretch, which is almost a mile long

RACE MOVES

Former F1 driver **Olivier Panis** is launching an LMP2 team which will compete in the European Le Mans Series, and also plans to race at Le Mans, next year. Panis has set up the team alongside former French international goalkeeper and now amateur racing driver, **Fabien Barthez**. The team will operate in collaboration with Formula Renault 3.5 outfit Tech 1 Racing.

Tony Stewart, the three-time NASCAR Sprint Cup champion, is to retire from full-time driving to concentrate on his role as a team owner with the Stewart-Haas team, which he runs in partnership with **Gene Haas**. Stewart will hang up his helmet at the end of the 2016 season.

Amato Ferrari, the owner of crack sportscar squad AF Corse, has set up a new team to compete in the Formula Renault 3.5 category next year. His new single seater operation will be called Spirit of the Race. FR 3.5 is to be run alongside GT Open, in which AF Corse has a strong presence, for much of next season.

Paul Russell is **Felipe Nasr**'s new race engineer at Sauber, replacing **Craig Gardiner** in the position. The change of engineer seemed to work for Nasr who finished sixth – after a poor run of form – at the first race with Russell as his engineer; the Russian Grand Prix in Sochi.

Andretti Autosports Indycar team manager, **George Klotz**, has left the outfit to take on the same role at AJ Foyt Racing. Klotz is a well-respected figure in the IndyCar paddock, having worked in the series and its CART and IRL forerunners since the early '90s, when he started as a mechanic. Klotz worked at Players-Forsythe before moving to Andretti-Green in 2002. Andretti Autosports has said it will hire from within the team to fill the now vacant team manager position.

John Morriss, Garth Rainsbury and **Darren Walter** are heading up Radical Sportscars' new dealership in the state of Victoria, Australia, trading under the Motorsport Leasing name. Radical also has a base in Sydney, New South Wales.

Greg Penske, the former CEO of Penske Motorsports – which operated race circuits before it was purchased by International Speedway Corporation – has joined the board of the Petersen Automotive Museum, as the Los Angeles institution gears up for its grand re-opening in December. Penske, the son of motorsport business magnate Roger, is currently CEO of the Penske Motor Group, one of the US's biggest car dealership businesses.

The new president of the Institution of Engineering and Technology (IET), **Naomi Climer**, has called upon employers to instigate a number of measures, including quotas, to boost the amount of female engineers in the UK. Currently only one in 10 engineers in the UK is female, the lowest ratio in Europe. Climer is the IET's first female president in its 144-year history.

Lord Astor of Hever has agreed to return to the role of honorary president of the Motorsport Industry Association (MIA). Lord Astor takes over from **Lord Drayson**, who recently vacated the position in order to concentrate on his business interests. Lord Astor was previously the MIA's honorary president from 1996 until 2010.

Oliver Blume has succeeded **Matthias Muller** as the chairman of the executive board at Porsche. Since the beginning of 2013 Blume has been a member of the Porsche executive board with the responsibility for production and logistics. Another new appointee is **Detlev von Platen**, who will become a member of the Porsche executive board for Sales and Marketing. Von Platen was previously head of Porsche Cars North America.

MIA launches mechanic school for winter months

Donington Park is to host a new off-season school for racecar and race bike mechanics in partnership with the Motorsport Industry Association (MIA).

The top 10 students from the school will each get a placement in 2016 with a professional race team, giving them a head start in their motorsport careers. But those wishing to sign up for the opportunity will need to get their skates on, as school starts on 21 November.

XPB

New winter mechanic school could help those hoping to one day ply their trade in Formula 1

Called the MIA Motorsport Technical School at Donington, and created in conjunction with MTS (Motorsport Technical School) at Monza, the initiative will give 40 students the chance to join two employer-supported programmes, studying for 160 hours over 12 weekends. Hands-on, pit garage practical and classroom courses will be led by successful, current racecar and race bike mechanics, who will share their experience to help upcoming young talent.

Dick Bennetts, team principal of BTCC outfit West Surrey Racing, said: 'This is a great initiative for students wishing to get into motorsport at a professional level, be it cars or bikes. We often find young people with the right passion, but not the experience, who need good training in the various motorsport disciplines. The MIA have created a rare opportunity; just what's needed in the UK racing business.'

Chris Aylett, chief executive officer, MIA, said: 'We are delighted to have created, with our friends at MTS Monza, these unique training courses to help young people. We want to give students the best possible start to their careers in motorsport and provide better-trained mechanics for UK race teams.'

Christopher Tate, managing director of Donington Park circuit, added: 'We are delighted that the MIA has chosen Donington Park to host this ground-breaking course. We know that – to keep ahead – we have to keep on innovating, as we have here these past five years.'

To book on a course, or for more information, visit the MIA website at www.the-mia.com/MIA-Motorsport-Technical-School-Donington-963.

Ex-Andretti men set up new sports marketing business

Two former co-owners of motorsport promotion company Andretti Sports Marketing have set up their own Indianapolis-based organisation dealing in the same business.

John Lopes and Starke Taylor headed Andretti Sports Marketing along with IndyCar team owner Michael Andretti, but they split with him earlier this year in an at times acrimonious bust up which almost ended in court action. Now they have taken on a new partner, John Herron, and have set up the new firm called LST Marketing.

LST says it will offer creative services, automotive retail marketing, sponsorship activation and hospitality management, as well as providing in-house marketing analytics capabilities.

Taylor will serve as president of LST and is responsible for day-to-day operations from its Indianapolis headquarters. He brings over 20 years of professional sports marketing and business experience to the firm, including a spell directing the sports marketing efforts for Phillips Van-Heusen in New York.

'This is a very exciting time for our dedicated staff and our clients,' Taylor said. 'Our expanded services will open new opportunities in the experiential marketing space as well as sports marketing, business and entertainment.'

Lopes, who will serve as CEO, announced the new partner in the business. 'We are honoured to welcome long-time utility industry executive, John Herron, to our ownership. His expertise in building industry leaders is an incredible asset to our team of professionals and clients.'

Herron previously served as the chief executive officer, president and chief nuclear officer at Mississippi-based Entergy Nuclear until 2013 and is currently on the board of directors for Duke Energy and Ontario Power.

RACE MOVES – continued

Matthias Muller has moved from his post as chairman of Porsche to take the CEO position at Volkswagen in the most high profile of the management changes to be made in the wake of VW's emissions scandal (see page 76). Muller replaces **Martin Winterkorn** at the top of the troubled group.

Hans-Gerd Bode has been appointed head of Group Communications, Investor Relations and External Relations, at Volkswagen. He succeeds **Stephan Gruhsem**, who is leaving the company by amicable agreement, VW tells us. Bode comes to VW from sister marque Porsche.

One-time Indy 500-winner and former IRL champ **Kenny Brack** has joined McLaren Automotive as a test and development driver. During Brack's long and varied career as a race driver he's raced everything from IndyCars to historics, and has even picked up a gold medal at the X-Games for his prowess behind the wheel of a rally car.

Brian Allen, the motorhome driver for NASCAR Xfinity driver **Brian Scott**, has been indefinitely banned from NASCAR for his part in an altercation between Scott and **Darrell Wallace Jnr** at the Kentucky Speedway race.

Sam Roach, the CEO of Volkswagen Racing UK, which promotes the successful Volkswagen Racing Cup one-marque series, was part of a team that broke the record for driving from South Africa to Norway. The team of three took just nine days and four hours to finish their epic journey, which was undertaken in a VW Touareg.

Laura Schwab has been appointed president of Aston Martin, The Americas. Schwab joins Aston Martin from Jaguar Land Rover, where she most recently worked as marketing director. She will report to global sales director **Christian Marti**.

Eddie Troconcis has taken over the crew chief duties on the No.54 Kyle Busch Motorsports Toyota in the NASCAR Camping World Truck Series for the final races of the 2015 season. He was previously race engineer on the No.51 truck in the same organisation, while he has worked as a crew chief in the Truck Series for Eddie Sharp Racing in the 2012 and 2013 seasons. Troconcis has degrees in mechanical engineering and business management, as well as a master's degree in marketing.

NASCAR crew member **Chicago Paskiecz** has fallen foul of the US stock-car governing body and has been penalised for unnamed infractions during the Charlotte Motor Speedway race weekend in October. The penalty is described as 'behavioural' and the misdemeanour has earned Paskiecz an indefinite suspension from NASCAR competition.

Co-driver **Andrew Mort** was killed in an accident on the Rally Mull in Scotland in October after the Subaru Impreza he was competing in with driver **John MacCrone** crashed out. MacCrone was injured in the accident, but was released from hospital two days later.

◆ 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**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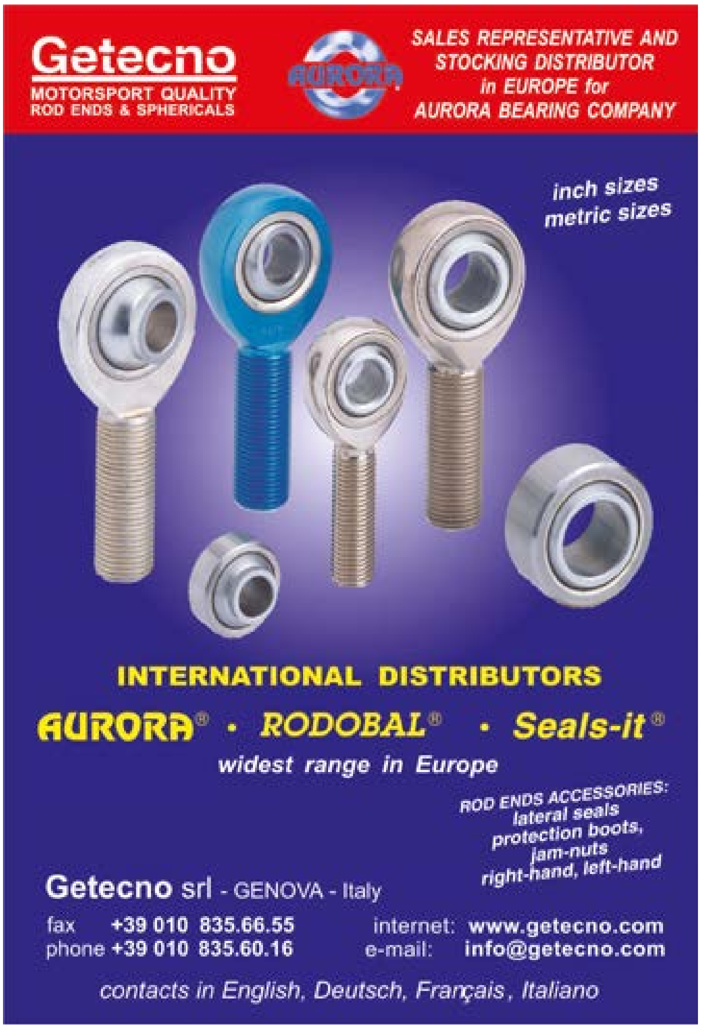
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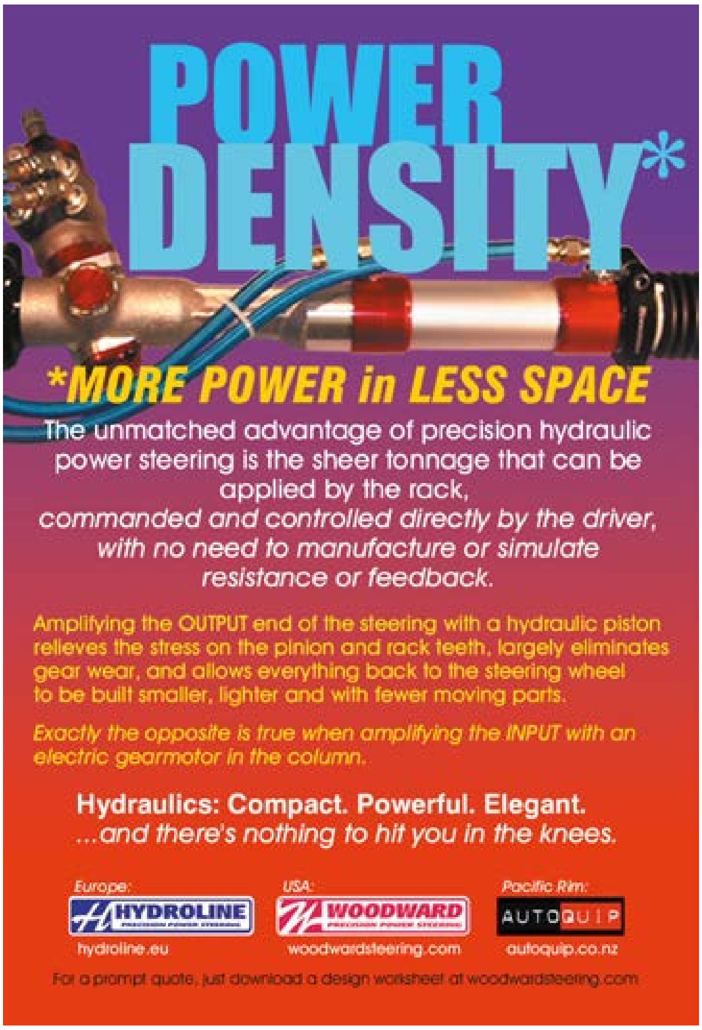
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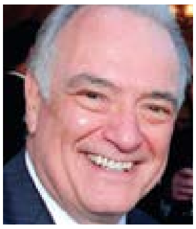

Opportunity knocks

These days there is more than one way to grow a motorsport business

The current state of the Formula 1 part of our industry obviously causes great concern, and it has an influence on the rest of motorsport in the long term. I am confident that much of the chaos will settle down and Formula 1 will continue, but I believe this is a watershed and it must change its business model to survive in the future. The current F1 business model has come to the end of its life and I am sure there will be a new approach in operation within the next few years. We will see a growth in income, far better fan engagement and communication, and fair value being created for all involved – teams, circuits and management alike.

F1 offers great global sports entertainment but it needs to catch up and overtake the other fast-growing sports. There are a growing number of successful business models which can help steer the direction of the new Formula 1 – possibly under new management. In this sense, I believe F1 has a bright future, but only once it realises that it needs to change substantially. There is so much goodwill for this series which is overlooked, or which F1 damages routinely, and with a slightly different and more generous approach, it will start afresh.

Future growth

When this changes, then other series which follow the leader will also change and all of these moves will be for the good. I look forward to series promoters focusing on filling the grandstands, thereby attracting sponsors and bringing wealth to the participants. There is no future in putting on an entertainment product in front of an empty house, and there never has been, whether in the theatre, in films or in sport; unless you have footfall to demonstrate popularity, steadily the sport is bled dry. Just look at the success of Formula E in building on the goodwill for motorsport in general and showing the way by attracting what is called 'a new audience' – and that's with a 'silent' car!

But frankly I don't think the FE audience is new; I think they have been enjoying motorsport as a computer game for years, they love watching a wide variety of motorsport on TV, and now there is a chance to go and enjoy it right in the centre of town. These are the fans that have been overlooked by F1 and others – they are a powerful, valuable and latent source of future growth.

On the subject of growth, over the next few months the MIA, in partnership with the UK government, will announce a Growth Plan for UK motorsport, looking towards 2020. This aims to increase sales and employment and attract new investment. I will certainly welcome your views once you have read it.

There are two clear streams of growth – one *within* motorsport and the other *without* motorsport. In the first case, we will review the growing opportunities around the world in new series – in rallying and rallycross in the USA for example; in electric powertrain events; in hybrid engines. Series by series, and country by country, motorsport has tremendous growth potential. We still have very little activity in China, India and Russia, while South America is going through tough economic times which has stifled growth. But a change in the domestic wealth in these countries will set alight the enthusiasm for motorsport, and the demand for engineering solutions and new race series will grow.

XPB

Dallara has grown to be one of the major players 'within' motorsport

It is true that the historic major markets in Europe of France, Italy and Spain, have been quiet for some time and remain so, but Scandinavia Germany and the Eastern European states grow every year. Sweden has now become a hot-bed of rallycross production for example, and in Italy, Dallara is still the world's largest single seater racecar manufacturer, but being chased hard by ORECA in sportscars in France. Talking of France, I am hopeful that Renault will find a way to return to Formula 1 and secure the jobs in Enstone, and so perhaps lead a resurgence in motorsport interest in the country – this will be good for both Motorsport Valley and the French motorsport supply chain.

It is obvious from a recent international marketing meeting which I hosted, that sports cars and GTs, in all their forms, are growing fast all over the world. This applies even to the developing motorsport markets such as the Gulf, China and India, and of course with the new USA IMSA sportscar programme, it is set to grow at an even faster rate under the control of NASCAR. New cars will be on track in 2017 and from that date Europe will link with the USA to create a true transatlantic opportunity for sportscar and GT racing.

There are two clear streams of growth; one within motorsport, and the other without

So much for growth *within* motorsport – but what do I mean by *without* motorsport? This is potentially the most exciting and prosperous area to focus on. The demands of delivering to a motorsport customer forces successful suppliers to be agile, ready to respond quickly and accept new innovations, and to attract the world's best skilled people who are aggressively competitive, and always deliver on time. These qualities are much sought after by many industries which are facing demands to produce solutions to ever-changing engineering problems to the point of prototypes being ready within weeks instead of years. Motorsport companies have the capability to meet these demands and can charge well for the service.

The sectors that are pressing the MIA very hard to engage with our membership are defence and automotive, but closely followed by rail, which is desperately keen to light-weight its trains, aerospace, which needs to cut its production time, and marine.

You will have read that the UK automotive industry is set to break all the records for production over the next five years, reaching two million cars produced by 2020. The largest increase is within premium brands, where it is now the second largest manufacturer in Europe behind Germany, and it is this class of car which can use the innovative, high performance engineering talents of motorsport most effectively. Hundreds of millions of pounds are being invested in researching and building prototypes for this market within the UK – and it's an ideal customer for motorsport capability.

Perfect combination

In the defence world the spend is still billions of pounds each year. They too are pressing hard for speed of response and innovative solutions, largely involved in light-weighting and energy efficiency. Again, the MIA is working on our Motorsport to Defence programme directly with the Ministry of Defence to bring about a change in our relationship with the industry. Take a look at our website – www.the-mia.com – to find out more.

These days you have to make maximum use of all your capability. So why not use your world championship and race proven resources to find new business, and so secure your business a more balanced future, whilst still engaging in the competition of motorsport and the rewards this brings? It's the perfect combination.


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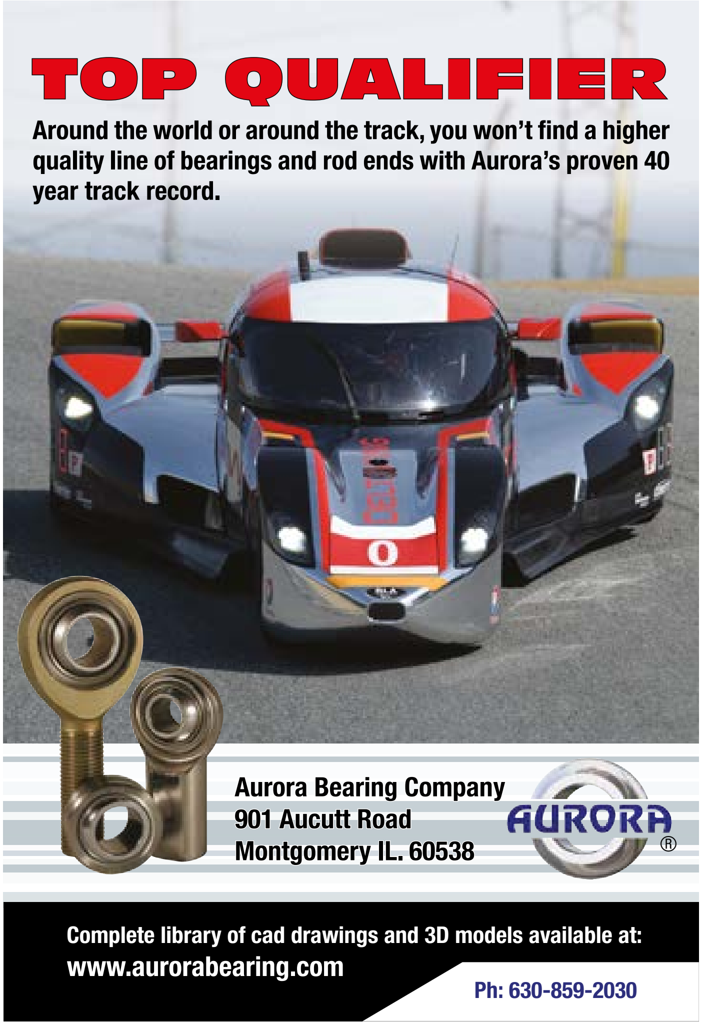
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Show business

Autosport International and its Engineering partner have become a must-attend event for those in the industry

Organisers of Autosport International will once again bring all the best cars and biggest stars of world motorsport together in Birmingham in January (14th to 17th), along with all the leading companies from the performance engineering and motorsport sectors, in what promises to be one of the biggest and best shows yet.

One of the headline-grabbing features at Autosport International is the attendance of Williams Martini Racing which is, for the first time away from the race paddock, erecting its Formula 1 motorhome and integrating it with the central Autosport Stage.

The towering structure will serve as the backdrop to a number of exclusive displays by Williams, which includes a selection of iconic championship-winning cars, plus appearances from current drivers, as well as famous faces who have contributed to the success of Sir Frank Williams' company in the past. The event will also gives fans a rare opportunity to learn more about the Williams Group, including its Advanced Engineering and Heritage divisions, in the form of fantastic interactive displays.

Meanwhile, the ever-popular Live Action Arena will deliver a number of indoor races, drift displays and celebrity appearances, as well as a driving masterclass from former WRC and World Rallycross Champion, Petter Solberg.

Those visitors wanting to emulate their racing heroes on track can head over to the indoor karting track in the Adrenalin Zone, where a number of arrive-and-drive sessions will be available for those wanting to showcase their skills at the wheel of a kart. In addition to this, a number of interactive and experiential features, such as racing simulators and racing games, will be rigged up in the Festival Zone over the weekend, this is located in Hall 9.

Performance cars

Running alongside the Autosport International Show is the Performance Car Show presented by Landsail Tyres in association with Autocar magazine and the PistonHeads.com website. The show will be launching an all-new and exciting theme for 2016, which will complement the stellar line-up of supercars and high-performance exotica.

Forming an integral part of the show is Autosport Engineering, continuing its long relationship with *Racecar Engineering*. Widely regarded by industry figureheads as motorsport's foremost technology show, it runs in association with the leading technology magazine, The show will once again bring together companies from the high performance engineering and motorsport sectors.

The show, running on two dedicated trade days between 14 and 15 January, will showcase the latest technological developments for the forthcoming season, as well as creating many new business and networking opportunities.

Ian France, Autosport International Show director, said: 'Visitors will be entertained from start to finish with world firsts such as the exciting Williams display, the ever-popular Performance Car Show or interactive and experiential features in the Adrenalin Zone and Live Action Arena. Fans will have the chance to meet their racing idols, too, in the autograph signing sessions, as well as witnessing live interviews on the Autosport Stage.'

France added: 'There are due to be many more exciting show announcements and we are looking forward to making next year's Autosport International the biggest and best yet.' Tickets are on sale now.

As always *Racecar Engineering* will have a major presence at the Autosport Engineering show in Birmingham

Useful information

Ticket prices:

- **Trade tickets – £28**
- **MSA members – £23 (available later in the year)**
- **BRSCC members – free (available later in the year). Members will need to contact the BRSCC for tickets**
- **Live Action Arena – £11**

How to book –
www.autosportinternational.com/trade
or call 0844 335 1109

Stand rates

AUTOSPORT INTERNATIONAL & PERFORMANCE CAR SHOW

- **Shell scheme – £345 per m² plus VAT**
- **Space only – £320 per m² plus VAT**

AUTOSPORT ENGINEERING

Turnkey shell scheme package: fully equipped 6m² stand package including shell scheme walling, carpet, power socket, strip light, nameboard and a table and chairs.

- **6m (3x2) – £2425 plus VAT**
- **9m (3x3) – £3638 plus VAT**
- **Space only – £320 per m² plus VAT**

The shell scheme price includes a modern attractive shell scheme system with
fascia board. All stands include carpet, cleaning, free stand listing in the official show guide and a hotlink on the Autosport International website.

The latest buzz in the build up to Europe's largest motorsport show – Autosport International 2016

Following on from the success of the Business Workshops in 2015, the MIA has presented its 2016 programme. These one-hour business workshops provide the perfect platform to propel your business, products and services to key buyers and decision makers at Europe's largest motorsport show – Autosport International 2016.

Claytex, Land Rover Ben Ainslie Racing, Base Performance Simulators and Williams Advanced Engineering are just some companies that have taken advantage of these business workshops to update attendees on their future business plans, launch new products and hold private meetings for their customers and suppliers.

Elsewhere at the show you will find the brightest and best companies from the motorsport industry, either exhibiting or getting down to business, including the following:

RPS

RPS is owned by HNZ Power Solution. Its RPS brand LiFePO4 engine start battery packs for racecars and racing motorcycles are characterised by strong, safe, stable, long cycle life, it tells us. All series battery packs have a Battery Management System (BMS) for protection. It says: 'Our controlling theory is exclusive; compared with other suppliers' BMS. Our control method is simple, economic, but feasible, stable. Its design is only for more safe and more cycle life.'

Hall 9 Stand E647

Jenvey

Jenvey Dynamics manufactures and supplies fuel injection throttle bodies and induction systems for all levels of motorsport; from road going sportscars, kit cars and track day vehicles, to World Superbike, S2000 spec Rally cars and World and British Touring Cars. Design and development services are also offered for specialist sportscar manufacturers and OEM prototyping. Jenvey says: 'The standard Jenvey range of twin and single bodies is extremely modular allowing customisation and fine tuning. Focusing on performance, reliability, lightness and value, backed up by our own motorsport success, we know what it takes to win.'

Hall 9W

MAHA

MAHA GmbH has been designing and producing chassis dynamometers for car manufacturers, universities and the tuning industry for over 40 years. It is the sole distributors for MAHA Dynamometers in the UK. 'MAHA UK Limited offers these premium quality dynamometers together with an unrivalled service and support network,' it says.

It offers a choice of twin roller per wheel, single roller per wheel, motorcycle, car (2wd or 4wd), and truck dynamometers, all using the same versatile and simple to use software written and updated by MAHA and periodically updated based on customer feedback.

Hall 9 Stand E472

Turbozentrum OST

The letters OST stands for 'Optimised Serial Turbochargers'. This refers to the process where a standard turbocharger gets a new milled impeller, which optimises the flow, and which is also especially lighter. In addition, a special friction bearing is installed, we're told, which has a special coating with very high dry-running properties. The OST optimisation is designed to give a turbocharger significantly better performance and longer life.

The company behind the product is TurboZentrum. It says that its technical department is only focussed on the re-manufacturing and optimisation of turbochargers. 'We are able to repair and optimise almost every turbocharger,' it says.

There's more to the company than that, though, and its retail outlet, TurboZentrum in Berlin, is regarded as the largest store for all the products and services that are needed for performance engines.

Hall 9 Stand E642

ARP

ARP has over 47 years experience in manufacturing threaded fasteners for use in motorsport, aerospace, and the oil and gas industries. It manufactures bolts, studs and nuts in a wide range of high strength materials, for racing teams and engine manufacturers around the globe.

It says: 'All of our manufacturing processes are performed in our own certified ISO9001 and AS9100 plants in California, USA, using state of the art machinery, including forging, heat treatment, machining, centreless grinding, thread rolling, finishing and testing.'

In addition to offering bespoke fasteners, ARP has a range of more than 4500 stock part numbers and says it has a worldwide distribution network as well as a UK-based European office.

Hall 9 Stand E670

DCE's Holley training

Staff from DCE's Mooresville production facility in North Carolina are now fully Holley EFi trained. The members of staff spent a week at Holley's HQ in Bowling Green, Kentucky, learning all aspects of the Holley EFi system. The DCE engineers will now not only be able to advise on the best system, but also assist in the programming of the ECUs, DCE tells us.

Jack Hastings, general manager of DCE, said: 'Holley is a well known brand in the US and by doing this course it gives us the opportunity to expand our product range. Not only can we now supply a wiring harness for the Holley ECU, but our engineers can now provide the ECU itself and also help programme it.'

Hall 9 Stand E181

Advanced Fuel Systems

This company will show its FIA-approved flexible fuel safety cells manufactured from a unique construction process which allows optimum fit to complex shapes, it says. It supplies complete fuel system design and manufacture for applications inside and outside of motorsport.

Hall 9 Stand E481

The meaning of Life

Life Racing has introduced a new product, the GPS-AG50, which it says is the world's first true 50Hz low latency GPS module with combined 6-axis motion pack designed for the professional motorsport industry.

GPS-AG50 uses advanced correction from SBAS (WAAS/EGNOS) to achieve high levels of position accuracy to within 2.5m and stores satellite information when powered off by means of a rechargeable lithium battery, allowing hot starts in under three seconds.

The motion sensor pack consists of a 3-axis accelerometer up to ±16G and a 3-axis gyroscope up to ±1000deg/s with individual software programmable filtering levels. All GPS and motion sensor information is available on CAN with update rates of up to 1000Hz.

The unit is enclosed in a compact light weight IP67 CNC machined case measuring 20x50x50mm with a single ASX Autosport connector and external aerial allowing GPS-AG50 to be AV mounted in space-limited locations.

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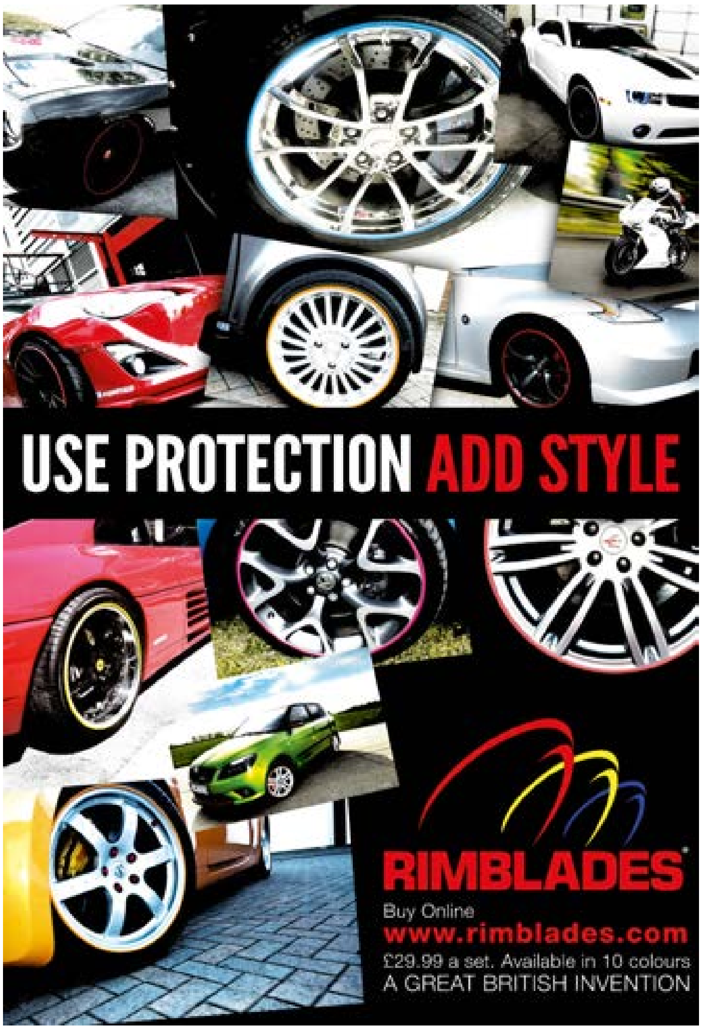
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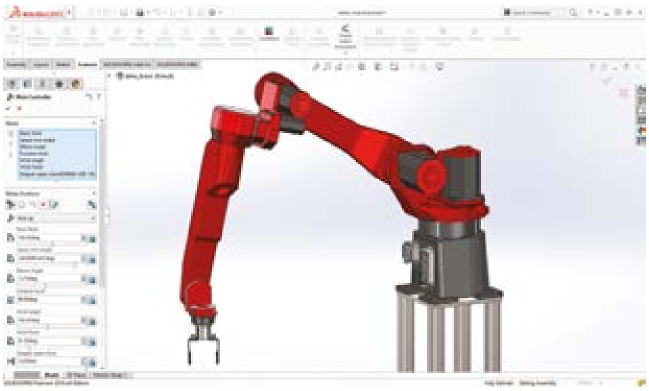

Dassault Systemes has launched Solidworks 2016, the latest in its portfolio of 3D design and engineering applications.

The new software covers all aspects of product development, while new user-requested enhancements include the ability to flatten any surface, visualise and help validate design performance, more efficiently communicate with manufacturing, quickly create marketing-quality images, and more easily access commands.

Along with many other new capabilities the software includes an improved user interface aimed to help designers and engineers focus on their designs, solve complex problems, streamline parallel design processes and fast-track designs through manufacturing.

Some of the key new tools are: 'Curvature Continuous Edge Fillets', which create super smooth blends or 'curvature continuous' fillets faster than ever before for all fillet types, including asymmetric and variable sizes.

'Sweep Command', which creates complex swept shapes faster than before with better, more reliable and predictable results, and automatically creates swept circular profiles in sections, with bi-directional sweeps in either or both directions.

'Thread Wizard', which accurately models standard and custom-defined threads with one quick and easy-to-use command.

'Breadcrumbs', which quickly and easily accesses any model without viewing the Feature Tree and thus reduces mouse travel.

'Innovative Design Simulation Tools', which give greater control and insight over operation sequencing, loads, part movements, forces needed and mesh quality.

And 'Flatten Everything', which quickly and easily flattens the most complex geometry for manufacturing, easily identifying strains induced when forming shapes back on to 3D surfaces, amongst other things.

www.solidworks.com

Engine components

Heavenly bodies

Omex has announced that it has expanded its facilities, while it has also released its own in-house designed and manufactured DCOE/DHLA manifold-compatible throttle bodies. The new bodies will fit all DCOE flanged manifolds.

By staying with the motorsport-standard DCOE flanges Omex says it has designed its throttle bodies to be compatible with the manifolds and air filters that are already on the market. This enables its bodies to be used on nearly all engines.

The throttle bodies include a two-step wall thickness design which provides the highest precision where it is needed – by the throttle plate – and the lowest weight everywhere else.

The product features billet aluminium machined levers and linkages; a large volume one-piece aluminium fuel rail, with various end fittings; protective coatings on all parts, including non-stick coatings on all the billet aluminium bits for longevity; and OEM specification throttle position sensors, for their proven reliability.

www.omextechnology.co.uk

Heat protection

If you can't stand the heat

DEI has brought its Onyx Series Flexible Heat Shield to market. Using a combination of advanced textiles and a reliable stand-off bracket design, this heat shield is said to provide maximum cooling and heat dissipation; preventing heat soak and burns.

The shield makes use of two durable materials to form a dual-layer design. The outer layer is a heat-treated glass fibre impregnated with molten aluminium that is formed into a tight weave for durability and strength. The inside material is a specially treated, high temperature resistant fabric (89 per cent silica) that withstands extreme heat – up to 1350degF – while all the hardware is stainless steel. DEI says this proprietary textile technology is designed to be flexible, and the shield fits many different applications and pipe diameters. In addition to use as a protective barrier on exhaust pipes, the shield is recommended for use as a heat barrier between transmissions, brake lines, hoses, electrical wiring, gas tanks and body panels.

www.designengineering.com/

Fire safety

In the line of fire

Lifeline has revealed the final variant of its newly FIA-homologated fire suppression system, the Zero 3620. The system has been awarded the FIA Gold Standard for use with unleaded petrol, diesel, ethanol and E85 fuels. Following the homologation, it has been mandated for use in the WRC in 2016, and officially recommended for all other categories by the FIA.

Lifeline's Zero 3620 has undergone extensive testing, development and validation in the motorsport and defence sectors. It is deployed in both the engine bay and cockpit, as per the new, stringent, FIA regulations.

The engine-focussed side of the system features Lifeline's patent-pending dual discharge technology. This is where the primary side of the cylinder quickly knocks the fire out and is then supplemented with a secondary discharge, which uses the residual energy from the first, to deploy a specifically blended coolant fluid to prevent any re-ignition.

The cockpit-facing system is available in two sizes (2kg for up to 2.3CuM and 3kg for 2.4 to 4.0CuM) and it features Lifeline's compression discharge technology, with the added option of either a fixed or remote outlet.

The entire system is controlled by a unique microprocessor which constantly monitors the state of the system and battery and will advise the user of any potential issues.

Lifeline has also homologated a remote activation facility, enabling the system to be deployed wirelessly from the pits or by members of the track safety crews.

www.lifeline-fire.co.uk

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PIT CREW

Editor
Andrew Cotton
@RacecarEd

Deputy editor
Sam Collins
@RacecarEngineer

News editor and chief sub editor
Mike Breslin

Design
Dave Oswald

Technical consultant
Peter Wright

Contributors
Mike Blanchet, Dr Charles Clarke, Ricardo Divila, Simon McBeath, Danny Nowlan, Leigh O'Gorman, Mark Ortiz, Peter Wright

Photography
James Moy, Shimpei Suzuki

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

Head of business development
Tony Tobias **Tel** +44 (0) 20 7349 3743
Email tony.tobias@chelseamagazines.com

Group Advertisement Manager
Lyndal Beeton **Tel** +44 (0) 20 7349 3700
Email lyndal.beeton@chelseamagazines.com

Advertisement sales executive
Jack Shannon **Tel** +44 (0) 20 7349 3745
Email jack.shannon@chelseamagazines.com

Marketing manager
Will Delmont **Tel** +44 (0) 20 7349 3710
Email will.delmont@chelseamagazines.com

Publisher Simon Temlett

Managing director Paul Dobson

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

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

Subscriptions
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Gentlemen of the track

The FIA's World Motorsport Council released its latest decisions on September 30 and immediately there was an outcry on social media. The Azerbaijan Grand Prix, held on a new circuit in Baku, has moved from its July 17 date to clash with the Le Mans 24 Hours on June 19. Elsewhere in the statement, we were told that the Le Mans cars would be restricted to 1000bhp, although this was later clarified to apply only to Grade 2 circuits, and therefore only the 24-hour race itself. Since then, it has been further clarified; the reduction in the energy from the fuel is 10MJ, as expected, and the power limit from the hybrid system has been set at 300kW.

Gerard Neveu, the general manager of the World Endurance Championship, called it a 'clear attack' on the series by F1 (according to Italian magazine *Autosprint*), and initially I couldn't help but wonder why 1000bhp, other than that this was the target for F1. This figure, or even an overall power cap, hadn't even been discussed in the Technical Working Group!

It is well documented that lap times at Le Mans have to be kept in check due to the nature of the circuit. In 2009, in order to limit cornering speeds without being too obvious to spectators, the ACO introduced a one tyre-gun policy, encouraging tyre suppliers to maximise the rubber's time on the car – go longer, save time and reduce cornering speeds. It was a great message, and has led to some rather interesting pit stop sequences, particularly when under pressure.

More power is always more attractive to drivers and teams

The reduction in power is a necessary next step, although the 10MJ reduction in fuel energy per lap is nowhere near enough. The thinking is more like 30MJ from the fuel and a greater reliance on hybrid systems. More power is always more attractive to drivers, teams, engineers and spectators. It is also more attractive to interested manufacturers – go further on less fuel? Sounds like a winner. Talking to Juan-Pablo Montoya in the US, he wanted to drive the 1000bhp Porsche. When I told him that rivals calculate Porsche's power to be closer to 1350bhp, he was even more interested. But, this power has to come from the right place, and a more efficient hybrid system is just the thing under the current regulations. The outright limit from the hybrid system doesn't make sense, therefore, but I guess that, in future, there will be significantly less energy in the fuel allowance and the instantaneous power delivery limit will be raised once again.

In October, the ACO announced that it will feature a GT3 support series on the bill of the European Le Mans Series, using Michelin tyres and the FIA Balance of Performance. With manufacturers targeting big wins, including the Spa and Nurburgring 24 hour races, and with the desire not to integrate GT3 cars in the main event, this seems to be a logical step on the face of it, with the manufacturers building the cars (Audi, Porsche, Ferrari, Aston Martin, Corvette) already competing in the series, but here the argument falls down. All of these, bar Audi, already run production-based cars in the European Le Mans Series. How the ACO will balance the performance is another question, one that the ACO's technical director Vincent Beaumesnil couldn't answer when I asked.

Stephane Ratel already organises a sprint and endurance series, has the most comprehensive BoP anywhere for GT3 cars, and is making a good business for himself and his teams. Why urinate on his parade, particularly when you could have an LMP3 series instead? Ratel, don't forget, was instrumental in bringing together the FIA and the ACO to produce common GT regulations when the two French bodies weren't even talking to each other. Will the ACO/FIA engage when balance of performance inevitably becomes an issue?

Not that long ago the World Touring Car Championship sought to revitalise itself and the manufacturers, BMW, SEAT and Alfa Romeo played their part. Each bought tickets to races that were important to them and distributed them through their dealer network. It sort of worked, until the pure business of racing got in the way. The gloves came off, the economic realities hit, and although the series remained strong, it lost that common goal to raise the profile of the series in which they were all racing.

Sportscar racing is in the same place. Gentlemen's agreements in technical meetings are becoming less valuable. The agreement for not having deliberately flexible bodywork on the cars (note, even in writing we have to be specific) was agreed on the grounds of cost control. Then Toyota turned up with an interpretation of the regulations that said, somehow, rotation was not movement.

'Equal refuelling time' was a topic covered in the last edition; Audi has found pretty much the full 30 seconds over a six-hour race in the time between the Nurburgring in August and Fuji in October to catch up with Porsche. The Audi team was pleased with itself for having done so, but at what cost?

Gentlemen's agreements are becoming a thing of the past, and building something new will therefore become all the more difficult. The competition has been raised to such a level, and so much is at stake, that no one can afford to be chivalrous. On track there is absolutely no room for such sentiment, but surely there should be room for it in the Technical Working Groups. As much as the FIA appears to have prioritised Formula 1 over endurance racing, in fact endurance racing has proven itself to be capable of consuming its own.

ANDREW COTTON Editor

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