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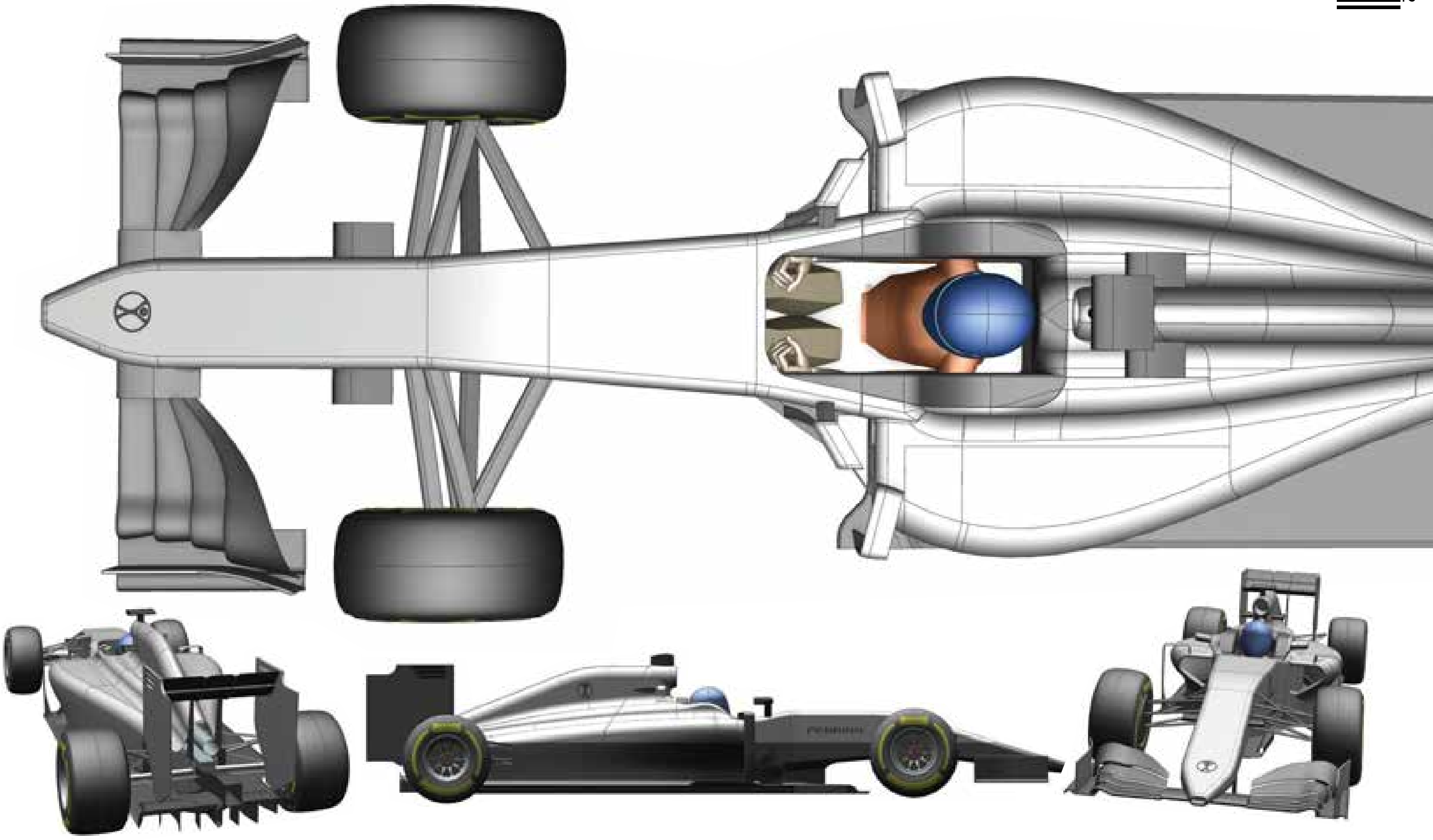
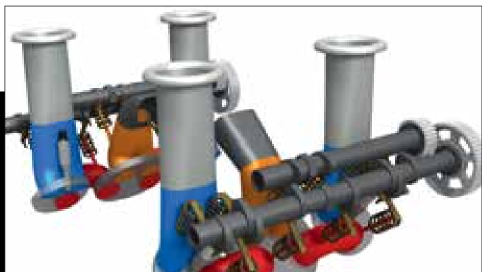
February 2015 • Vol 25 No2 • www.racecar-engineering.com • UK £5.95 • US $14.50

Formula 1: The future

New cars, new concepts, new rules





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Panel games

Using instruments to gauge your engine's performance can be an imperfect science

The ancient Etruscan divination by looking into the entrails of animals (haruspicy) was supposed to give intimations of what the future would bring. In the same vein instruments show what state your engine, gearbox and tyres are in, and slowly dropping oil pressure or climbing water or oil temp gauges can reveal the future of that particular thrashing machine.

Weights and measures were among the earliest tools invented by man, useful for building dwellings of an appropriate shape, making clothing and bartering measurable portions of food or materials. Parts of the body and natural surroundings were mustered as measuring instruments.

Length was first measured with the forearm, hand, or finger and time was measured by the periods of the sun, moon, planets and stars, as noted in the Bible and early Babylonian records.

Filling containers such as gourds or clay vessels with plant seeds that were then counted gave the measure of volumes. With the development of scales as a means for weighing, seeds and stones served as standards. The carat, still used as a mass unit for gems, is derived from the carob seed.

We will not go into the relative merits of metric or imperial systems, as they at least uniformized measurements over great areas of the world and imperial measures gave us the inch, hand, chain, yards, the rod, the pole or perch, the furlong and the impressively named slug for air density. The fact that they are subdivided in 12ths, 64ths and other strange units is a heritage of conventions that date from Assyrian or Babylonian times. Metric is a bit easier to calculate, escalating in orders of tens.

As a side note I find it intriguing that the need for a single worldwide coordinated measurement system was recognized over 300 years ago. Gabriel Mouton, vicar of St Paul's Church in Lyons and an astronomer, proposed in 1670 a comprehensive decimal measurement system based on the length of one minute of arc of a great circle of the Earth.

Mouton also proposed the swing length of a pendulum with a frequency of one beat per second as the unit of length. The beginning of mechanical power with steam intensified another requirement to monitor the optimal functioning of the contraption and warn of the danger values for boiler pressure and other portents of doom.

Since society abandoned walking en masse for riding in upholstered comfort atop a metal box harnessed to a series of small explosions, the requirements to monitor it brought more instruments, specially in racing when they were pushed to the limits, and often over.

Veglia, Jaeger, VDO, Smiths are names with a good pedigree in racing, the majestic rpm counter sitting on the dashboard being the guiding light for the exploitation of the engine and the assorted pressure and temperature satellites guarding the reliability of said engine ensuring the operating limits were respected.

Quantum physics changed this by going solid state. Electronics changed the view behind the wheel, to the point drivers are now drowned in information, most of it digital. We are analog animals, very good at perceiving information by shape, numbers being difficult to grasp quickly. A bar or a needle that can be discerned by positional reference is hard-wired into our brains; a digit has to be interpreted by the cortex.

We have other senses which are underused, the coupling of sound into the driver's earpieces can be useful by giving a bleep when the revs are ripe for a gear change, taking away the need to have the shift lights in the visual field, same for wheel lock warnings, bipping up in intensity with percentage of slip, and having left and right earpieces for front or rear locking.

A red light just meant you could switch off before the damage became expensive

We are analog animals – and even in the digital age this can be catered for

Ken Tyrrel once remarked that the use of instruments on his car was a waste of weight, as 'Schechter couldn't see them and Depailler didn't understand them.'

One has found that sometimes the instrument panel or dashboard (another leftover from the past, as most of the instruments and lights are on the steering wheel, the visual field in most racing cars being restricted to it) tend to be laden with too much information, just because we can do it. With the advent of telemetry in the major formulas most of the supervising of the engine, gearbox and running ancillaries is done at the pits, with no need for the driver to monitor it. Some of the analog instruments were a liability, as piping fuel and oil directly to the instrument in the cockpit gave the possibility being sprayed by fuel or oil if you had an instrument failure.

The practice of fitting a hypodermic needle inline before the gauge itself helped by restricting the petrol leak to innocuous drops in case the bellows that actuated the needle giving fuel pressure ruptured, at the small cost of a lag in reporting the pressure.

The lack of reliability of the analog instruments left them to be omitted, leaving only the revcounter as a guide, and a big red light for oil pressure, basically so the driver could switch the engine off before extraneous bits of metal came out of the side, and caused the car to stop with an 'electrical failure' as Ermano Cuoghi explained at Alfa: 'The electrical failure was caused when the conrod came out the side of the block cut the ignition wires.'

All other signal lamps were really redundant, green not really necessary as all was well, yellows in sprint races meant you had to pit, so race over, and red only useful to avoid even more expensive damage.

Endurance racing had other needs, as nursing a car till the end of the stint allowed it to be repaired for the continuation. But now even 24-hour races are run as sprints.

Cameras pointing backwards at the highest point of the tail eliminate the blind spots caused by the high wheel arches and thick pillars required to withstand the crash tests, plus having a self dimming function for laser blasts from the headlights of following cars at night. These cameras can also have tracking arrows that change colour with approaching cars and which side they will be overtaking, using motion-sensing software. Tyre pressure monitoring systems are essential to know when you have a slow puncture, as it can keep the driver from arriving at Mulsanne, oblivious of any problem as the tyre is centrifuged to maintain its shape, but collapsing as you go into the corner.

The advent of new energy recuperating systems, plus fuel flow limits increases the workload exponentially, all these parameters being monitored, and the conclusions fed to the driver by radio, and some of it by the instruments on board, with the data being analysed, then fed back.

A good example that earlier racing was different and could be classified under the motto: *Ignorance Is Bliss.*


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A hybrid mix-up

The engineering solutions fascinate, but are new F1 rules bringing results?

The Oxford English Dictionary indicates that the Cajun or Creole (take your pick) dish 'Jambalaya' comes from the Provençal word 'jambalaia', meaning a mishmash, or mix-up.

Well, it can be argued that a jambalaia is what we have in much of motor racing right now, and none more so than with the introduction of hybrid technology. Like many, I confess that I find the engineering solutions being brought about by the regulations quite fascinating, and I understand that there is seen to be a relevance to future road car development that may have drawn in some major automotive manufacturers.

But – and this is a big but – what I suffer angst about is the perception that all this expensive kit is actually succeeding in its stated purpose.

Leaving aside those rocketing power unit costs that are damaging F1 and bringing teams to their knees financially, analyse the main thrust of the FIA's claim that the new regulations have resulted in a saving of 30 per cent in fuel consumption over the same race distance. Unless everyone is telling lies, they have (but performance has suffered, which takes away some of this kudos). However, I challenge anybody to tell me that the same saving could not have been achieved by other, less expensive and conventional means. Such as -

- **More efficient (and safer) aerodynamics creating much less drag for similar downforce (for example controlled ground-effects tunnels – the mandatory flat bottom configuration must be one of the crudest performance regulators the sport has ever imposed and is still in force 30 years from its instigation, virtually overnight, as an emergency measure).**
- **Better tyres on roadcar-relevant wheels, up from archaic 13in diameter to 18in. Slowing less for corners means not having to accelerate as much afterwards. This equals fuel saving.**
- **A non-hybrid turbocharged motor of, say, 2.0-litre displacement otherwise similar to the ICE now employed but without the additional 50kg plus weight caused by carrying around and cooling all that hybrid kit.**
- **More regulation freedom to encourage innovation that could improve overall efficiency.**
- **A reduction in minimum weight – for inspiration look at the Nissan Zeod project and in particular the little gem of a three-cylinder ICE, which with turbo develops circa 9 PS/per 1kg of weight!**

I don't buy the argument that weight reduction automatically leads to higher cost. With the same restrictions on the use of exotic materials as already included in the F1 regulations, it's hard to imagine how engineers could spend more money than they already have done in struggling to get down to the bloated 691kg of the 2014 cars (701kg for 2015!).

LMP1 also suffers (albeit to a lesser extent – the cars already have excellent tyres, big wheels and better aero efficiency), from the same insistence on hybrid power being the only way to reduce fuel consumption for a given level of performance. At least the ACO's more imaginative regulations have encouraged a wonderfully diverse range of power units, all of them impressively close in performance. But still the enemy is weight, perversely greater than equivalent prototype coupés of 40 years ago despite the advent of carbon-fibre and other advanced materials for chassis and bodywork and FEA design in almost all mechanical components, not least engines and transmissions. Not all this extra mass is safety-related either, as mentioned above. All this prevents LMP1 cars from weighing-in at a probable 750kg or less, instead of 870kg minimum as now. Colin Chapman must be turning in his grave… So in essence I am saying that other and better means exist to improve racing-car efficiency (using less fuel but still going fast) than by imposing mandatory hybrid power units.

It's hard to imagine how engineers could spend more than they already have done getting car weight down

A reduction in minimum weight? For inspiration look at the Nissan Zeod project's three-cylinder ICE

Political influence

At the heart of the jambalaia of course is the ACO and the FIA wanting to appear technologically and environmentally friendly, to stave off criticism from politically influential 'anti' lobbies and the fickle headline-seeking media that motor racing is a polluting and dangerous activity that should have no place in our modern risk-averse world. They want instead to attach the positive label of racing having a direct relevance to road car development.

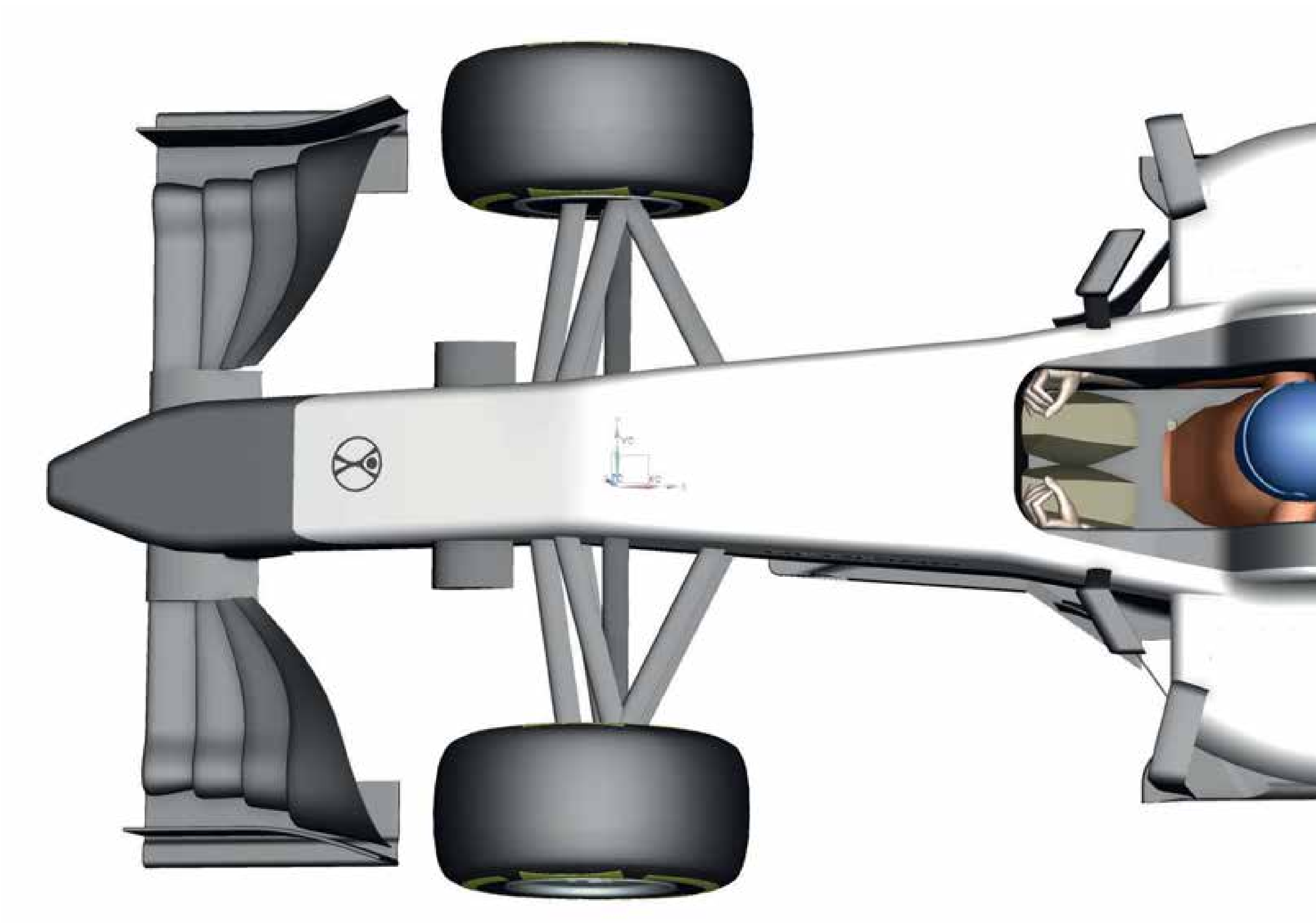
One can see the justification behind this thinking, and reference the ACO applaud its inclusive attitude towards different routes of attaining the objective, albeit all hybrid. If this is purely a political decision with the aims indicated above, then I suppose well and good. However, I would like to see an audit of the performance gain/fuel saving/cost implication of each hybrid component versus the extra weight incurred. Engineering complexity for the sake of it is not good engineering, which in my book should be about the simplest, lightest, safest and least expensive way of providing a solution to a need.

Just as the Green perception has driven motorsport regulations, so it has affected road car demand. Virtually every motor manufacturer has hybrids in its range because the car-buying public, strongly-influenced by the media, has been led to believe that they will save money on fuel use and help protect the environment. A very senior engineer from a major manufacturer told me recently that it's all 'bollocks', driven by global government regulations and the marketing reaction. He was clear that a great deal of efficiency gains remain to be found in refining conventional technologies and that carrying all this battery weight around with its poor manufacturing, recycling and operating characteristics is a blind alley. Consider – until last month, diesel cars were supposed to be much better environmentally than petrol, right? All change now; motorists are being actively discouraged from buying and running cars with combustion ignition engines as diesel has proven to be more damaging and cities are moving to penalise diesel drivers even more. Electricity used in charging batteries, other than during energy recovery (a small percentage of running time on track and on road) is not free, it simply moves the pollution issue of creating it from one place to another. It is only a matter of time, surely, when sanity comes through on this one too.

Future series

Designing in parallel – rather than in series – is a new approach to grand prix and LMP1 car development

By SAM COLLINS



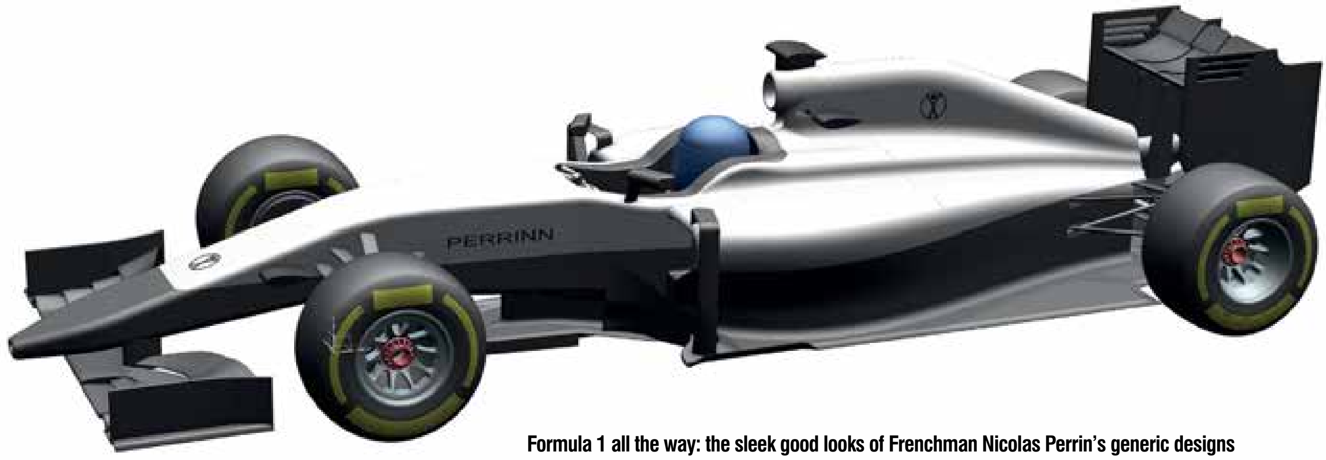
Nicolas Perrin has taken unusual steps in his career. He had worked with Courage Competition as a race engineer, and then joined the Williams F1 team as a race performance engineer. But he gave it all up to develop a new top-level competition car design methodology. He built a Le Mans prototype, the Pescarolo 03, around the tub of the Aston Martin AMR-One but that debut at Le Mans was beset by problems. He designed an LMP1 car and sought funding through a public campaign, and now has designed a Formula 1 car to 2016 rules.

'I always wanted to design a full car and I've always wanted to work differently from the others,' says Perrin of his career choices. 'When I was race performance engineer for Nakajima at Williams, I stopped what I was doing and became a designer. Normally from that position in your career you work hard, get better and end up as the lead race engineer on the car. But I was so interested in the project overall that I switched streams. At the age of 30 it was a one-way thing. Luckily Williams gave me the support and helped me. When you are a race engineer your main tools are Excel, and other data management things, but you rarely use CAD. So I found myself learning how to do CAD with a bunch of guys almost 10 years younger than me fresh out of university!'

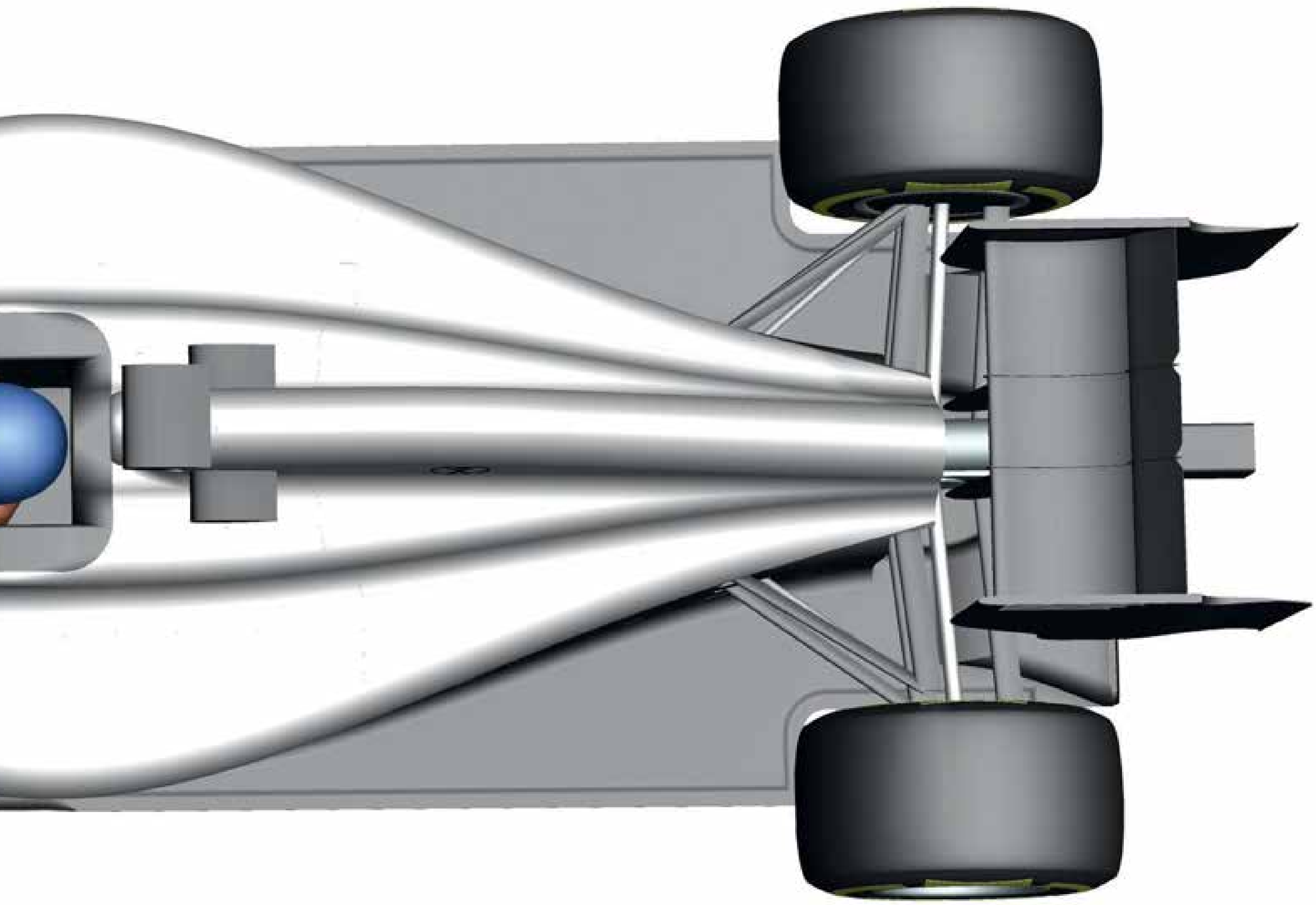
Perrin eventually parted company on amicable terms with Williams and started up on his own, in a small office in the Yorkshire Dales. 'I started work in 2011, with the aim to deliver a car for Le Mans in 2014.'

He had decided not to work like a traditional design consultancy, instead he had a new approach which he believes is more efficient.

'I was inspired by Adrian Newey and the success he has had at Red Bull, it gave me the confidence to do this,' he says. 'It showed me that designing and delivering a good racing car is not just about having an army of people and a complicated structure. We are not doing mass production here, it's crafted high-end design so I think that it is important to have one person in charge of the whole thing. That person had the whole car in his head and everyone under him



Formula 1 all the way: the sleek good looks of Frenchman Nicolas Perrin's generic designs



follows his lead, rather than giving too many people the opportunity to try out whatever pet project they have. That's how I did the LMP1 car.'

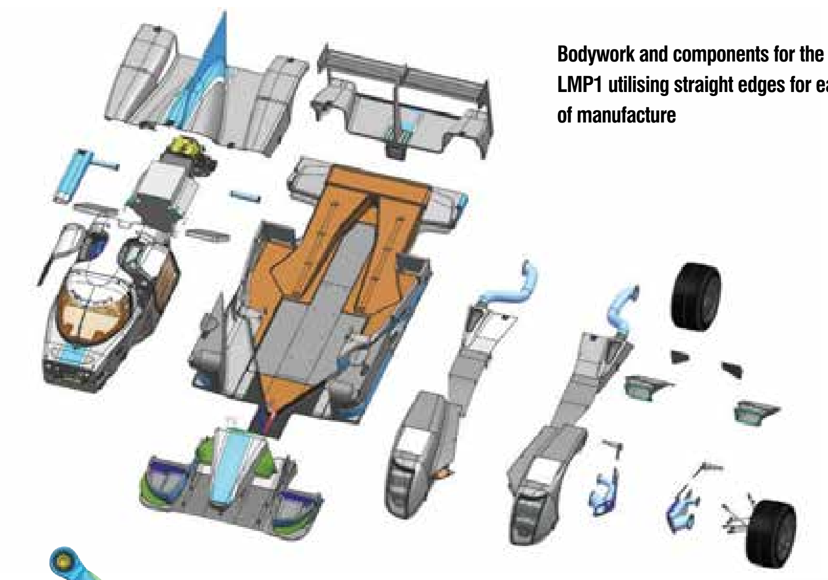
Perrin started work sitting in his office with the rulebook, working out what he could do with the design. 'I read in *Racecar Engineering* what Newey was doing. Back in 2009 there was the big rule change in Formula 1, so before that he just went away for two or three weeks on his own with the rulebook and started sketching things. I did that with the LMP1. You work out all the big things, nobody questions you.

'So before I brought in a team to do the detailed design I sorted all the main questions, the architecture of the car was complete. That saved so much money, there were no meetings to discuss things, no committee meeting to decide the wheelbase for example. I decided all of this on my own. Of course you can revisit it later if something happens,' he explains. 'I was the first person to start proper work on a 2014 LMP1, starting three years in advance, 18 months ahead of Porsche. I started work before the rules were finalised and fed back a lot at the FIA meetings because I was the only one working on the new rules at that time.'

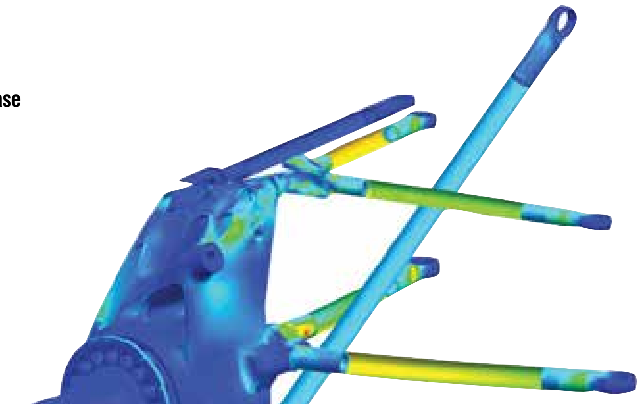
Into the detail

Once Perrin had worked out the major design elements he started work on the detailed subsystems. 'But then I brought in other designers to help on the details. On the uprights for example I worked with a guy I knew from Courage. He designed the whole upright on his own. But I gave him the suspension points, all the kinematics, all the offsets, the brake disc, everything. Then we fully designed the components right down to the MMC material used and the machining. The FEM was all done, all of the normal things were done. But instead of doing it in parallel we did it in series.

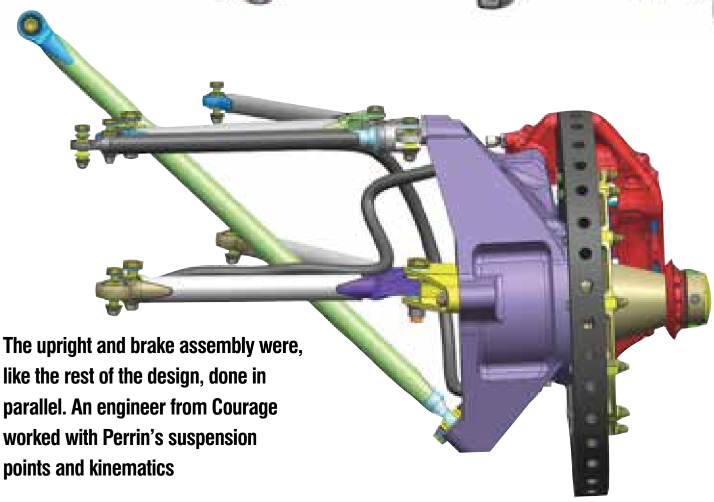
So a normal constructor would need a stress department always working on optimising parts, an aero department getting the best flow structures and all of that. But I spent a year on my own just doing the aerodynamic work, then, with some other people, three months just doing the FEM.'



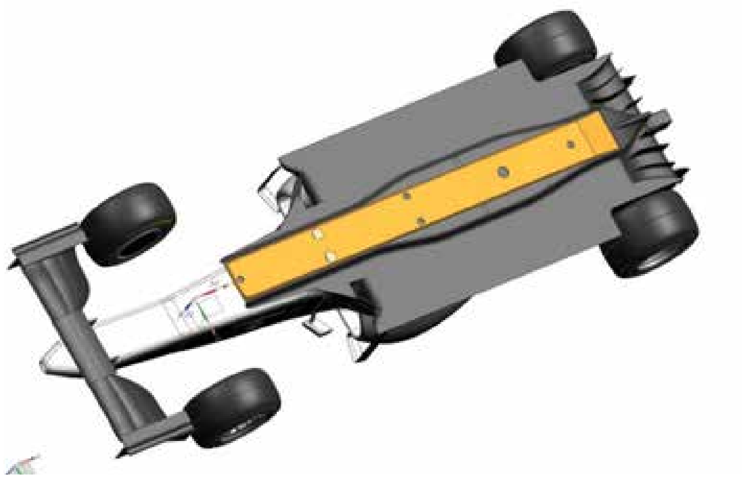
Bodywork and components for the LMP1 utilising straight edges for ease of manufacture



'We fully designed the upright components right down to the MMC material used and the machining. The FEM [pictured here] was all done, all of the normal things were done'



The upright and brake assembly were, like the rest of the design, done in parallel. An engineer from Courage worked with Perrin's suspension points and kinematics



Once the design details were completed the extra designers, who had been working on a freelance basis were all released. It is a key part of Perrin's approach, working through the project in series, tackling each problem and subsystem in turn rather than developing different parts in parallel.

'I am not doing things for the sake of being cheap, it's just my way of doing things. Rather than managing a group of designers I tend to design a lot myself. I put a line through the car from front to rear, it is all my work,' he explains. 'I don't split things out into modules, and give them to different teams, so it's a very different way of working to normal.

'The model is very cost effective. We do not have an infrastructure that we have built up, we do not have to pay 200 people every month even if there is no work to do. We have done it differently. Rather than rushing the design and spending money to do things in a short amount of time we have taken longer. If you allow lots of people in a committee to get involved you end up just driving costs up to a level that is unsustainable so this is a low cost way of working, but it's also a way of delivering a very low cost car. Its important to stress that we want to deliver a high quality car still.'

Designing in series

Perrin believes that his approach of designing the car in series also allows for a number of very pragmatic approaches to the car. 'Normally in Formula 1 an aerodynamicist will come up with a new wing design, the part is scaled then tested in the wind tunnel. If it is good then it is signed off, but then it ends up being redesigned for CAD quality purposes, most teams have people just re-doing surfaces, that then goes to the composites and manufacturing department who take the shape and turn it into an assembly, with a structure inside, they will work out the thickness of the composite lay up and all of that,' the Frenchman explains.

'But what I do is different. Before I get into all of the CFD work and things like that I do the composites first. I have learned that if you do not push yourself to design the final component including the thickness it will have, you end up thinking of of shapes and solutions that are not really possible in terms of manufacturing. But if you work only on the final components you save time and money because you know that it can be made.'

During the development of the Perrinn LMP design (the company name spelled with a double 'n') its creator was sidetracked by a separate car design project, the Pescarolo 03. History shows that the Aston Martin AMR-One based, Judd-based design was not a success but Perrin learned some important lessons.

'On that car I did not use the method of thinking about the final part. I did a pure conceptual aerodynamic package, and when we got the go ahead, we then had to make it around existing designs and had to work in a real rush,' he admits. 'When my aerodynamic surfaces were turned into real components they did not fit on the car easily. As a result, in some areas that are quite sensitive and critical, especially under the chassis, were not sealing properly, and that cost performance because the parts were too complex to make. Now, I want to be sure that you can make a real car with the parts. If I knew then what I know now I would have done the concept design differently.'

"We do not have an infrastructure, we do not have to pay 200 people…but I'm not doing it for the sake of being cheap, it's just my way"

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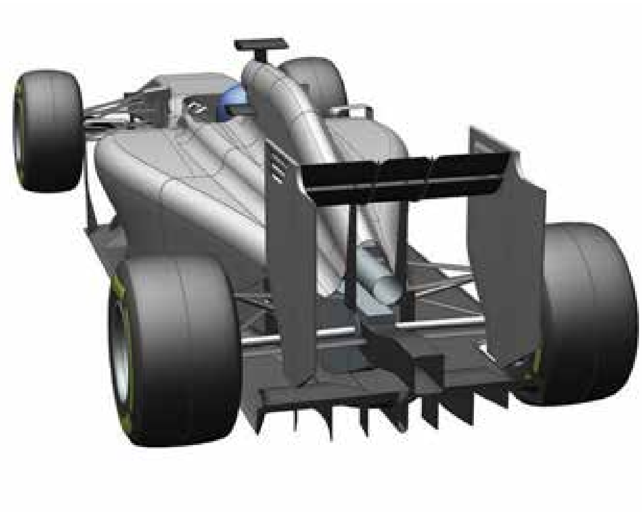


'With this car a driver could be fully ready for F1,' claims Nicolas Perrin. 'It is a way for young drivers to prove what they can do.'

This approach changes how Perrin develops every part on the car, ensuring ease of manufacture and reduced costs. 'If you look at the car as an end product first, what will it look like as a real car, not on a CAD screen, then it helps. A car is merely an assembly of components, so to think of a real car you have to think of all of the components, how all the panels fit together, where you put the splits to make them seal properly. With some cars you find that the panel splits are complex with angles and curves. It is really hard to ensure it is properly to make it fit and seal properly, and that costs performance.'

Having worked on the design of three Formula 1 cars, an LMP2, and engineered many others Perrin feels that many designers tend to overlook the usability of some parts. 'A good example of how I design you can see in the LMP car, all the splits are straight,' he explains. 'There is a 30mm return, no joggle and the sealing should be perfect. It makes manufacturing easier too with everything starting on the flat. But you can only do this if you work the way I do, thinking of the end product in detail at the concept stage. Otherwise things like the shape of your chassis won't allow it. A normal LMP with the straight edges would mean your rear brake ducts would have to move. In most design offices the guys who design the bodywork will not even consider where the splits are.'

Indeed Perrin feels that many car designs are overly complex for no real reason, and that some systems seen as essential by many people are actually just areas that can cost more performance than they deliver.

Quick change

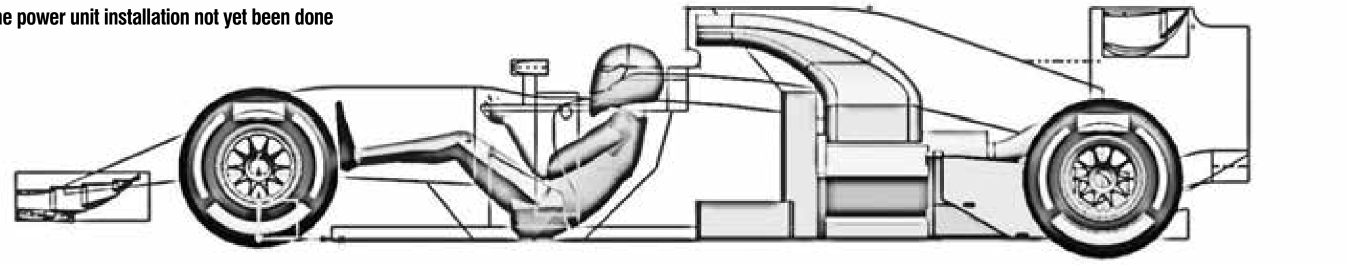
'In LMP everyone has a quick change rear end where you can change the whole rear end in one – it's really complex to do but some people think it gives an advantage,' Perrin states. 'I ask how many people have ever done a quick change doing the race? I've never seen anyone do it. Actually I have found that doing a quick change rear creates its own issues because of the sealing of that split in the floor, and that creates losses. You ended up taping, it to ensure the sealing, but then when you remove the tape it ends up half broken. At one point a lot of cars were breaking their legality panels in races, but the extra stop to change it was so punishing they just made the panels stronger.'

Perrin also believes that this tendency to over-complicate things also applies to some mechanical components. 'I remember an extreme case, an old Reynard, where everything was made to be quick change, I think the 2KQ. The gearbox was not part of the car, the rear suspension was on the bell housing, so the bell housing was massive. It went over the gearbox just so that they could change the gearbox quickly. You can imagine how heavy that was, and the stiffness was really bad, and it hit performance. Even at the top level, a racing car should be as simple as possible, like a kart. But doing it my way you can't afford to spend the time on these kind of solutions anyway. You just spend time doing the things that matter, lightweight components and simple mechanical systems.'

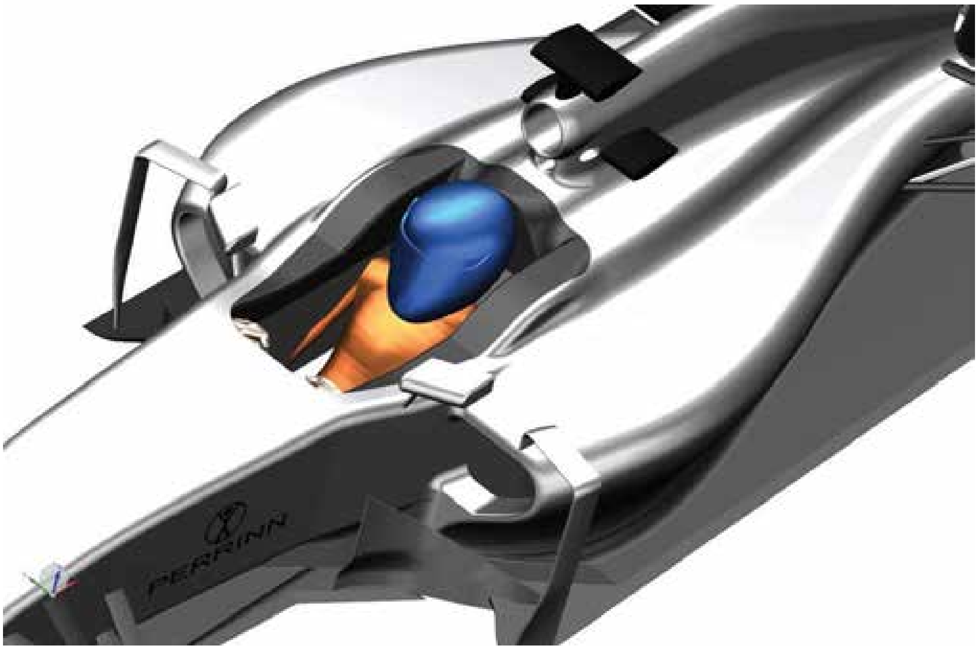
The first product of this new approach is the Perrinn LMP1, a Judd-powered hybrid with twin energy recovery systems. While the car has only been built to a mock up stage the design is fully complete and the car is ready for manufacture. Currently the company is looking for around £2 million in order to build and run the first chassis in 2015. However while the hunt for funding continues a new project had started, the Perrinn grand prix car.

'This is not an official Formula 1 car,' admits the designer. 'Instead it is a car fully designed to the Formula 1 technical regulations. We are not a Formula 1 entrant and we have no intention of being one. It means we have a lot of potential. We could be an engine manufacturer or technology testbed. Young drivers could use our car to get a super licence or to get up to speed with modern F1. Ultimately though I want the design to be racing, either a manufacturer

"This is not an official Formula 1 car. Instead it is a car fully designed to F1 regulations. We are not an F1 entrant and have no intention of being one"



Perrinn F1 by design: typical of the generic parameters of the project, the power unit installation not yet been done



'What all these drivers want is a shot in a F1 car, but unless they pay huge money to do a young driver test (and not all teams sell the seats) there is no way to prove what they can do it'

adopts the design or a group comes along and sees what we have got and decides to race it,' Perrin admits.

The design is based on the 2016 Formula 1 technical regulations and uses the same design philosophy as the LMP1 car, but now fully developed. While the 2016 rule book is not published, in draft form at least it largely carries over from the 2015 rules. But in the current financial climate in Formula 1, developing an all-new project like this seems unlikely from a business point of view, especially for a start-up like Perrinn.

'Actually for a company like this Formula 1 is better commercially than LMP1,' says Perrin. 'Firstly, there is more money in F1 than there is in WEC, and the teams are so much more restricted with what they can do with their cars. We can do what they cannot do.

'How many young drivers are there out there with a budget trying to get into F1? Many came to me when we announced the LMP car and I realised from speaking with them what they really wanted was an F1 car. For them, LMP1 is something to do after F1. They see it as a retirement fund. What all these drivers want is a shot in a F1 car, but unless they pay huge money to do a young driver test (and not all teams sell the seats) there is no way to prove what they can do. There is no car that is close enough to an F1 car that lets them show it. Not just in terms of lap time because cars like Super Formula and GP2 are not that far off, but also in terms of sensitivity and the way it handles.

'Also you can't get a super licence with a GP2 car, and from a publicity and marketing point of view, a GP2 car does not look like a Formula 1 car. Even if they do not use it for a super licence its still important for a driver. Yes, they can go on the simulator and thats valuable. It's only good up to a point, this is the next stage. With this car a driver could be fully ready for F1.'

The design of the car is in the very early stages, with Perrin currently working through the main components and overall car architecture, but the design is advancing quickly. At this stage the power unit of the car is not finalised and indeed with a choice of four suppliers currently, and the possibility of a rule change in 2016 Perrin is keeping the design flexible.

'We could use an older V8 engine, if we could not get a V6 turbo,' he admits, but insists that the main aim is to build a fully compliant 2016 car. However, with the suppliers keeping data very close to their chests it would on first impression seem like a difficult challenge to design an adequate installation for the 2015/2016 specification units, even if the rules stay the same. 'I think the installation of these power units is not as complicated as some people make out, putting an engine in a car. Its all about making sure it cools properly and that vibrations are handled,' Perrin contests. 'Yes it is a Formula 1 car, so it's a bit more sensitive in some areas, but for me it's no different to putting an engine in an LMP1 car. We need the information to do it of course. But I can say that we already have some ballpark figures.

'But overall we will have to design the car without the final numbers for the power unit, but we will be within 10-15 per cent plus or minus in terms of cooling. That was the same case for the cars that turned up in winter testing last year though.'

Customer solution

In terms of the car's transmission Perrin will almost certainly adopt a customer solution, Ferrari and Red Bull both offer off the shelf units, though that does not give much freedom in terms of rear suspension layout. But he feels that a long trusted supplier is the best bet. 'We want to use an off the shelf Xtrac system in both LMP1 and F1,' he reveals. 'For the LMP we already have it integrated into the design and for F1 we can do the same.'

In terms of manufacturing the car in time for winter testing in 2016, Perrin plans to outsource all of the manufacturing to mainly UK based suppliers. 'I would rather build a network of companies which all have some shares in Perrinn,' he says. 'They will build the parts and we will do the assembly here in the Yorkshire Dales, I think it's important to assemble the car so you can see how it all comes together.'

Perrin intends to give the supplier a fully optimised and ready to produce set of drawings, with the only major exception being the

"Overall we will have to design the car without the final numbers for the power unit, but we will be within 10-15 per cent in terms of cooling"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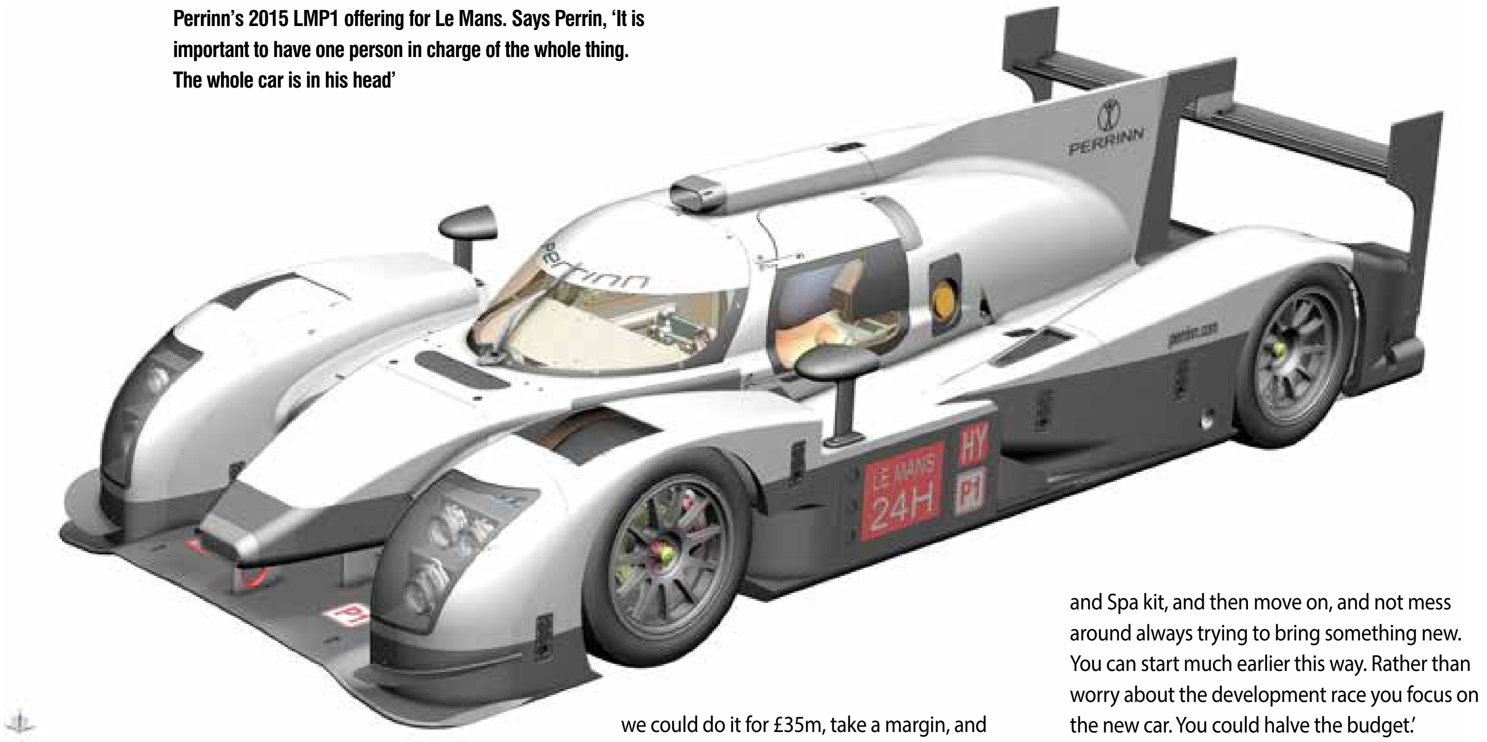
Perrinn's 2015 LMP1 offering for Le Mans. Says Perrin, 'It is important to have one person in charge of the whole thing. The whole car is in his head'



composites, although extensive work will be done in this area. 'I calculate the thickness of both the honeycomb and the skins. This gives the total thickness of the monocoque so the inserts can be accurately designed early on. This also allows for detail design of the composites too. Everything has to be done properly, that is my philosophy. When we do the F1 crash test we need to have an FIA delegate there. We would not run the car if it was not homologated. But to homologate it and have the FIA sign the papers is the same as LMP1 really in terms of process and cost.'

The current situation with F1 costs is something that Perrin is apparently enthused by. Indeed, he thinks it makes his design method even more relevant. 'There is lots of talk now about the model of F1 financing and how it works and my answer is simply to use the regulations as they are, stop trying to fight the regulations. It's tiring, meeting after meeting. It was the same at Le Mans, trying to change the rules. But in F1, take the regulations as they are and be a bit clever and spend less, to make sure your business does not fail. In fact, the best thing about Formula 1 is that the teams know exactly how much they can guarantee that they will pocket every season from FOM. That's a nice place to be, it's better than it is in WEC where they don't give you any money. So, if tomorrow someone said they have to put together an F1 team, I already know what my budget is, and I could do something really good. You know we could do it for £35m, take a margin, and spend 75 per cent as the team budget. But don't expect a factory with 400 people. You will perhaps only have 40-50 people. If you employ 300 people to start with, that would kill the budget. It is all proportional to how many people you employ. If you have 200-300 people you have to keep them busy doing the R&D work and the development parts. You could do F1 for £25-35m if you kept very few people.'

Huge budgets

Perrin feels that the culture of some F1 teams is a major factor in the huge budgets they are spending, and he also feels much of the money is squandered. 'The so-called development race in F1 makes me laugh,' he says. 'It is the reason some teams cannot meet their budgets; they spend so much money racing themselves, not the others, just to get new bits out. I don't think it makes sense for a small team in F1 to come up with ten upgrades a year or more. Up to Barcelona of course it is worth it because you can see up 0.5 seconds a lap gain, but after that they often do not see any gains. They are just keeping the engineers busy and pushing parts out to justify the investment. Sometimes the updates appear on the track just to show the investors what it is they are paying for. Is this new £50,000 front wing worth it? Sometimes they do not even show a gain on track.'

If Perrin were to field a grand prix team, which he emphasises is not the plan, he would use his design approach to cut costs. 'I would suggest that you do one car a year with a Monza and Spa kit, and then move on, and not mess around always trying to bring something new. You can start much earlier this way. Rather than worry about the development race you focus on the new car. You could halve the budget.'

That philosophy would carry across to the team as a whole. Most of the staff would be employed on a freelance basis, with only some roles, such as chief mechanic, being full time salaried positions. 'I would have a lot fewer people in the garage; you don't need all the data the cars have now,' says Perrin. 'When I started, I wanted all the data I could get because I wanted an insight and an understanding of everything. I wanted a fully strain gauged suspension, all the loads, everything. There are so many sensors, and getting them all to work properly is tough. It's 15-20 channels per corner. Then you do a huge amount of work to reduce the data to the contact patch loads per corner. Then you look at the results, compare it with lap time simulation data, and other data and realise its all the same. If you do the simulation right you don't need all the sensors. With experience you realise you don't need it or all the people to do it.'

Of course, for a company like Perrinn it seems illogical to come into being and then to immediately design cars for two of the top international motorsport classes, both of which are limited in terms of actual entrants, but Perrin believes that the seemingly more logical, F3, F4, LMP2 and the new LMP3 markets are actually a tougher area to operate in. 'I only want to do F1 and LMP1 as a company. I ask this question, who do you know who can deliver an F1 or LMP1 car these days? There are not many and thats why we have a big chance. The LMP2, LMP3 and F4 markets are really crowded. Why should I spend time at a lower category when we can be strong at the top categories?'

Perrin is looking for investment of around £2 million, which would see the LMP1 car built and tested. That process would also advance the development of the F1 car. If that happens, then what you see here could be a very interesting new car constructor coming into existence.

"If tomorrow someone said they have to put together an F1 team, I already know what my budget is, and I could do something really good"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The next step?

In 2014 F1 welcomed, if reluctantly, hybrid power unit thinking and shed its anachronistic tag, but what in this cost-conscious world, what's next?

By SAM COLLINS

The introduction of advanced hybrid technology into Formula 1 has not been a smooth process. When McLaren first tried to use a modest hydraulic energy recovery system in 1998 the concept was quickly banned for fear that it would give the team an unfair advantage. Energy recovery systems would not reappear until just over a decade later in 2009 with teams able to run 60kW units, which today look weighty, cumbersome and deliver rather mild performance. But most competitors struggled to get them to work properly and the costs of developing the technology were felt to be excessive. The teams agreed not to use hybrid systems in 2010. In 2011 they reappeared, but failures were still common and the uptake was not universal until 2013. Throughout this period it became very apparent that Formula 1 was seen as a technical anachronism, using very old fashioned port injection V8 engines which were fixed in specification mated to the very mild hybrid system.

The new power unit rules introduced in 2014 took the technology to the next step, as regulations followed the automotive industry trends of increasing efficiency, downsizing the engines' capacity while increasing the potency of the hybrid systems. Formula 1 was becoming road relevant and the new rules attracted one new manufacturer, Honda, and almost a second, namely Volkswagen.

Despite much fanfare and excitement from the manufacturers, almost as soon as the new power units hit the track there was a backlash against them. Initially it was led by the mainstream media which struggled to understand and explain the technology, instead opting to write articles criticising the sound of the cars or to ignore the new technology all together.

During the season the backlash became more serious with Bernie Ecclestone taking many opportunities to criticise the noise of the cars. Then, as it became clear that Mercedes had done a much better job on developing its power unit than its rivals then some teams including Red Bull and Ferrari joined in.

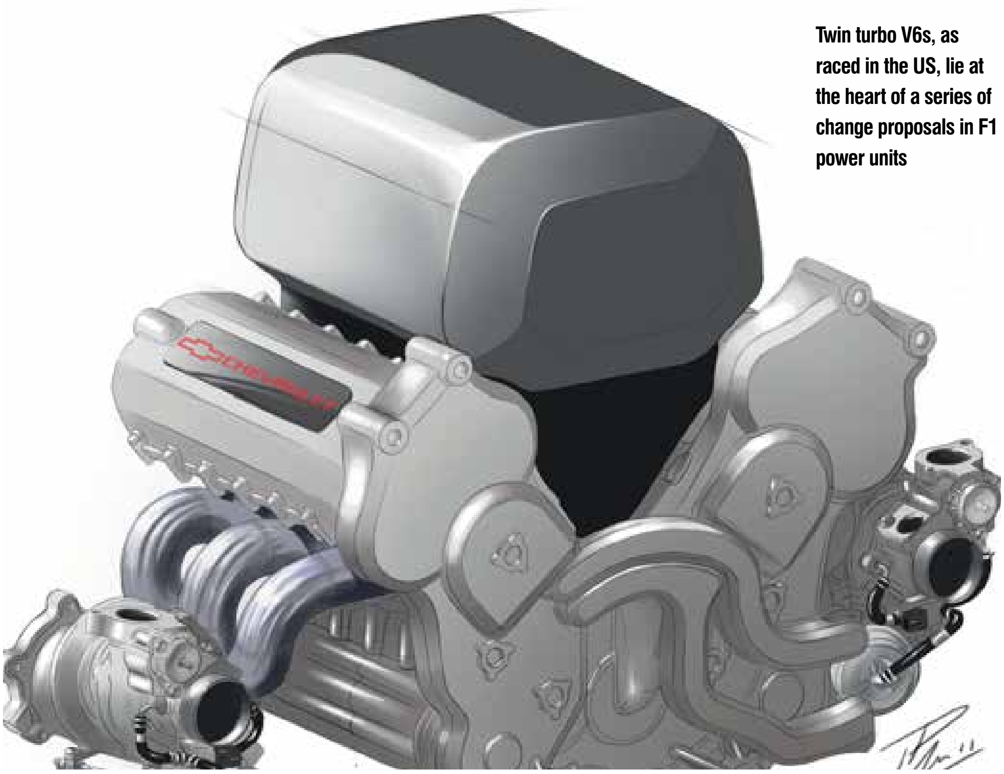
When asked at the US Grand Prix about the ongoing crisis surrounding the financial viability of the smaller grand prix teams Ecclestone went out of his way to hit out at the rulebook.

'We need to change the regulations, we have to get rid of these engines, they don't do anything for anyone, they are not Formula 1 and we are going to try to get something changed in the off season,' he complained. Ecclestone later went further in a BBC interview and seemingly suggested that a single-make engine could be used in future; 'It is often thought that having a one-make formula like GP2 is a good idea. We built Formula 1 on a one-make engine, apart from Ferrari, and that was the Cosworth DFV.'

It was clear that the power unit rules were, and indeed still are, under discussion. But after initial suggestions were that a return to the old V8 engines could have been on the cards it was quickly pointed out that any major change would be unrealistic for this season.

While no formal proposition has been made for 2016, some details of what has been put on the table have been revealed. 'An awful lot can be done for 2016 and maybe we need to even go as far as looking at a different engine. Maybe still a V6 but maybe a more simplified V6 that controls the cost', explained Red Bull team boss Christian Horner. 'The scenario at the moment is such that it's unsustainable, it's unsustainable for manufacturers, any of the manufacturers, to keep spending at the level that they are, and therefore, rather than perhaps going backwards with the V8, maybe we should potentially keep the basis of what has been achieved but look at simplifying it.'

Regulations followed the industry trends of increasing efficiency, downsizing the engines' capacity while increasing the potency



Twin turbo V6s, as raced in the US, lie at the heart of a series of change proposals in F1 power units

The cost of racing of Formula 1 has been widely documented and it is clear that a number of teams lay this at the feet of the engineers behind the new rules.

'These regulations were given to engineers, but unfortunately when a bunch of engine engineers are left on their own to come up with a set of regulations, they come up with something tremendously complicated and tremendously expensive,' Horner complains. 'The engines that we have today are incredible bits of machinery, incredible bits of engineering, but the cost to the collective manufacturers has probably been close to a billion euros in developing these engines, and then the burden of costs has been passed on, unfortunately, to the customer teams.' Mercedes claims that it spend around £100m on the development of its 2014 power unit.

With the basic architecture of the current 1.6-litre V6 internal combustion engine seemingly at the core of all of the serious proposals it is the ancillary components that may be changed.

'I think we have to recognise what has been done from an engineering point of view and now look to simplify things, potentially retaining the V6 philosophy but perhaps going to a twin turbo that would address the sound issues that we've had this year,' Horner continues. 'We've had a standard ECU, why not potentially take it a step further. A standard energy recovery system would dramatically reduce the costs, dramatically reduce development and therefore the supply price to the customer teams also.'

Switching to a twin turbo layout would significantly change the layout of the rear of a 2016 car, especially in terms of packaging and cooling. More significantly it also suggests that Horner favours dropping the exhaust gas energy recovery system from the power unit as an adoption of twin turbo would also require twin MGU-Hs.

Indeed some, like Bernie Ecclestone, are in favour of dropping the turbocharger altogether in an attempt to get a more fan-friendly sound from the cars. 'I have been proposing and am going to propose that we go back to a normally aspirated engine with some hybrid bits built into it,' Ecclestone admits. 'The manufacturers will have to call it a McLaren hybrid, Ferrari hybrid or a Williams hybrid so that it will get the message across. It would be a bit of a dream for them to build a normally aspirated engine and then develop it to about 1,000 horsepower which is what I believe we want.'

This is something not all that far removed from what both Porsche and Audi are doing in the World Endurance Championship. But in that series the manufacturers are largely free to develop the power units – something that is restricted in application for reasons of reliability, cost and safety in Formula 1. With the dominance of Mercedes, both Renault and especially Ferrari want more freedom to work on their designs in season. 'We need to look at something different in 2016. In terms of power unit and in terms of regulation,' former Ferrari boss Marco Mattiacci said. 'For 2015 it is clear we will have to accept the status quo for now but we are definitely not going to accept the status quo for 2016. The cost of the power unit is a problem and the fact that we cannot enhance our power unit during the season is a cost for us.'

The introduction of the new generation power units has had a mixed response and many feel that it will be impossible for Renault and Ferrari to catch up with the dominant Mercedes PU106A hybrid design. And it remains that many feel that the new units are just far too expensive.

'We will not attract new manufacturers into the sport and we may well drive current manufacturers out of the sport,' Horner adds. 'So we have to think, not just about today but about the future. For 2015, there's very little that can be done with the regulations but for 2016, an awful lot can be done and I think that the teams, together with the FIA and the promoter, have to have that responsibility to ensure that those issues are addressed and the sport is sustainable and attractive to new manufacturers to come in.'

Ferrari and Mercedes have committed to staying in Formula 1 until 2020, Honda has claimed that it 'will never leave F1' and rumours continue to surround the arrival of other new manufacturers. A majority vote is required to change the regulations, and that would have to happen by March this year.

Mercedes, which has a dominant position in the sport and controls the votes of at least two teams in F1, is openly against any change.

'The current format of power units was actually proposed by Renault back then and for us, as Mercedes, it's a hugely important showcase of technology, road-relevant technology, hybrid technology, the future. It helps us to attract sponsorship and for us, as a car manufacturer – and I guess the same was the case for Renault when they came up with the idea – that is very important. It's less important for Red Bull, for sure, but for us it's crucial,' Toto Wolff, Mercedes Motorsport boss argues. 'Reversing everything, changing the format, changing the engines would just increase costs, it would be the opposite for what we need for Formula 1 at the current stage.

'We are all talking about costs and if you would open up the regulations in the way it has been described, that clearly means you don't care about costs because that would be like digging a grave for F1.'

However it does seem likely that some kind of compromise will be reached over the power unit regulations for 2016. How far that compromise will go remains to be seen.

"The engines we have today are incredible bits of engineering, but the cost has probably been close to a billion euros in development terms"

Formula end game

For much of the 2014 F1 season survival was a struggle for Marussia, but its engineers still planned a special future

By SAM COLLINS

The Russian Grand Prix of 2014 was something of a watershed moment in Formula 1. As Vladimir Putin presented the winner's trophy to the Mercedes Grand Prix team, the staff of two other teams already suspected that they faced unemployment when the cars got back to Europe.

While the Caterham F1 Team continued to fight for its existence as *RCE* closed for press, the Marussia team had quietly closed its doors and auctioned off its wares. The team was one of three new outfits that entered F1 in 2010 (as Virgin Racing), initially with the understanding that a £40m coat cap would be applied.

That limitation on spending fell by the wayside, and the three new teams had to fight for their existence. Virgin Racing became Marussia F1 following investment from a nascent Russian supercar constructor. That company collapsed in late 2013 after producing very few cars, but the F1 team bearing its name continued, not least due to the support of the Chilton family and Ferrari, Max Chilton being one of the team drivers, as well as Ferrari junior driver Jules Bianchi.

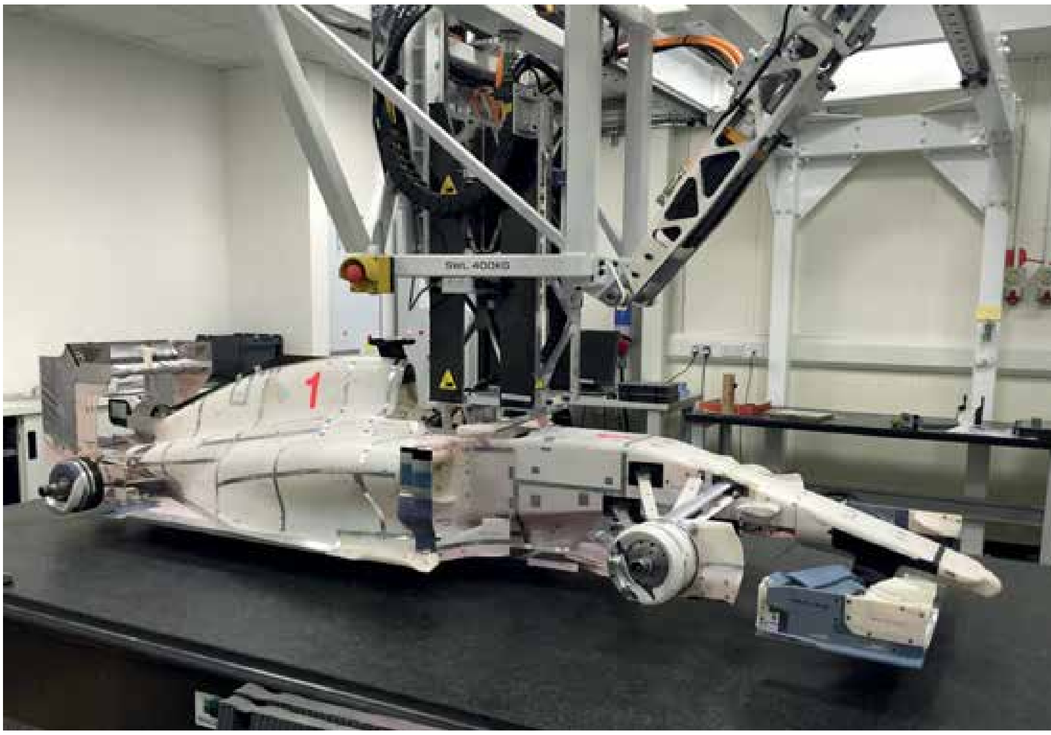
At the Russian Grand Prix it was clear that the team did not have the funding to continue and despite a number of rescue attempts, including one that saw the cars loaded and ready for shipping to the Abu Dhabi Grand Prix, the team went into liquidation.

Around 190 people lost their jobs when the team finally closed its doors, among them some of the most promising young engineers in Britain, as well as some of the most experienced.

The Marussia team had long had a philosophy of blending the best and most innovative young engineers with some of the most seasoned senior technical staff in Formula 1. *Racecar Engineering* has been in touch with a number of these now unemployed staff and has discovered that the car that they were developing was probably something a bit special, especially considering the budget constraints the team faced.

'I'd say we were a bit different in the way the engineers were hired to other teams,' claimed one former team member. 'The guys that came here out of university usually came with a bit of racing experience, maybe from a year out or maybe from racing before they got to uni. It was not just Formula Student, though that was really important. As a result the staff tended to come from the more practical universities like Oxford Brookes or Cranfield,' he explains.

This resulted in the team having a group of young engineers willing to work hard and experiment, and perhaps the ultimate expression of this was the stillborn 2015 design. Internally staff referred to it as the MR04 but, due to bankruptcy of the Marussia car company, the team planned to change its name to Manor Grand Prix, in deference to Team Boss John Booth's Manor Competition team which ran the likes of Lewis Hamilton in the junior categories. The 2015 car would have been known as the Manor MNR1, and it had reached an advanced stage of design before the team collapsed.



Marussia retained a 50 per cent scale model when most teams used a 60 per cent subject. The team felt that its correlation between CFD, tunnel and track was very good and budget constraints also encouraged it to remain at the smaller scale

Following the team's entry into administration and later closure, its assets were auctioned off to the highest bidder and this included the wind tunnel model used to develop the aerodynamic package of the MNR1. As part of the auction catalogue images of the 2015 design were released, revealing much about the cars concept.

Immediately apparent is the low nose of the design. This is a result of a subtle rule change for the 2015 season, introduced purely for aesthetic reasons. When the 2014 grand prix cars rolled out in public for the first time in Jerez, Spain they were widely ridiculed as the ugliest ever, some more polite people likened them to a Proboscis monkey but most people including the UK's leading 'Adult Entertainment' store likened them to sex toys. The FIA and the team realised that it was unacceptable, and for this season the rules have been changed.

This has led to a far more elegant looking design overall, with the front nose height blending gradually towards the nose tip, which on the MNR1 still has an exposed front crash structure. Aerodynamic demands, however, saw the lower portion of the chassis remain at a similar height to the 2014 car leading to a much smaller front bulkhead. Indeed it appears to be less than half the size of the 2014 design, and this is an area where the innovate spirit of the Marussia engineers is highlighted. The 2014 Marussia MR03 uniquely utilised a metal front bulkhead for cost and adaptability reasons and it is a concept that would have carried over to the MNR1, albeit on a much smaller scale.

'I know everyone looks at us oddly for that but we felt it was good in terms of weight and stiffness,' says another former team member. 'Also, it gave benefits as all of the bolts and things on the bulkhead were not required to be inserted as per a fully carbon design. They could be final machined along with the rest of the chassis and threaded as required. It was so much easier.'

The low cross section chassis of the MNR1 was apparently made possible by a breakthrough in the car's suspension concept. Exact details are not clear but the layout of the internal components was something never previously seen in grand prix racing.

'The '15 car was quite different in terms of suspension, as the vehicle performance mob had been let off the leash for the first time,' one of the team's former engineers claimed. 'They had a significant input in terms of simulation to define the suspension. The heave and roll split was done differently in terms of springs and dampers front and rear. But the front was a bit special; it got rid of the the usual left/right torsion bar but still maintained an additional third element.'

He would not be drawn on the exact details of the layout but suspects it will be employed on some other 2015 or 2016 cars after the former Marussia staff find berths in other teams.

'Our system was small and compact as it used gas springs rather than coil springs,' another team member reveals. 'In reality though, on these cars with so much to package in side pods and so on, even a small gain is useful so losing the interconnected suspension in mid 2014 really helped us.'

On first inspection of the wind tunnel model the MNR1 chassis appears very similar to that of the Marussia MR03 but detailed inspection reveals it is anything but. The monocoque was to have been fully reworked in terms of composites in an attempt to save weight, a process generally common to all teams but in 2014 Marussia had faced a larger uphill struggle than its rivals.

'The 2015 design was all about sorting out the details a lot more for the new rules,' says a team member. 'Changing powertrain supplier at

"I would say we were a bit different in the way the engineers were hired compared with the other teams in Formula 1"

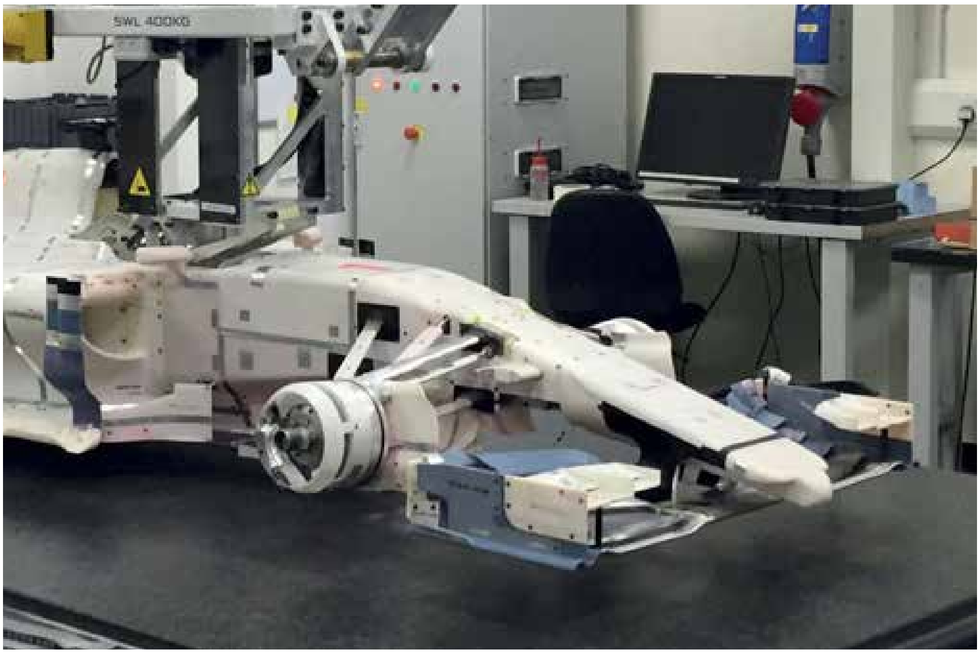
the end of '13 as well as powertrain type was a big task for a small team last year and there were so many late nights. Everything was different, which is true for the physical parts as well with other teams but for us it was also true of the people and the procedures way we worked, it was all so different. With the 2015 car we had a year of data and much more experience with Ferrari.'

Nobody had really expected the Marussia to be on track at the opening test in 2014, especially as the likes of Red Bull were struggling badly, and at the start of testing in Jerez the team failed to turn up with a car. But a huge effort in its Banbury HQ plus an overnight drive for its truckies saw the team arrive at the circuit and clock up a few laps.

'I could not believe the effort that every one put in to get the car running in Jerez. It was amazing,' an engineer says. 'We had so many issues but when we look back now a lot of those issues were small, but it stopped us getting the most out of the car performance-wise.'

A colleague of the engineer in question added; 'We just didn't have the ability to even think about performance as we were fighting too many small fires. But what we did is sort those issues out quickly and had a reliable car.'

The Y-Lon rearing support and monkey wing seen on the model here is actually the same as MR03 as at this stage of testing. New designs of rear wing supports and monkey wings were designed and were due for testing



Notable on the front of the wind tunnel model are blisters above the inboard pushrod pickups – but these were simply to allow the complex electronics and sensors of the model to be installed and would not feature on the final car

That reliability had almost become Marussia's trademark. Driver Max Chilton had finished every grand prix he had ever started, totalling 25 straight finishes until the 2014 Canadian Grand Prix, where he ran into his team mate.

'In designing the 2015 car, much more emphasis was put on performance than reliability which we knew already was good. For example in packaging electronics we were dealing with incremental change not a completely new system that we were learning about as we designed it,' one of the car's designers adds. 'Also in many areas we had a baseline, which was probably reasonably conservative as we knew that reliability would be king. So from this baseline we were obviously able to work properly on optimising weight, stiffness and CG height with a good baseline for how far we could push it in terms of reliability.'

In other words Marussia – or Manor Grand Prix as the team would have become know – expected to be a lot more competitive than in previous seasons.

'The 2014 car was on the weight limit but we could not exploit it in terms of the forward weight distribution,' a race performance team member reveals. 'For 2015 there would have been the additional ballast allowed by the regulations at least but also more as it was clear that redesigning to the 2014 limit the car could have been at least 10kg lighter.'

As the MNR1 was to retain the Ferrari power unit (albeit in 2015 specification) the cooling system layout was to have been generally similar. As with the 2014 car an intake below the main roll hoop would have been a feature of the car feeding additional coolers at the front of the power unit. This area of the chassis was quite neatly packaged as above it sloping off on each side were two rhomboid shaped heat exchangers feeding from the roll hoop via a Y-shaped duct similar to the 2013 car.

But here the difference would have ended, as the overall cooling layout was substantially different based on the team's experience and data gained during the 2014 season. As a result (and also of improvements made by Ferrari) the cooling apertures on the car were much smaller.

The rework of the cooling system also changed the overall architecture of the car – the wheelbase for example would have been drastically reduced in comparison to the 2014 design – being more than 100mm shorter.

'The MR03 was quite conservative with cooling layout especially around the roll hoop fed coolers, this meant that we had to use a relatively long fuel cell, but on the '15 car those coolers were different and the tank was more conventional' another engineer admitted.

"We had so many issues. Looking back now a lot of those were small but they stopped us getting the most performance-wise"

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'Aerodynamically this turned out to be a really good thing with new avenues for development opening up which hadn't worked as well on the 2014 car. The aero guys reckoned this was due to the front being better at relating to the rear in terms of flow structures.'

The images seen here of the MNR1 wind tunnel model show the cars overall aerodynamic concept, as well as the new low nose the car also features an all new front wing as well as a revised rear wing. Marussia's engineers felt that they had some tricks up their sleeves with the aerodynamics of the new cars and the claim that a new nose treatment and rear wing support were part of that. However they will not reveal details of these solutions, hoping that they can carry these tricks to new employers.

'We had some really nice updates planned for mid-season which were in the raw concept stage,' says one of the team's youngest engineers. 'I'm not telling you what they were or how they worked because I want to have something other than just experience to show new employers. I reckon the other teams will be thinking about some of it, they are not stupid, but I think maybe that the Marussia solutions were perhaps simpler but still got a performance benefit!'

Overall, though, the design was visually very similar to the 2014 car. 'It was an iteration of 2014. As the rules were young I expect most people will be following this trend, although the nose area will of course be different. The model was being developed with three different front wings initially and this was a major area of development,' one of the aerodynamic team claims. 'We were significantly up on the 2014 car when worked stopped in September.'

The Manor MNR1 was expected to be a Q2 regular, unlike the MR03 which regularly struggled to get out of Q1.

When worked stopped many team members knew that the writing was on the wall, but they did not want to believe it. While bigger more established outfits pigeon-holed young engineers, Marussia allowed them to experience the full range of modern competition car engineering, partly by its overall philoshopy and partly because of budgetary restrictions.

'The small teams were very important for training young engineers,' rues one of the team's more experienced former employees. 'Everyone talks about the drivers but its the technical guys with talent that are harder to find. In the same way young drivers used to be schooled and experienced through the small teams like Minardi, it is very similar for the engineers.

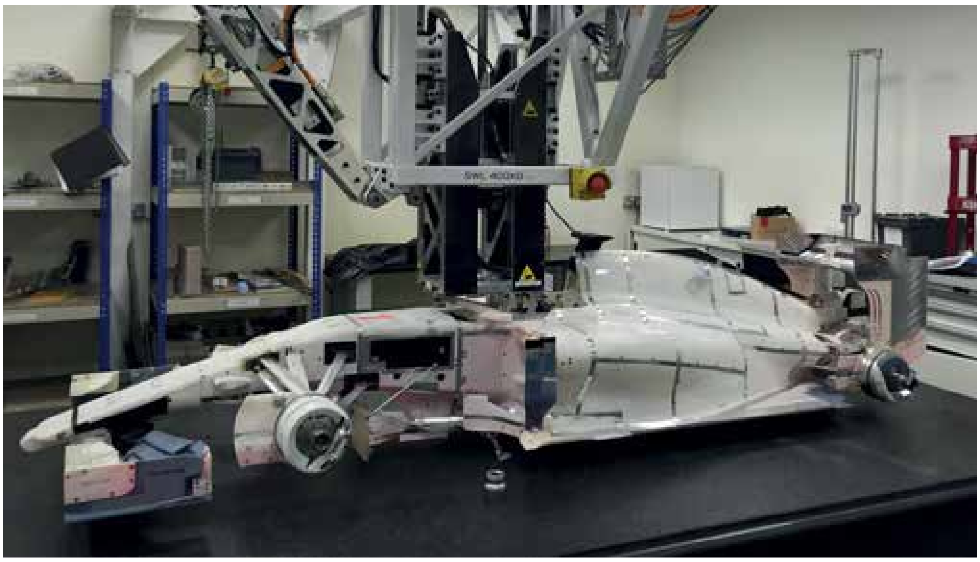
'With a small team the younger guys tended to have responsibility for a lot more areas due to the lack of resource.'

For this reason it is likely the staff behind the design of the MNR1 should be in high demand as they have been shown to create a good car under a tight budget. This way of working could be a crucial performance advantage if and when any cost or resource restriction is applied to grand prix teams. 'You will never find a better or more skilled group of racing enthusiasts,' one of the teams senior management concluded sadly.

The Marussia MR04 or Manor MNR1 reached the stage of becoming a wind tunnel model, but went no further. Once McLaren had removed the elements of the model that it owned, including the spine and support pictured here, the MNR1 became a sad pile of 3D components that were hawked off to raise money, including the design computers and team equipment.

The MNR1 is sadly a car that will be consigned to the pages of obscure Formula 1 history books. However those behind it seem certain to design world championship challengers of the future. CVs of former employees are available through the MIA and other outlets.

The wind tunnel model was stripped ahead of being sold off at auction for just £2,600, although the McLaren spine was removed – the result was simply a pile of components



The wind tunnel model pictured here is in incomplete condition. While new front and rear wing endplates are evident, the model lacks some parts as it was in preparation to be shipped to McLaren's wind tunnel before the team shut its doors

Marussia's engineers felt that they had some further tricks up their sleeves with the aerodynamics of the new cars

New on the track

The FIA's junior category of Formula 4 has brought a good response with three designs in process

By SAM COLLINS

When the FIA announced its new junior single seater category, Formula 4, the response was almost instant, and many constructors announced interest in supplying cars, even before the technical regulations were finalised. The concept of F4 is for a cost-capped single seater, using a carbon fibre monocoque chassis, a limited aerodynamic package and a relatively small capacity engine producing around 160bhp. Any registered constructor or engine builder is able to provide a product, but each national series will pick a single car design for use by all competitors. No rolling chassis may cost more than €33,000.

As time has passed since the initial announcement, three designs have actually become reality. The first of these, the Mygale took to the track in late 2013, but has yet to take part in a race as its customer championships have not yet begun. Meanwhile the second car to run built by Italian firm Tatuus has already contested a full championship in Italy. Finally Dome, which had set out to build the fastest of all the F4 cars ran its car for the first time in Japan last summer.

The chassis of the cars are, in essence, based on the safety requirements for the new FIA F3 regulations and are significantly larger than many expect when they see a FIA F4 car for the first time.

'The FIA regulations make the whole car quite big,' explains one of the engineers behind the design of the Dome F110. 'The cockpit template is so large. Its much bigger than our older F4 car.' Japan already has a strong F4 category, for which Dome also supplies all of the chassis. 'This car will be slower than the old Japanese F4 car,' the Dome spokesman continues. 'The FIA rules engine does not have the power of the current Japanese F4 engines.'

The chassis of the existing Dome F4 chassis are also cheaper to construct than the new FIA specification versions due to an innovative construction technique dubbed UOVA. This does away with the honeycomb core in the monocoque and allows for much faster and lower cost manufacturing. While it increases the chassis weight it does not reduce its performance significantly otherwise.

'With this car we respected the overall design concept of UOVA, but the regulations force us to use honeycomb in some areas. Generally the regulations are quite restrictive and there are very few areas of freedom on the chassis, so the cars are all quite similar in that respect. But ours is different in some areas. We have discrete upper and lower chassis sections on the new F4 , and the lower section is made

"The new cockpit template is so large – it is much bigger than our older F4 car"

Dome has set out to have the fastest cars in the category and ran its first cars last summer. Inset: the F110. 2.0-litre TOM'S engine

using a male mould to reduce the cost and working time – it has no honeycomb. So this section is basically UOVA – overall we only have honeycomb in the areas where the regulations force us to have it, around the fuel tank and in some sections on the side,' the Dome engineer reveals.

Both the Tatuus and the Mygale use more conventional composite construction. Indeed the chassis, nose and rear crash structure are the only areas of the car where carbon fibre is allowed to be used, meaning that most of the bodywork is fibreglass.

While some elements of the cars' aerodynamic design are free (as can be seen looking at the pictures of all three designs here) other areas are tightly defined.

The front and rear wing profiles are defined in the technical regulations and the must be made of aluminium-based alloy while the front wing endplates must be made from plastics or wood and the rear wing plates must also be in aluminium.

'Everything on this car was a clean sheet of paper, the regulations are too different to the old F4 car for us to be able to carry anything over,' the Dome engineer continues.

'Most of the design shape is defined by the regulations. Even the aerodynamics are largely defined by the rules, so we have made a lot of effort to push the rules in some areas right to the limit. We have used the Furyusha wind tunnel with this car and we have done as much as we are allowed, using lots of shapes, but the wing profiles are defined by the rules and that really limits what you can achieve.

Ideally as engineers we would like a smaller chassis, a proper diffuser, and to put a flap on the front wing. We would also like to use carbon fibre body work, but its not allowed.'

The suspension layout of the cars is also fairly heavily restricted. Only twin damper layouts are permitted front and rear with third elements and mono shock layouts specifically outlawed. Anti roll bars are permitted as long as they are the common torsion bar type, with only five adjustment settings. The pickup point inboard are also partially defined in the regulations. The wheelbase must be between 2740mm and 2760mm with a minimum track of 1200mm.

As with the other areas of the car the transmission is conventional by regulation,

Mygale was on-track by 2013 but has yet to be raced as its customer championships have not yet started

“Once the cars are homologated it is then up to series promoters to pick a package to go for”

The Tatuus chassis – the only area of the car in which you can use composites

with six speed sequential designs the order of the day. The Mygale and Tatuus designs both use a Sadev box but Dome has opted to use a Japanese supplier, Toda Racing, for its transmission. ‘We looked at the Sadev and a Hewland design but we felt that the Toda was best. Its also important for us that it is Japanese as we wanted to make this car with domestic suppliers to help the Japanese racing industry,’ Dome’s spokesman reveals.

In terms of power, the cars have a lot more freedom and, as with the chassis, they are cost-capped, with a maximum retail price of €9,500 and a maximum rebuild price of €4,000 (after a minimum of 10,000km). Engines can be of any configuration or capacity, with both normally aspirated and turbocharged designs permitted, within some dimensional restrictions and a 138kg minimum weight. Rather than restricting the performance of the engines by way of detailed regulations or fuel or sonic restrictors all engines must be homologated by the FIA and have a performance curve entirely within a specified range. This essentially limits the cars to around 160bhp max.

So far Ford, Geely, Volkswagen, Abarth and TOM’S have homologated engines for F4 but more are expected to follow. Once the cars, and engines, have been fully homologated it is then up to series promoters to pick which package to go for and a number have already been announced, Mygale will supply its cars to the official series in Australia, Great Britain and China. Tatuus will supply the Italian championship, Northern European (Baltic) series and the German championship while Dome will supply the Japanese championship. The French and South American series use an older Signatech design which largely meets the new rules but will be replaced in the years to come.

Many of these new F4 series are already filling their grids and in the UK there is the slight anomaly of there being two very separate FIA F4 rules championships. The official British series is dubbed MSA Formula, which is a direct replacement for Formula Ford and is backed by Ford itself. However Motorsport Vision (MSV) which owns most of the premier race circuits in the UK (Donington and Silverstone excluded) already has its own F4 championship run in conjunction with the British Racing Drivers Club.

That series currently uses a bespoke tubular chassis car, but it will roll out a fleet of FIA specification Tatuus cars for its winter series later this year.

It looks like the two series will both run with relatively strong grids but it looks like the BRDC version rather than the ‘official’ MSA version will have the bigger field. ‘F4 is already established as the first step on the single eater career level and one of the reasons its the cost’ MSV boss

Tatuus, on track and preparing to race in the near future

F4 cars have to be designed to accommodate a wide range of engines

Jonathan Palmer explains. 'Our existing BRDC F4 is much less than half of the cost of Formula Renault. Our car is also much quicker.

'Formula Ford being finished means that there is not anything else at this level.'

When assessing which car to buy Palmer was faced with the choice of engines (plus some yet to be homologated) as well as the three chassis. 'Dome was too far away in Japan really, we know Mygale, and we know Tatuus, they are very competent organisations and we felt that they had more experience of building a composite chassis single seater than Mygale. The Germans, North Scandinavia, and Italians have all chosen the Tatuus. We were impressed by the engineering quality of it, we believe that it is the best F4 chassis out there. I heard that the Germans selected it as it performed better than the Mygale, and we feel it is the better car. We have not revealed all of what we are doing with the new cars, but its reasonable to say that there will be some cost increase but our series will still be significantly cheaper than MSA formula.'

Palmer feels that with the new cars his championship will prove more competitive than its domestic rival, especially in terms of cost, with sporting regulations left largely up to each promoter the series around the world tend to have quite different models.

'Our new car will make its race debut in the F4 Winter Series at the end of 2015, but our main series will run using the older cars in 2015,' says Palmer. 'So in 2015 the big difference is budget, in MSA Formula £200k to £250k a season is being talked about for MSA formula in the top teams. Thats a big difference too the MSA Formula has attracted top teams like Carlin, Fortec, Double R, who will all use their great engineering resources to this very junior level and charge accordingly. So the budgets go up, if you can't compete with the resources of the top teams then you are not going to competing on a level playing field.

'Another difference is that in the MSA Formula you can run 15-year-olds, and in our series you can't – but I think 15 is too young anyway to be in a single seater. They should still be in karting in my view. But there are going to be some 15-year-olds who will spend £250,000 with a team, and totally blitz the series because he has the best team out there. That sort of thing is putting off the average driver, but you look at BRDC F4, we have some great teams already, most of them have F4 as their leading category and they are very competent, we don't have big F3/GP2/World Series teams and he budget is lower as a result. The championship was open right down to the final round in 2014 with six drivers able to win, just shows how close it was.'

Future events

When the FIA first created the new F4 category the rules were written in such a way that different series cars would have similar performance, so that perhaps in future a Formula Ford Festival or Marlboro Masters style event could be held with all of the top cars and drivers from around the world competing against each over. But currently no promoter has plans to run the event. 'I don't think a shootout event is as easy at it seems on paper as you have different cars and different engines,' Palmer says. 'The reality is you could run the Germans and Italians together as they are on the same Pirelli tyres and using Abarth engines in the Tatuus chassis, but I have no doubt that there will be a performance difference to the Mygale, which in the MSA Formula will run on Hankooks with a Ford turbo engine. It is a shame there are no plans for a shootout; perhaps there could be in time. If it does prove to be pretty close it could happen but you'll find that there is an imbalance between the countries, one will have a faster package and none of the others will want to take part knowing that their cars are a bit slower, but I might be wrong,' Palmer concludes.

F4 looks set to grow globally and new series are expected to be announced throughout 2015 as the main championships start to find their feet. One thing is certain; despite a restrictive rulebook, the way F4 has been created has let a number of constructors once again compete with one another, even if right now that competition is for sales and not on track.

Empire building

Rule changes two years ago catalysed the creation of a new breed of 'sports libre' car in UK hillclimbing. But will the breed be allowed to survive?

By SIMON McBEATH

Figure 1: The Empire Evo sports libre racecar's debut caused much discussion

The first of what looks set be a new genre of hillclimb car rolled out of the busy raceshop of Somerset, UK, constructor Empire Racing Cars last August for a very public shakedown at a British Hillclimb Championship event at nearby Gurston Down, Wiltshire. Inevitable teething gremlins restricted the car to running in practice only, but by then the internet forum grapevine was rustling noisily as people digested and discussed the car's design (**Figure 1**). Curiously many seemed surprised by the general layout, despite the aerodynamics of the concept having been fully discussed by *Racecar Engineering* in its October 2012 issue (V22N10). Even more oddly there was some vociferous opposition to the whole concept. But the general view seemed to be that it represented the latest exciting innovation in a sport renowned and frequently featured in *Racecar* precisely for its ingenuity and clever engineering. So what is all the fuss about?

The Empire Evo is a sports libre racecar for UK hillclimbing and was designed specifically to exploit the latest incarnation of the sports libre regulations that accommodate single racing cars with full width aerodynamic aids and bodywork, although this interpretation of the regulations has proven controversial (see sidebar 'Concept evolution').

The basis for this particular car was in fact Empire's first single seater creation, the '00' series **[Figure 2]**, and in essence the sports libre Evo is the same car with sidepods and wider wings, where single seater racing cars are limited to body and wing widths of 1500mm ahead of the front axle and 1400mm behind it.

Figure 2: The single-seater racing car '00' series Empire inspired the Evo sports libre

The chassis construction and the thinking behind aspects of the aerodynamics bear closer inspection, and *Racecar* visited Empire boss Bill Chaplin to get the details.

Hybrid chassis

Working to a relatively tight budget on the Empire Evo precluded a full carbon chassis, but the '00' series chassis already featured an ingenious, proven and relatively low cost solution. This consists of a minimalistic chrome-molybdenum steel tubular spaceframe reinforced with carbon and aluminium skinned honeycomb panels bonded and riveted between the tubes, and a moulded monolithic carbon shell bonded under the lower half of the chassis. The end result, says Chaplin, is not only demonstrably stiff yet light enough to do the job, but also provides a strong and safe cell for the driver. In particular Chaplin believes the steel spaceframe affords

Figure 3: Hybrid chassis construction combines tubular steel spaceframe with composite sandwich panels and a monolithic carbon/epoxy 'wrap'

Figure 4: Carbon/honeycomb side panels and aluminium honeycomb floor panel are bonded and riveted to the spaceframe

Figure 5: The pared-down cockpit setup on the workshop production line at Empire Racing Cars

Figure 6: Tubular steel cradle and a machined billet alloy sump pan/floor panel support the Suzuki Hayabusa engine and transmission

Figure 7: Tubular steel cradle and a machined billet alloy sump pan/floor panel support the Suzuki Hayabusa engine and transmission

Figure 8: Machined billet rear bulkhead carries the rear suspension mounts and carries the final drive assembly

improved front-end protection, and the forward chassis features a notable increase in sturdiness to this end. A further bonus of the hybrid construction is simpler and cheaper repairability than a full composite chassis. **[Figures 3 to 5]**

The UK MSA specification main roll hoop is a simple wide based, triangular device with twin rear-directed braces as defined for single seater racing cars. The chassis also features a forward roll hoop connecting to a shoulder-height tube running around the cockpit periphery, which at the rear joins to twin shoulder-height bulkheads that sandwich the main roll hoop.

This particular chassis was made two inches (50mm) wider for the customer 'for comfort'.

Aft of the main roll hoop, the engine and transmission unit are held in a long-since perfected combination of tubular steel cradle and machined billet alloy sump/floorpan. A rear machined alloy bulkhead picks up the aft legs of the rear suspension and also carries the differential and chain tensioning mechanism. **[Figures 6 to 8]**

The suspension is to Empire's usual designs, the geometry and kinematics of which were devised by Dave Spires when on work placement from the University of Hertfordshire some years back, and who has since progressed to the role of aero mechanical design team leader at the Lotus F1 team via spells at Brawn GP and Toro Rosso. The front suspension sees the usual Empire pushrod actuated monoshock arrangement with anti-roll adjustability via Belleville washers; at the rear is a pushrod actuated two spring and damper arrangement with the option for a third element between the rising rate bellcranks.


Figure 9: Front suspension and AP brakes


Figure 10: Rear suspension


Figure 11: New Techniques assembled and developed the engine

Figure 12: TTS Performance supplied the supercharger kit, which included a machined alloy plenum

At the request of the customer this particular Empire Evo is fitted with AP radial mount calipers instead of the usual Empire calipers, but AP discs are employed as usual. **[Figures 9 and 10]**

Supercharged

With an engine capacity pressure charging equivalency factor in hillclimbing and sprinting of 1.4, a popular choice for the up to 2000cc sports libre and racing car classes in the recent past has been a supercharged or turbocharged Suzuki Hayabusa engine and transmission unit, with supercharging being the more numerous option at the moment. The standard Hayabusa capacity from 2008 onwards of 1340cc multiplies up to 1876cc equivalent, well inside the 2000cc limit, and although larger capacity variants do exist there is apparently a reluctance to increase bore size too far because of narrow cylinder spacing creating potential head gasket sealing issues. That said, supercharged 1340cc engines have not only been dominating the 2000cc sports libre and racing car classes in recent seasons but also scoring outright 'Top 12 Run Off' wins and hill records against 600bhp plus 3.5 and 4.0 litre V8 engined cars, although there are undoubtedly question marks about the longevity and reliability of the more highly stressed 'blown' units in some cars.

For this car the customer specified that the engine should not be over-stressed and as such it retains some standard components, including camshafts and valves. The supercharger kit, supplied by Silverstone-based TTS Performance, is based on the Rotrex C30 unit (see sidebar). While the physical engine installation in the chassis was done by Empire, engine assembly, plumbing and wiring were carried out by British Hillclimb contender Tom New's race preparation business New Techniques, based near Southampton in southern England. Replacement Wossner conrods and pistons were installed, which produced a compression ratio of 9.5:1, and some cylinder head porting work was also carried out. The TTS kit included the billet aluminium plenum and features eight fuel injectors, four in the plenum and four in the throttle bodies. The engine runs on regular petrol/gasoline fuel, with no current plans to convert to methanol as some with these engines have done. **[Figures 11 to 13]**

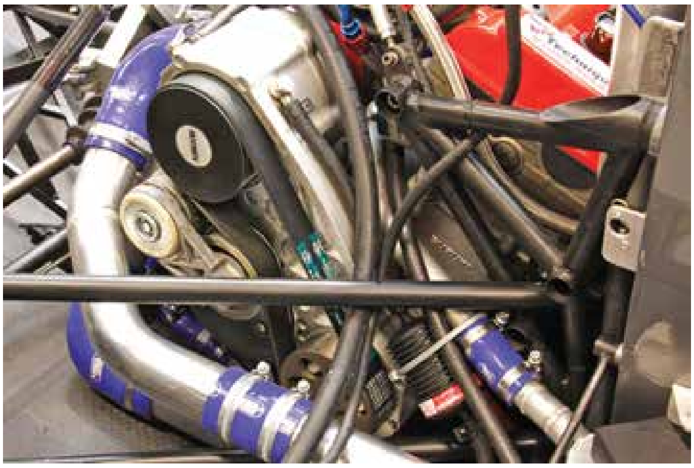


Figure 13: The compact Rotrex supercharger sits on the right side of the engine

New Techniques carried out some dynamometer development on the exhaust primaries, the original system being somewhat restrictive, but shorter, bigger bore primaries that fed into a 3in (76.2mm) single collector pipe released more power. The modified exhaust created a clash with the left sidepod floor when the engine was put back in the car, but a modest faired bulge minimised any potential flow disruption.

A DTA SA80 engine management system looks after sparks and fuelling, and some minor re-mapping will be carried out over the 2014/15 winter to alleviate cold start issues found during the car's August 2014 shakedown.

Figure 14: Intercooler, radiator and supercharger oil cooler sit line astern in the right sidepod

Figure 15: Wheel fairings – one of the features to provoked reaction at the unveiling of the Empire Evo…

Figure 16: Detail of wheel fairings

Rotrex superchargers

Danish manufacturer Rotrex claims its centrifugal superchargers offer unique compactness, efficiency, low noise and reliability. Much of this is down to its 'traction drive' mechanism utilising a specially developed synthetic oil that increases its viscosity under high surface pressure to provide the friction required to drive the impellor, while cooling and protecting. Drive gear ratios of 10:1 provide impellor speeds up to 100,000rpm in the unit used in the Empire Evo (Rotrex model C30-94), generating a maximum flow rate of 0.28kg/s (485CFM) and a peak pressure ratio of 2.5:1 plus. As well as its unique internal drive mechanism, it has the latest centrifugal compression, characterised by high adiabatic efficiency and low noise.

A wide range of four-wheeled and two-wheeled vehicles is catered for, and Silverstone-based TTS Performance is distributor for Suzuki Hayabusa applications among others.

Figure 17: Viewed from the front, the underbody's generously radiused leading edge can be seen

Figure 18: Voluminous diffuser – and entire underbody - is from the '00' series single seater racing car

Although not a highly stressed variant of its type, cooling nevertheless requires a water radiator, an intercooler (these two items made by Empire), and also a cooler for the supercharger 'traction oil' feed, all three coolers located in line within the right sidepod. **[Figure 14]**

The single seater sports libre concept is aerodynamically attractive because of the ability to use a narrow chassis, a potentially full width underbody, full width wings front and rear, wheel fairings and, at present, no requirement to cover the suspension as, for example, the SCCA's P1 and P2 categories are required to do. All this should add up to downforce and efficiency (downforce to drag ratio) levels well in excess of anything a single seater racecar with narrower underbody and wings, and exposed wheels could generate, or indeed a traditional sports racecar layout with a wide chassis that compromises the inboard underbody region.

That's the theory; how has Empire approached the concept in practice? In essence the Evo sports libre retains the underbody of the racing car variant but now has sidepod covers, all to the maximum permitted width for racing cars at 1400mm; it has a rear wing with a span equal to the car's overall width of 1780mm; the front wing has been widened so that its outer ends are in line with the inside of the front wheels, which with the complex end plates actually makes them slightly narrower than full width; and then there are the wheel fairings. **[Figures 15 to 17]**

So the car has some very interesting details, but some of the available freedoms such as front wing and underbody width have not been exploited to the full, and to an extent this was down to pragmatism and using available parts and moulds. But it was also because of a degree of uncertainty about the path the technical regulators might take in the

near future as the discussions over the single seater sports libre concept continue. For, as Chaplin remarked, 'it would take just a few minutes to convert the car to racing car specification; we'd just have to remove the wheel fairings and fit the relevant width wings.'

However, let's suppose the concept is here to stay while we focus on the interesting details of the Evo sports libre. The wheel pods attracted a great deal of comment and they may indeed have pushed the boundaries of rule interpretation too far, though this remains to be seen at time of writing. The purpose of the plan view streamlined 'extended tear drop' shape of the wheel fairings is to reduce the region of raised static pressure ahead of the wheels and also to tidy up if not remove the wheel wakes, so drag should be reduced and downstream downforce generation may also be enhanced.

The main point of contention though is the apertures in the tops of the wheel fairings. Although there may be a debating point about whether the wheels of a sports libre car based on a single seater racing car need covering at all within the rules as they are currently worded, most readers of the technical regulations point to the rule that requires wheel coverage over a 120 degree arc in which louvres are permitted but the tyre may not be visible from above. Bill Chaplin however cites the wheel arch apertures on LMP cars and reckons this should allow the freedom to do something similar in hillclimbing. 'Besides' he commented with a grin 'apertures are cheekier than louvres!' Either way, the purpose is to reduce suction over the upper surface and reduce positive pressure beneath in order to reduce the positive lift that wheel coverings generally create.

Regular readers may recall the Empire Wraith hillclimb single seater racing car featured in our June 2014 edition (V24N6), the aerodynamics of which was entirely down to Chaplin's friend and advisor Willem Toet, head of aerodynamics at Sauber F1. But Toet's indirect input on the sports libre Evo was limited solely to the design, some years previously, of the wings and end plates. The rear wing is the same profile as used on the single seater racing cars, widened to the maximum width of the car in this instance. The bottom rear corner of the rear wing end plates feature an interesting 'twist', which would appear to produce a vortex counter to the normal rotation of the tip vortex at the bottom of an end plate, no doubt as an efficiency enhancer.

The racing car-width (1400mm wide) underbody is simple – and effective – in design and execution, and features a well-radiused, raised inlet section that gently transitions to the short throat area (aligned with the centre of gravity), and a fairly steep, wide diffuser under the full width rear wing.

Evo trending

The Empire Evo may well be the first of a new trend in UK sports libre hillclimbers. As this article is being written there is at least one other hillclimb constructor contemplating building a similar concept single seater sports libre car, and others have expressed conditional interest, given that the regulators are still discussing the matter. With 'single seat sports racing cars' already competing in the UK, such as the Speads RS06D and the Radical PR6 (in a sense…), and others in Europe and the US that could be eligible, it is to be hoped that the inclusive ethos of the UK hillclimb sports libre prevails.

TECH SPEC

Empire Evo Sports Libre

Category: UK Hillclimb

Class: Sports Libre cars up to 2000cc

Chassis: Hybrid steel spaceframe/ honeycomb panel/monolithic carbon wrap

Engine: Suzuki Hayabusa, supercharged

Transmission: Suzuki Hayabusa-based 6-speed sequential gearbox; chain drive to Empire/Quaife final drive and LSD

Data system: To customer requirements

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

Dampers: Koni 2812 double adjustable

Brakes: AP Racing radially mounted two-piston calipers, AP 275mm discs

Wheels: Evo Corse F3 magnesium, 8in front, 10in rear

Tyres: Avon, front 195/530 R13, rear 245/600 R13

Fuel tank: Fabricated aluminium, 3 litres

Safety: TRS 6-point HANS safety harness. Roll bar to RAC MSA technical regulations, carbon/honeycomb nose box incorporating the front wing hangers

Dimensions: Width: 1780mm; Height: 900mm plus roll hoop; Wheelbase: 2270mm; Track front: 1500mm, rear 1500mm

Weight 330kg wet

Concept evolution

The 'sports libre' category in UK hillclimbing is a slightly curious one. It developed from earlier and more conventionally defined sports racecar classes, which offered chassis that were notionally wide enough internally to accommodate two seats, and the UK MSA's definition of a 'sports racing car' still specifically states 'two seater'. But it also became a category that accommodated cars from other superseded categories, such as spaceframe chassis special saloons, no longer eligible for the modified series production classes, alongside sports racers. **[Figures 19 and 20]**

Then in early 2003 the Force SR4 and its twin-engined sister, the SR8 appeared, which featured one central seat though still with a cockpit aperture that met the 810mm (31.9in) minimum width regulation that prevailed at the time. Subsequently Bill Chaplin sold Force Racing Cars to Ian Dayson, who in 2010 unveiled a new sports libre concept, the LM001, based on the company's single seater PC model but with a chassis widened to meet the 810mm minimum chassis width. This car was featured in Aerobytes in November 2001 to January 2012 (V21N11 to V22N1). Once again the single seat was central, and the desire in the designers' minds to be able to run a single seater clad with bodywork and aerodynamic devices was in evidence! **[Figures 21 and 22]**

Then in late summer 2011 one of the regular UK MSA Motor Sports Council 'Rule Change' bulletins was published giving notice of regulation changes for implementation on 1 January 2012. Among the changes was a complete re-structuring of the sports libre regulations and in particular the definitions of cars that henceforth would be accommodated in the category. It was apparent that the wording was intended to clarify and broaden the inclusivity that had prevailed for some time so that there was no confusion about where vehicles like old Group B rally cars, special saloons and so on could run.

Figure 19: Traditional two-seater sports racing car, the Pilbeam MP43, runs in the 'sports libre' category

Figure 20: Former 'special saloons' with spaceframe chassis are also accommodated in 'sports libre'

With the requirement for a minimum chassis width having been dropped from the regulations at some prior point too, this, plus one key clause in the new regulations and accompanying cross references caught your writer's attention in relation to his own long running hillclimb design-and-build project. The opening definition, which is now a part of the UK MSA Year Book (the 'Blue Book' as it is colloquially known), stated:

'Regulations for Sports Libre Cars.

Description: 14.1. Vehicles that comply with any of the following Groups:

(a) Any vehicle that does not comply with any other category, as defined in 10.10.1 to 10.10.5, or 10.10.7…'

Now, 10.10.1 to 10.10.5 and 10.10.7 are all the other categories that are eligible for hillclimb (and sprint) events in the UK. And 10.10.7 is for 'Racing Cars – Cars complying with S15', where S15 lays out the dimensional requirements such as maximum body width and so on for racing cars in speed events.

By stating in 14.1(a) that a vehicle would be eligible for sports libre if it did not comply with any of the other categories, it seemed clear that the sports libre category was now open to racing cars that did not comply the racing car category. The new rule did not stipulate any required basis or limitations for 'non-compliance'. So, it could reasonably be argued that by exceeding the hillclimb racing car body width and/or wing width requirements a car would be classified as 'sports libre'.

This is what motivated the writer to switch his own design project to a sports libre car in order to exploit the theoretical aerodynamic advantages of a single seater racing car layout with narrow chassis but with full width wings and enveloping sports libre bodywork. The UK MSA's technical director confirmed to the writer in November 2011 that the concept, as presented, of a racing car with covered wheels and full width bodywork and aerodynamic devices did meet the new sports libre regulations as written. And this magazine featured your writer's CFD evaluations of the concept in its October 2012 issue (V22N10). **[Figure 23]** At around the same time hillclimber Chris Cannell, who commissioned the original, unique Force SR8 and had driven it during the intervening decade, asked former Force Racing Cars owner and now principal of Empire Racing Cars, Bill Chaplin to construct a new sports libre car that followed the writer's single seater sports libre concept.

Your writer was invited to carry out the detail design of the aerodynamics but practicalities saw him decline, although he may be found guilty by association… And the Empire Evo Sports Libre was born. **[Figure 24]**

Meanwhile there has been a degree of disagreement on what seems (to this obviously biased commentator!) like a straightforward interpretation of the technical regulations, and the Hillclimbing and Sprinting committee that drafts the regulations in the UK, and its overseeing body the Speed Event committee were due to discuss in the coming months whether the rules required modifying.

However, following conversations with senior figures on the specialist committees the writer remains optimistic that this unique branch of motorsport will retain its philosophy of inclusiveness.

Figure 21: The Force SR8 put the driver in the centre

Figure 22: The Force LM continued the central seat trend but still met the old cockpit width rule

Figure 24: Empire Evo owner Chris Cannell (in car) in discussion with constructor Bill Chaplin at the car's August 2014 debut

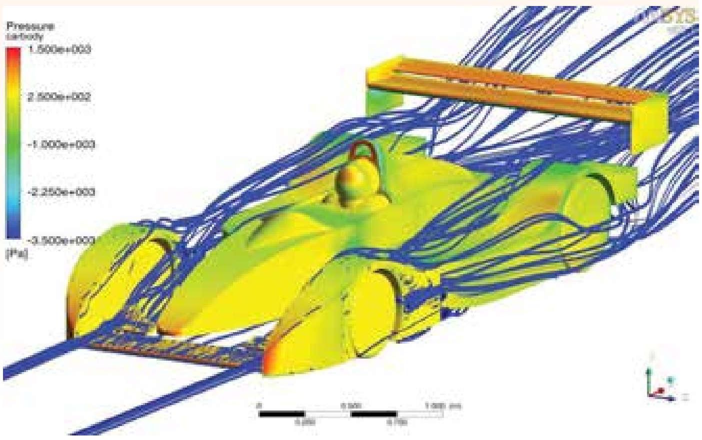


Figure 23: The writer's single seater sports libre concept, though far from novel, was approved by the UK MSA for hillclimb sports libre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Open season

Will V8 Supercars follow the DTM lead and introduce coupé designs?

By STEFAN BARTHOLOMAEUS

In a world filled with touring car categories that feature increasingly homogeneous vehicles, Australia's V8 Supercars Championship is taking a bold leap as it attempts to secure its future.

The 2017 season will see one of the biggest technical shake-ups in the championship's history as it works to attract manufacturer support for its teams. While last year's move to the 'Car of the Future' was billed as 'opening the shop front' to new marques, it has been met with a mixed response in the marketplace.

Car makers outside of Ford and Holden have been welcomed for the first time in 20 years, but they have to field a four-door sedan fitted with a 5.0-litre V8 if they want to play.

Just two, Nissan with its Altima and Volvo through its S60, have joined in a factory capacity, while Mercedes-Benz E63 AMGs are on the grid as part of a customer programme.

Only 12 of the 25 cars on the 2014 grid enjoyed direct financial support from a manufacturer; a number that V8 Supercars is keen to increase. Although appealing to the fan base with their speed and sound, the continued stipulation for V8 engines has proven a major turn-off for marques that prefer marketing more relevant technologies.

Those that have invested, meanwhile, have been stung with the expensive task of developing engines specifically for V8 Supercars.

The current control chassis will remain in 2017, but much of the remainder of the rule book will be torn up under what is being dubbed the 'Gen2' overhaul. The only stipulations laid down by organisers are that the road car must be sold in Australia, be right-hand drive, front-engined and with four seats. The racing version must be rear wheel drive and fit on the current control chassis.

Configurations

In terms of body styles and engine configurations, 'bring what you want and we'll make it work' is the clear message to car companies from V8 Supercars CEO James Warburton. He engaged discussions with a variety of marques before presenting a 'white paper' proposal to the V8S board and its teams.

The former television executive is adamant that the new rules will attract new players for the 2017 season, and help retain current ones.

In a case of poignant timing, Ford formally announced just two days before V8 Supercars' scheduled Gen2 launch that it will withdraw funding from factory team Ford Performance Racing after the 2015 season. The announcement of Gen2 also saw confirmation the 'V8' prefix will be dropped from the category's name during the next few years.

'The current climate in world motorsport is absolutely clear,' said Warburton at the announcement in December. 'Manufacturers want choice in what they go racing with, otherwise they won't participate.'

V8 Supercars has also stressed that cars must 'accurately reflect the look of the road car', a point that continues to be seen as key for local fans, harking back to the category's production car roots. The current array of control parts including a six-speed Albins transaxle, Triple Eight-designed independent rear-end, AP Racing brakes, 18-inch Team Dynamics wheel and Motec M190 ECU, will also remain as the category aims to ensure there is no change-over cost for those without factory funding.

The key to managing the new formula will come through a continuation of the category's recent work on parity, particularly in the areas of engine performance and aerodynamics. V8 Supercars' technical department initially tried to match new-generation Nissan and Mercedes engines against the power curves of top Fords and Holdens, only letting new parts be homologated where power and torque outputs remained close to that of the incumbents.

The difficulty of managing such a process soon, however, saw it scrapped in favour of a cumulative horsepower system, which was formally put into place last March.The new process sees horsepower measured on the category's appointed engine dyno at 50rpm intervals between 5800rpm and 7450 rpm

"The current climate is clear – manufacturers want choice in what they go racing with, otherwise they won't participate"

The development costs of the 5.0-litre V8 engine for the Australian series is considered too high and the technology not relevant enough to justify costs. Manufacturers are pushing for small-capacity turbo engines

To attract new manufacturers into the Championship a switch to four-seat, two-door coupés has been tabled as a potential solution

(there is a hard cut limiter set to 7500rpm on all cars). Homologation upgrades are allowed so long as the cumulative horsepower in that range does not exceed 20,654bhp.

While many teams lamented the height of the ceiling, which triggered an expensive engine development war this season, the basic concept has been widely praised by the teams.

Warburton says that he reached out to several offshore categories, including the British Touring Car Championship, during the formulation of the Gen2 concept, and is adamant that V8 Supercars' current parity system is world class.

'When you look at what we've got, the way we now manage the engines, we're now fielding a lot of inbound inquiry about what we are doing,' said Warburton, who has placed an emphasis on beefing up V8 Supercars' technical department since taking his role midway through last year.

'People are looking at us and going "what a great system". Don't be confused by the "not invented here" syndrome, we've actually done a pretty bloody good job.'

V8 Supercars says it will now set about developing a framework for exactly how it will deal with homologating Gen2 engines, with an outline due to be formalised by mid-2015.

The majority of existing players are expected to stick with the tried and true V8s in the short term, which Warburton insists will continue to be competitive.

Hybrid systems

The need to ensure the continuation of the approximately 650bhp V8 engines is, argues Warburton, a key factor in why the eligibility has been blown wide-open, rather than simply shifting to a single new formula.

'You've got to start with what you've got, rather than throwing everything out and starting again [with a new formula],' he said.

'This category has made great decisions about the racing product and we believe it's about a blend of both in the future, rather than going in a different direction. We're starting with the strength of what we've got and adapting it.'

Even hybrid systems are being encouraged by V8 Supercars, although Warburton reports that no manufacturer has yet made a serious approach about integrating such technology into the category. Gen2 also looms as an aerodynamic challenge for the championship as its testing procedures will have to cater for a far greater variety of body shapes.

The control chassis features a set track and wheelbase, but has been designed such that models as diverse as the Ford Mondeo and Ford Mustang can be fitted over the top without straying too far from the look of the standard vehicles. The category has worked hard to improve its aerodynamic testing methods this year, but continues to persist with open-air coast downs to measure downforce and drag.

Warburton says that he reached out to several offshore categories, including the BTCC, during the formulation of the Gen2 concept

While teams and manufacturers have made their own Computational Fluid Dynamics models during the process of developing aero packages, the category has resisted the expense of delving into CFD itself.

Nissan Motorsport owner Todd Kelly, whose team is preparing to homologate changes to the aero on its Altima for a third year as it chases a reduction in drag, says the attitude to aero will be put under the microscope by the new rules.

'The technology is out there to ensure the aero side of the parity can be just as good as the engine side, which I'm confident in,' he says.

Nissan's global motorsport manager, Darren Cox and Australian CEO Richard Emery have both already spoken about the possibility to reintroducing the GT-R body shape and turbo technology to the championship under Gen2.

The nameplate dominated the final years of Australia's Group A touring car era before the 5.0-litre, Ford versus Holden, ruleset took hold in 1993. The V8 Supercars version of the VK56DE has required millions of dollars worth of development to get it up to speed under the tight current rule package, testing the patience of both the manufacturer and Kelly's team.

V8 Supercars promises that Nissan and other manufacturers will, with some tuning, be able to 'plug in' their 2.0-litre, 4-cylinder turbos from the Super GT/DTM technical alliance if they choose to do so.

'The turbo engines in particular are going to be relatively easy to dial into our cumulative horsepower formula, compared to the naturally aspirated engines,' said Warburton.

'There are three or four (engines from different manufacturers) that we have seen that could be adapted relatively easily and I think if you look forward to the proposed DTM regulations from 2017, that provides another opportunity for re-use of either engines or technology from those manufacturers, should they be interested in being involved.'

In a country where marketing programmes such as motorsport all require approval from off-shore management, better integration of the championship into the rest of the racing world can only help deals get the green light.


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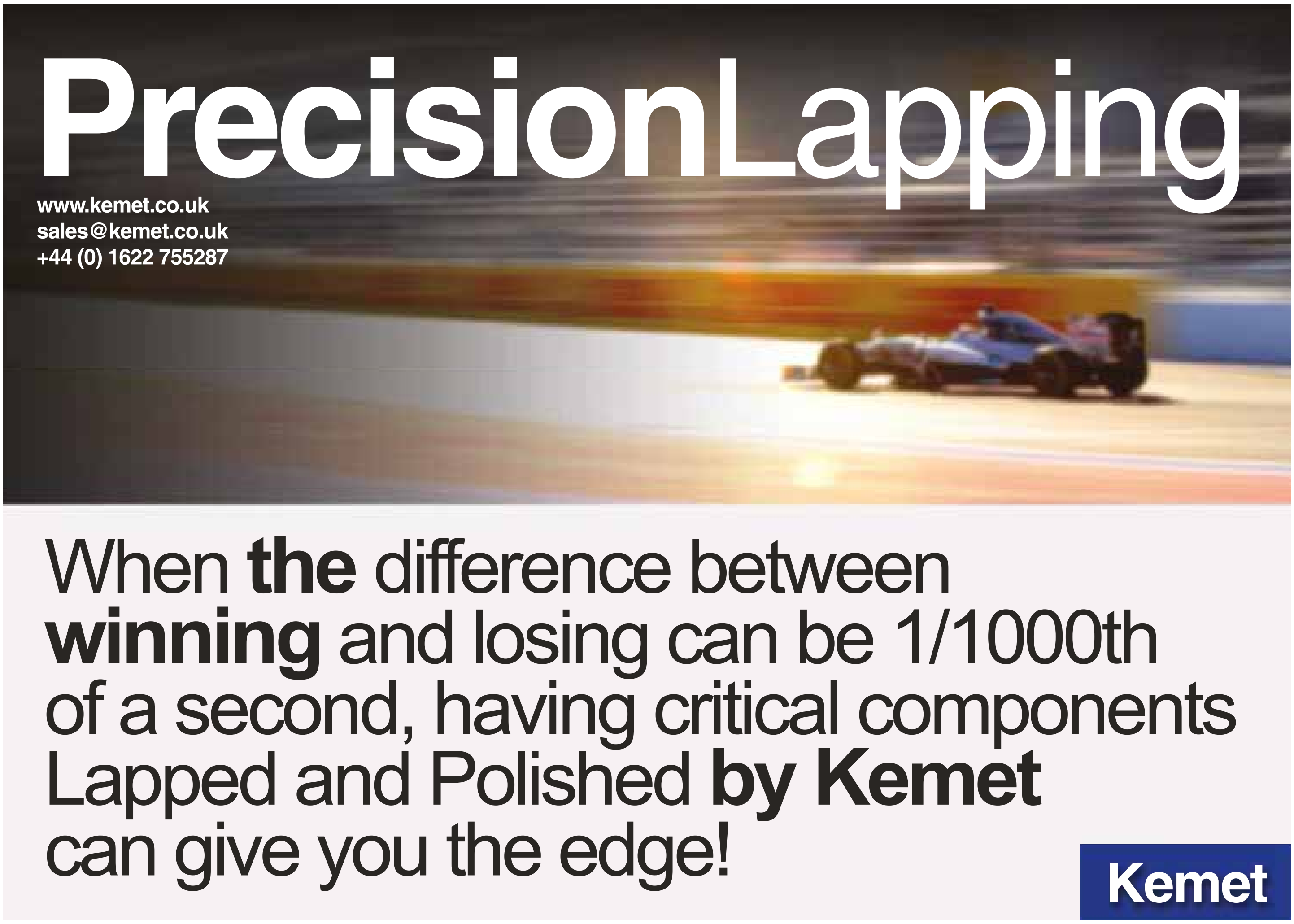
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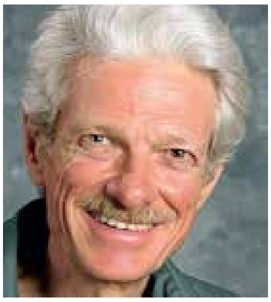

It's more complicated than scaling

Short wheelbase and Formula Student design investigated

Question

In searching for a simple physical explanation for the inherent agility advantage smaller cars seem to have – they always seem more responsive, nimble and communicative than larger cars – a simple physics model was used. In this model yaw acceleration was taken as the index of agility, the car taken as a rigid body, and then the torques and inertia scaling investigated. The inertia of a rigid body about a vertical axis through the C.G. scales as the mass multiplied by the square of the dimension. Since mass scales as the cube of the dimension, the MOI scales as the fifth power of the dimension. The torques about the C.G. have two components: The distance of the tyres from the C.G. scale as the dimension, while the loads on the tyres that determine the tyre frictional forces scale as the mass or the cube of the dimension. Thus the torques scale as the fourth power of the dimension. Hence the yaw acceleration, T/I, scales as the fourth power/fifth power, or as the inverse of the dimension, that is to say as the size increases the inherent yaw acceleration capability decreases. (Alternatively, since mass appears in both the numerator and denominator of this quotient, the effects cancel, and the dimensional scaling alone remains and determines the scaling result given.) That seems reasonable, and tyre load sensitivity would add some additional scale effect in the same direction. Diminutive athletes now dominate gymnastics and diving sports for similar physical reasons, probably. Conversely, large cars should be inherently more stable than small cars. Excellent engineering can camouflage these inherent characteristics, of course. I still rate a 1,500 pound 1965 Lotus Elan as the most responsive car ever, but after 50 years it may only be in relative terms, then versus now.

Are these conclusions from this simple physical model qualitatively correct? If so, it suggests that of the various car types rear engine cars (rearward C.G.) are inherently more nimble than other types because they have the longest lever arm to the front tyres that provide turning torques about the C.G.

It then follows that mid-engine cars (central C.G.) are next most nimble and front engine cars (forward C.G.) the least nimble. This all seems qualitatively consistent, but excellent engineering. Again, is this qualitatively correct?

At the other extreme of the handling spectrum, spin or oversteer skid recovery, or control, these rankings would be reversed. Here the rear tyres would be key in regaining traction. Front engine cars with the longest lever arm to the rear wheels would seem to be quickest/easiest to control or recover from spin/oversteer conditions. This ease of control perhaps explains why drifters and sprint cars are typically front engine/forward C.G. machines – they are inherently easier to control. Then mid-engine cars next in terms of recovery/control and rear engine cars last – they have the least leverage from the rear tires. And, yes, that was indeed a snap spin in the 911 RS America! Again, this seems consistent with experience and common understanding. If so, why do scribes commonly state regarding mid-engine cars that 'they are very difficult to spin, but once initiated they are gone quickly and can't be recovered'?

Perhaps since many mid-engine cars handle very well the tendency may be to overdrive and when the spin occurs it indeed is very difficult to detect or control.

So, is this physical model a reasonable basis for making the conclusions reached?

Are the conclusions reasonable? Couldn't find any such macro summary of vehicle design characteristics on handling in my modest library.

The answers are undoubtedly contained in Milliken, for example, in all the math, but a concise summary is not offered. Your views would be highly valuable. If not this model and conclusions, then what simple basis is appropriate?

In this model yaw acceleration was taken as the index of agility, the car taken as a rigid body, and then the torques and inertia scaling investigated

The consultant says

Actual designs are more complicated than the simple model proposed. One never can simply scale anything up or down. However, that said, the simple model proposed is not unreasonable, and the questioner has correctly understood its physics.

If:

- **We have a mass that we are angularly accelerating about a center of rotation with a known force;**
- **The mass's radius of gyration and the force's moment arm are in a constant ratio to each other;**
- **The magnitudes of the force and the mass are in a constant ratio to each other;**
- **We vary the radius of gyration and the moment arm, maintaining the above conditions,**

Then:

- **The linear acceleration of the mass will be constant**
- **The angular acceleration of the mass will be inversely proportional to the radius of gyration**

If we double the size of the car, and the coefficient of friction at the contact patches doesn't change, then the car will have half the yaw acceleration at the limit of tyre adhesion.

With real cars, there are a number of other

The wider the car is, the less the driver is able to straighten out the turns

considerations. Sheer bulk makes a car harder to manage in the confines of real-world road situations, and requires us to slow down to avoid hitting things. The wider the vehicle is, the less we are able to straighten out the turns. One of the big advantages of motorcycles is their ability to take much straighter lines through turns, especially tight ones, than cars can. As we lengthen the wheelbase, we get more off-tracking.

In tight turns and at low speeds, the rear wheels track further inside the fronts. In sweepers, the rear wheels track further outside the fronts. This increases understeer in tight turns and oversteer in fast ones.

As the wheelbase gets longer, we need to steer the front wheels more to make a given turn. As the car gets heavier, we need to use slower steering to maintain a given level of steering effort, or we need to add power assist, or use stronger power assist. Good power steering can be pretty nice, but it's hard to beat the feel of well-designed unassisted steering in a small, light car. In any case, for a given steering ratio (hand wheel degrees to road wheel degrees), a smaller car will need less steering wheel movement to negotiate a given turn, at any speed.

Are cars with low yaw inertia more or less inclined to spin, and are they harder or easier to catch? Well, they accelerate in yaw faster. That means it takes less to destabilise them but also takes less to catch them. The car will do a bigger wiggle when it hits a slick spot while cornering. It will oversteer less on exit in a chicane or lane change. It takes a smaller correction to catch a slide, but you have to be quicker with it.

Sprint cars are required by the rules to be front-engined. They are not nose-heavy, thanks to ample engine setback. They are actually quite tail-heavy.

Drift cars are required to be sedan-bodied. That rules out anything mid-engined. They have hydraulic handbrakes using a second set of rear calipers. The drivers use these to get them to turn in and get sideways. Drift cars are helped by more rear percentage, mainly to help forward bite. I'd be interested to see what one of those four-door Porsches could do, or whether a 911 could be qualified (they do have back seats, sort of) – or maybe a Corvair?

Engine swaps are legal, as long as the new engine is from the same corporate family.

FSAE/Formula Student ideas

Question

I am currently a member of my school's Formula SAE club and would love to ask you some questions to possibly help us design a better car. I'm not in charge of the chassis so I don't have any specific questions but I know a big issue for us this year is trying to save weight. I was wondering if you had any tips on materials or designs to help save weight in regards to chassis? Also, would there be any other relevant design features you think worth mentioning?

The consultant says

I haven't been to an FSAE competition since 2006. They've changed the rules quite a bit since then. One always wants to take weight out of a racecar. In FSAE/FS, this is compounded by the fact that the event is partly a judged competition, and one criterion traditionally used to make the cut for the design finals is car weight.

If a team goes with a steel tube space frame, the diameters and wall thicknesses of most of the tubes are prescribed by the rules. About the only way to save any large amount of weight there is to eliminate parts of the frame entirely. The big place to save weight is the engine. The really light cars use singles or in some cases twins, rather than fours. The UNC Charlotte car is using a KTM single this year. They've used Aprilia twins in the past.

Making the cut in 2014: the lightest car in last year's Formula Student where weight remains a crucial factor

For performance, making the car compact is probably as important as making it light, at least for the autocross and endurance events, because the courses are so narrow and tight.

If I were doing an FSAE/FS car, I'd give a lot of thought to laying it out like a go-kart: engine beside the driver, probably on the right. The engine and the driver would then be in the same bay of the frame, and the engine bay would be eliminated. The driver's head and the rear roll hoop would be in the region of the rear axle. The driver's feet would be offset from his body, toward the centre of the car.

The big place to save weight is the engine. The really light cars use singles

It should be possible to have the driver entirely within the wheelbase this way, while getting the wheelbase down to the 60in minimum. The front bulkhead and the impact attenuator would be just ahead of the front axle. This would maximise plan view area available for a front wing. Plan view area for the rear wing would be reduced. Under current rules, the rear wing can't be forward of the rear roll hoop and it can't extend more than 250mm (9.8in) aft of the rear tyres. However, the front is where an FSAE car needs more wing. For autocross with full-size cars it makes sense to have the centre of lift (downforce) fairly far back, set the car up mechanically loose, and use the aero to stick the back end if there are high-speed turns. But in FSAE there are no high-speed turns and the cars all fight understeer because of small radii.

A big overhead wing, as on a sprint car, would work very well, if it were legal.

A go-kart layout would lend itself to beam axle suspension. At the front, there would be room for a beam axle if the driver's feet are behind the axle line. A lighter option.

With an offset drive chain, there is a question of what to do for a diff. The lightest, cheapest approach would be to use a locked axle consisting of a simple tube with a spool, as in a mini-sprint. The car would have to corner with the inside rear tyre airborne or lightly loaded, but FSAE cars all do that anyway. Driving style with a spool and a tight course involves unloading the rear for turn-in by trailbraking. Drivers vary in their ability to drive a spool car. You could create a beam axle incorporating a locker: a device like a Detroit locker that lets either wheel overrun the sprocket individually, improving turn-in.

Diffs for FSAE get a lot of discussion on forums, and would make a good topic for a future newsletter.

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.

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Traction control **Part 2**

Configuring the ECU to provide driver comfort and confidence

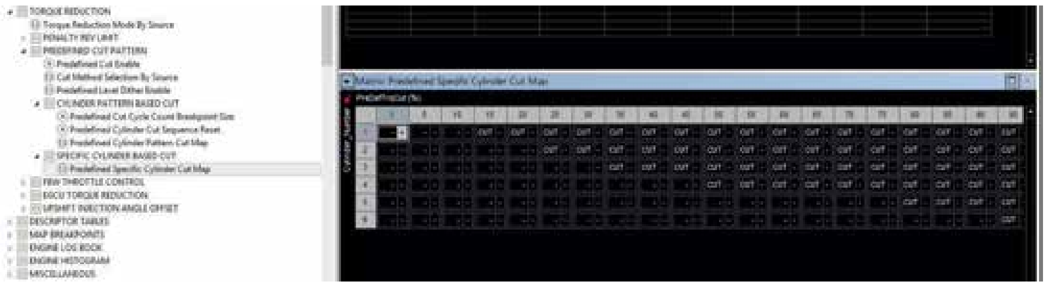
Last month we introduced the principles behind traction control strategy for race cars. There is a significant benefit for this type of strategy if it is allowed, but it is still imperative to emphasise that traction control is not a tool that makes the car go faster. This is due to the inherent nature of the control, which is to limit the torque at the driven wheels. Traction control is a driver aid and as such is used to assist with consistency. In most cases a professional driver is faster over a single lap without the use of traction control but over the course of multiple laps it helps with getting more consistent lap times. This brings us to the key element of traction control tuning; it has be done based on the feedback of the driver. We then correlate that to what we can see in the data and make changes based on both. It is all well and good to have a wonderfully configured traction control, but if the driver lacks confidence then its work down the drain.

It was already said that most drivers prefer the ignition cut method for torque reduction in a traction control system. Cutting the spark means there is better feedback for the driver and he or she gets a better feel for what the car is doing. This provides confidence and repeatability. We therefore need to configure the ECU to cut the spark to reduce the torque. This might seem like a simple thing to do, but we must be careful. For example if we start to cut one cylinder per engine cycle straight away there will be a very steep loss in torque, resulting in a less than favourable situation for the driver. It is therefore necessary to start more gradually and cut one cylinder every 3rd cycle and then increase the severity if more torque reduction is needed. Using this method requires a lot of work on generating the matrix for the cylinder cut as the table needs to be very large to control the torque reduction adequately. Pictured is an example of a table used for pit lane speed limit and although this one is quite large, it is far too small for traction control.

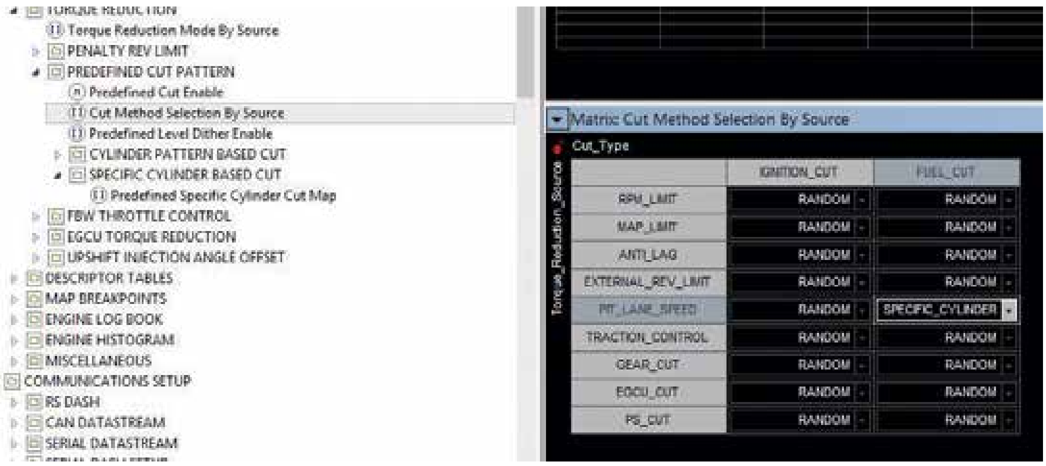
There is, however, a solution that makes life easier, and that is to use a randomiser for the ignition cut. This uses predefined parameters and smooths out the torque reduction.

Once the torque reduction method is set, it is time to look at some of the other parameters. As a reminder, the following parameters all influence the traction control.

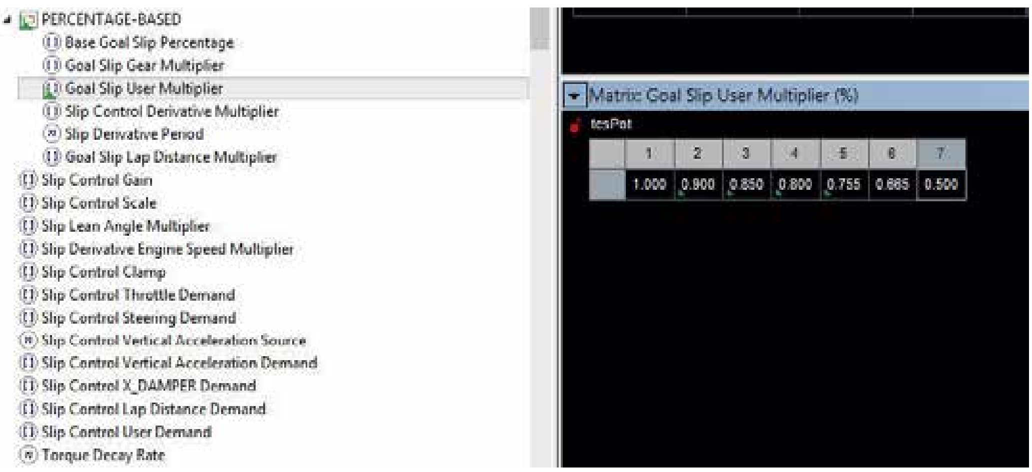
If we look at for example the User Multiplier, it is useful to give the driver a bit of control over the severity of the traction control. The same switch is also used to set the maximum allowed slip so it is necessary to be careful when configuring this value. Some of the other parameters can then be seen on the left hand side. Do we want to control it is the spin or slip of the wheels. How much slip is there and how fast is the slip building up?



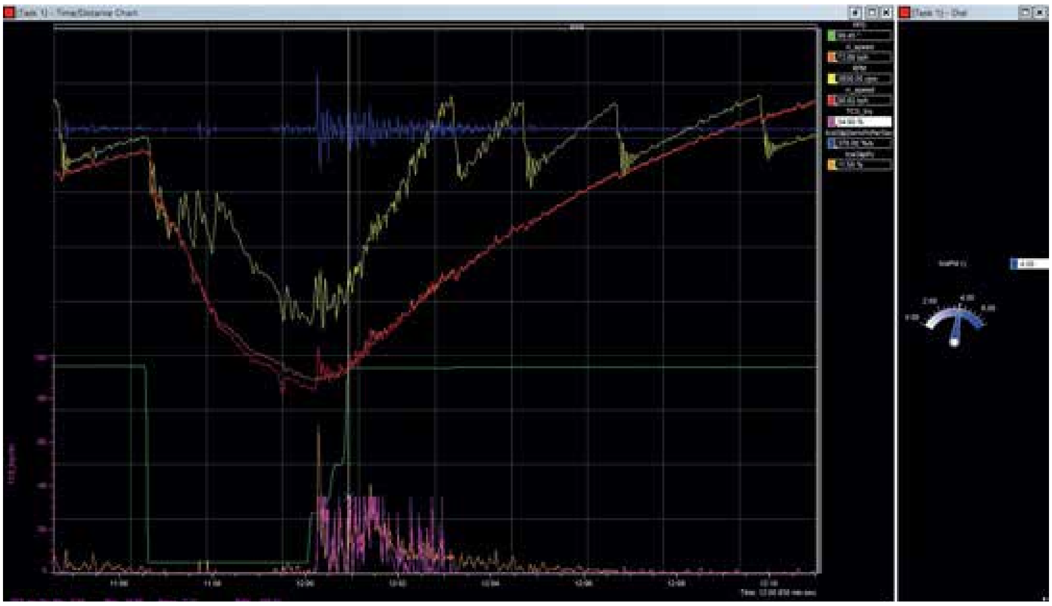
A table used for pit lane speed limit



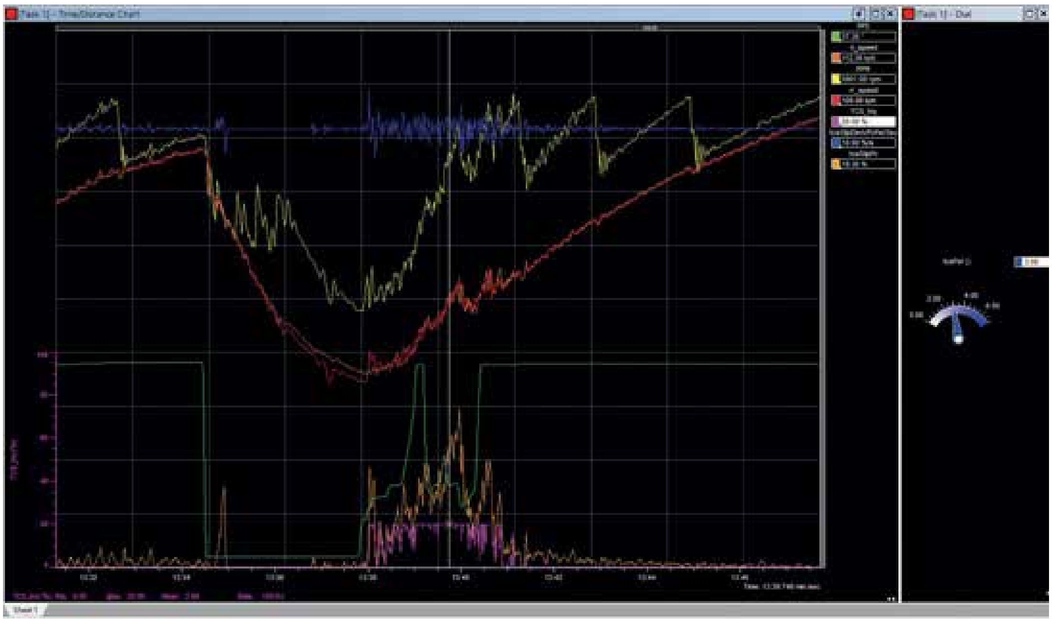
A randomiser used for ignition-cut is one solution



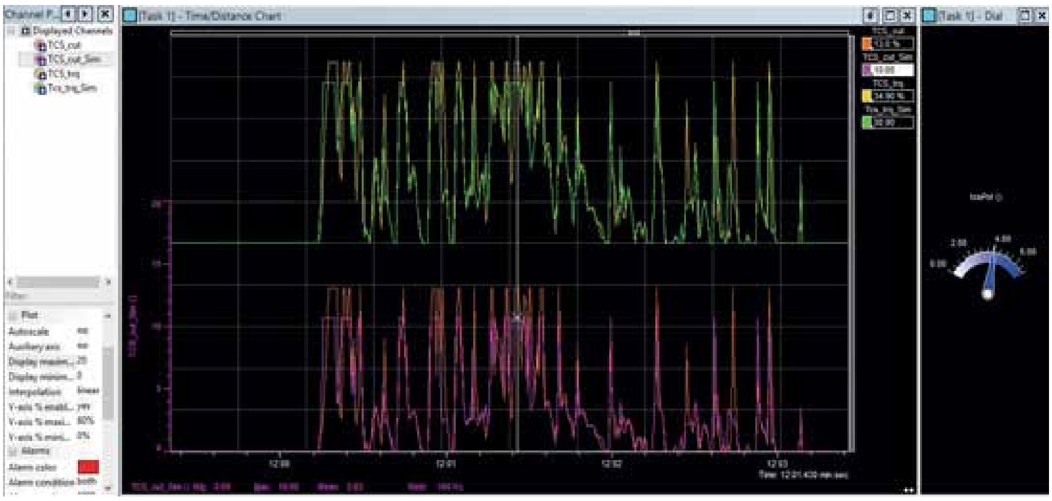
Parameters are viewed down the left-hand side



Data from a specific corner with traction control set to 4



On the next lap the driver chooses a less-intrusive setting…



The user torque limit is reduced to 30.9 per cent so we can see the effect this will have on the TCS torque

Looking at some data for a specific corner, we see the traction control is set to 4 and the torque reduction is limited to 34.9 per cent – this setting appears to suit fairly well, at least it inspires confidence as the driver keeps his foot flat and slides the car around. We could probably do a bit more to smooth out the torque reduction as the rpm does fluctuate a bit due to the ignition cut.

On the next lap the driver tries a less intrusive setting, but as the assistance is reduced the confidence is lost and the driver interferes and goes out of the throttle. We also see much more action in the slip percentage (Orange line at the bottom) indicating excessive slip. This is clearly an effect of less maximum torque reduction indicated by the pink TCS_trq channel.

No doubt the driver's feedback will be that setting three is probably not appropriate for the current level of grip, but setting 4 might be a bit too intrusive so there might be a happy medium between the two. It is then necessary to adjust some parameters to create the traction control settings that are likely to work. In order to do so it's a good practice to set up a simulation. There are two elements needed for this; a good analysis tools package and the calculation method used in the ECU to determine the level of torque reduction. The way to do this will be different depending on software and hardware, in Pi Toolbox the lookup table function allows us to generate two dimensional maps in excel which directly replicate what is used in the ECU calibration tool so the simulation becomes relatively easy. Pictured are sample screenshots of simulated torque values versus the current ones which make it easy to predict the behaviour on track.

In theses instances we have reduced the user torque limit to 30.9 per cent so we can see the effect this will have on the TCS torque. Additionally the simulation shows the level of cut produced by the traction control strategy.

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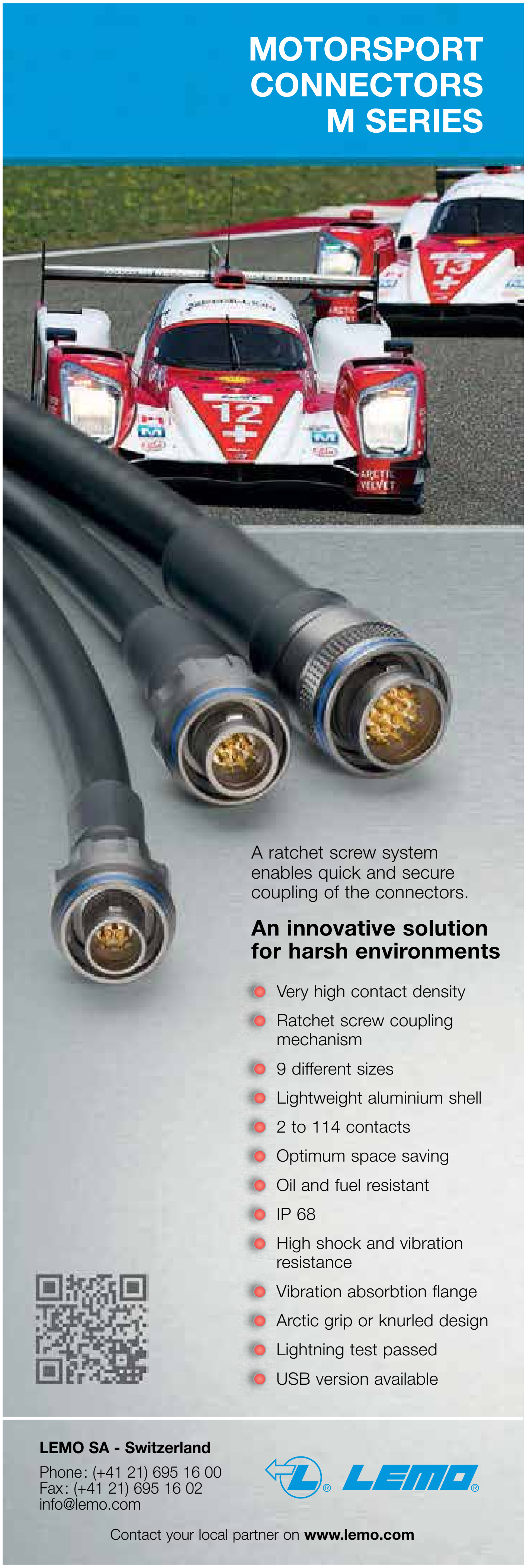
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Bulk just an illusion for A-Class Merc

A new project on one of the newest entrants in the BTCC

Wix Racing's (formerly Cicely Motorsport) decision to run the new model Mercedes A Class in the 2014 British Touring Car Championship brought the marque back into the series for the first time since the 190 competed in the 1980s. Chief engineer Paul Ridgway and his team were able to transfer the NGTC running gear from their previous Toyota Avensis into the new Mercedes to good effect, their first season seeing generally improving, regular top ten grid positions, a couple of fastest laps, a win in the season finale and 10th overall in the championship. So it was a treat to get them into the MIRA full-scale wind tunnel during autumn 2014 as the team prepared for its 2015 campaign.

As hatchbacks go, the new model Mercedes A Class looks superficially to be quite large, but a comparison of its overall dimensions with those of the top three cars in the 2014 BTCC (BMW 125i, MG 6 and Honda Civic Tourer) demonstrates that the illusion of largeness is just that. In fact, multiplying the NGTC equalised width of 1875mm (73.8in) by the height of the base production variant of each car sees the A Class having the second smallest 'gross' frontal area of the four cars.

So, with front and rear aerodynamic devices fairly tightly defined in the BTCC regulations, obtaining a competitive aerodynamic package in this very closely fought series is all about attention to small details.

Given that the Mercedes is very much a current car, and that the publication of this and subsequent Aerobytes columns on it will be ahead of the 2015 season, we will preserve a degree of confidentiality in the data we use to describe the effects of modifications by using 'delta values' only, that is, the amount by which the aerodynamic parameters changed with modifications, rather than publishing the absolute coefficients at this stage.

Front end modifications

The NGTC regulations prescribe a 'specified front aerodynamic device incorporating a flat floor [back to a certain point], the apertures for the radiator, brake cooling ducts, the intercooler and the side exits.' There is also a maximum height above which shape changes are not permitted. So really only quite subtle changes to the shape of the airdam above the prescribed splitter within the 'free zone' can be made. What effect would such subtle changes make? The first configuration change was to add a small infill to a horizontal recess immediately above the splitter, creating more of a flat front below the radiator aperture **[Figures 2** and **3]**. The effects are shown in

Figure 1: Wix Racing's Mercedes A Class was one of the newcomers to the BTCC in 2014

Only quite subtle changes to the shape of the airdam above the prescribed splitter within the zone can be made

Table 1: The effects of adding an infill to the lower gap above the splitter

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.001	+0.010	+0.016	-0.006	+3.85%	+0.026

Figure 2: The baseline front bumper arrangement featured a recess directly above the splitter

Figure 3: Filling in the recess above the splitter produced a clear result

Figure 4: Covering over the outer, upper parts of the original bumper generated a somewhat surprising outcome

Figure 5: Levelling off the tops of the front wheel arches produced the expected result (it does happen sometimes!)

Table 2: The effects of larger, outer fillet infills on the bumper

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.007	-0.009	-0.010	-0.001	-0.85%	-0.015

Table 3: The effects of flatter front wheel arch tops

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.003	+0.004	+0.005	-0.001	-0.83%	+0.013

Table 1 as changes to coefficient (and %front) values, or delta (Greek letter Δ) values, relative to the baseline configuration with its 2015 splitter.

So, a modest increase in front downforce was achieved with this modification for no increase in drag, always a good cause for celebration. Downforce at the rear wheels reduced a little, probably just by the mechanical effect of a change ahead of the front axle, and overall the balance shifted forwards (%front increased). Like previous front wheel drive touring cars we have analysed in Aerobytes, the Mercedes had a very high %front value.

That a tangible front downforce gain was achieved by this modification makes it worth pondering on possible mechanisms.

The horizontal recess above the splitter in the original configuration was in an area of high pressure, hence the high pressure both above the lower surface and under the upper surface of the recess might have been expected to cancel out. So why did the infill create an increase in front downforce? Presumably because inserting the infill shifted the stagnation line on the splitter further forwards (this is where the flow divides to go over or under the car).

This in turn would see more mass flow pass under the splitter than previously, which in turn would create an increase in velocity and a greater reduction in pressure under the splitter.

The second modification to the bumper saw large fillets taped over the outer, higher parts **(Figure 4)** and the results compared to the configuration with just the lower infill in place are shown in **Table 2**.

So this modification produced quite a different response, with a reduction in drag but also a reduction in front downforce.

However, the combination of these first two modifications still saw the front downforce slightly higher than the baseline trim, but drag was between 1.5 per cent and 2.0 per cent lower overall, which was the direction in which Ridgway wanted to head.

The mechanisms for the reduction in drag and downforce may have been down to the dive-plane-like devices on the outer parts of the original front bumper being covered up by the outer fillet infills. Dive planes create downforce but often with a drag increment, so perhaps smoothing over this section of the bumper simply took their draggy downforce out of the picture.

NGTC regulations also permit 'stylised front and rear wheel arch extensions', a statement providing room for manoeuvre

NGTC regulations also permit 'stylised front and rear wheel arch extensions', a statement providing room for manoeuvre! The Mercedes was thus fitted with flatter tops to its front wheel arch extensions **(Figure 5)**, and the effects are shown in **Table 3**. As might be expected from another fairly subtle shape change, the effects of this modification were quite modest, but nevertheless, drag decreased and front downforce increased.

The mechanism here is quite simply explained. The convex upper surface of a wheel arch generates low surface pressure by accelerating the airflow over the top. So terminating the convexity sooner shortened the low pressure region, which saw less lift created here, resulting in more front downforce; and the rearward facing component of the arch's upper surface was eradicated, which meant the drag increment from here was also eradicated.

Next month: More detail changes on the Wix Racing BTCC Mercedes A Class.

Racecar Engineering's thanks to James Kmieciak at Percam Engineering, Nigel Rees at GSD Racedyn, and all at Wix Racing.

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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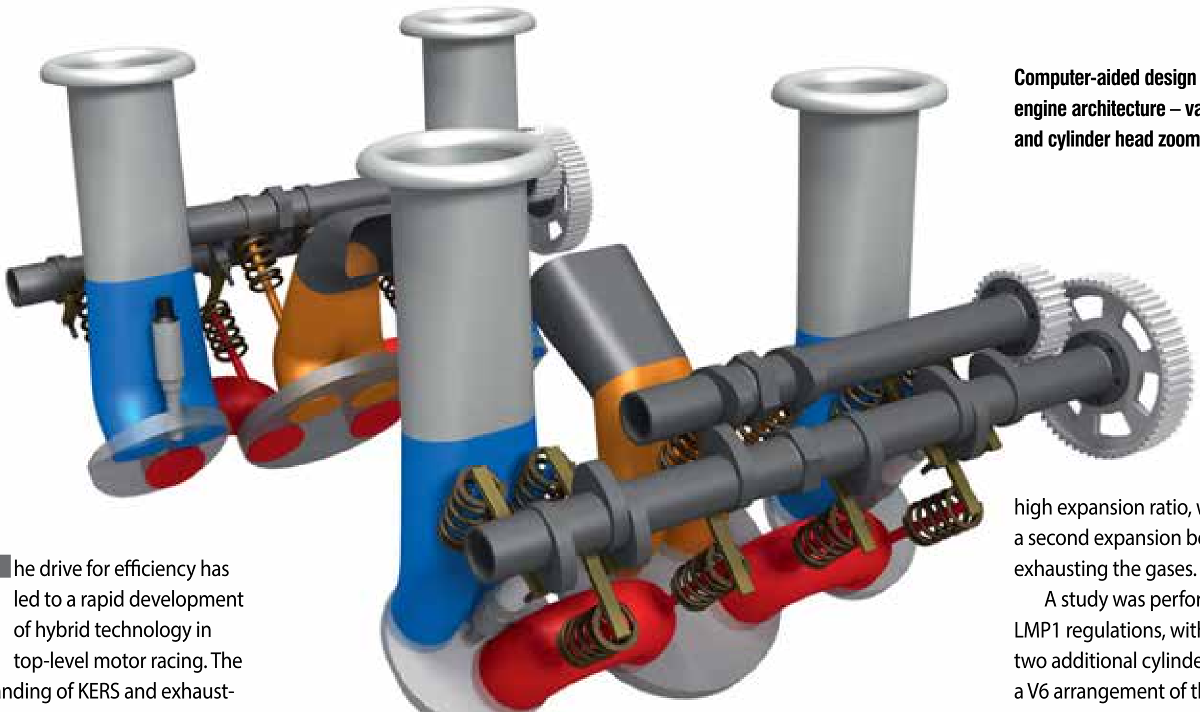
Efficiency drive

With F1 and the World Endurance Championship striving for efficiency, Cranfield University student Fabien Fiquet questions whether or not a 5-stroke engine is an option



Computer-aided design of 5-stroke engine architecture – valvetrain and cylinder head zoom

The drive for efficiency has led to a rapid development of hybrid technology in top-level motor racing. The understanding of KERS and exhaust-driven energy recovery systems has increased dramatically this year alone but there is another option, one that has been investigated and dismissed by manufacturers for now, and that is the 5-stroke engine.

When the rules were being written for the World Endurance Championship, both Porsche and Audi were in favour of allowing such technology. It was not that either wanted to bring it to the track – both had other solutions that better served their purpose – but neither wanted the idea made illegal in case a manufacturer in future was able to make it work.

The FIA considered that it already had enough of a challenge to perfect the Equivalency of Technology factor, a balance of technology between petrol and diesel, and the different energy storage categories, and so stipulated in the regulations that 'only petrol and diesel 4-stroke engines with reciprocating pistons are permitted', yet the ACO's general manager, Vincent Beaumesnil, confirmed that 'if some day it comes, then we will have a look at it'. Yet, already there is a loophole. The 5-stroke engine takes the exhaust gas from the cylinders and re-uses the energy in an extra stroke. This, it could be argued, is an exhaust gas energy recovery system and could therefore be permitted afterall.

Audi could not use a 5-stroke system as, it says, there are more efficient ways of producing energy through its VTG turbo. However, Porsche's 2.0-litre, four-cylinder engine uses a turbo wastegate and therefore benefits more from a 5-stroke configuration.

Yet the company chose instead to concentrate on a KERS system from the front axle, and was the only one of the three manufacturers in LMP1-H to adequately develop an MGU-H as its second ERS. So, why would Porsche dismiss a technology that offers an improvement of Brake Specific Fuel Consumption when the regulations are looking for just such an effect?

Former Cranfield University student Fabien Fiquet looks at the advantages and disadvantages of the 5-stroke racing engine.

A 4-stroke deficiency

The weak link in the energy transformation chain of the power unit is the 4-stroke internal combustion engine. One efficiency limitation is its identical compression and expansion ratio, where the latter would ideally be higher to extract more work. However, in pressure charged engines, the compression ratio is limited to prevent abnormal combustions and knock. The 5-stroke engine concept, patented by Schmitz, enables an extended expansion ratio. The concept relies on two cylinders performing a 4-stroke cycle that transfer their exhaust gases alternatively to an additional cylinder. This additional cylinder features a high expansion ratio, which allows a second expansion before exhausting the gases.

A study was performed, based on LMP1 regulations, with a V4 featuring two additional cylinders, constituting a V6 arrangement of the 5-stroke engine. By way of a 4-stroke engine baseline, the Porsche 919 LMP1 V4 engine was used. Its specifications were interpreted by the author with support from Cosworth engineers. The two engines were simulated using AVL Boost 1D modelling software and the results obtained were compared at full load.

Simulation results suggested BSFC gains of more than 10g/kWh from 2000 to 6000rpm, down to 207.6g/kWh at 4000rpm, a 7.7 per cent reduction. The efficiency gains were positive up to 7000rpm, whereas BSFC at higher speed were degraded due to higher frictional losses and 5-stroke engine design limitations. The 5-stroke was more efficient up to 7000rpm with a friction torque twice that of the 4-stroke engine.

The widely used and developed four-stroke engine presents limitations on achieving higher efficiency due to its Otto cycle base. This is because the compression ratio and expansion ratio are linked

A 2.0-litre, 4-cylinder engine would stand to benefit

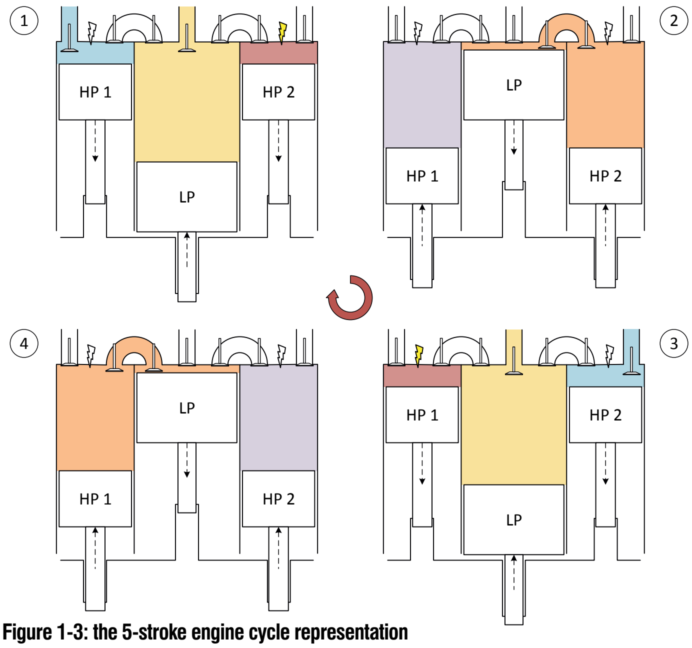


Figure 1-3: the 5-stroke engine cycle representation

Table 1-1: the 5-stroke engine cycle steps

Stroke Ndeg	High Pressure Cylinder 1	Low Pressure Cylinder	High Pressure Cylinder 2
1 (0deg-180deg)	A- Intake of charge	F- Exhaust of gases	C- 1st Expansion of gases
2 (180deg-360deg)	B- Compression	E- 2nd Expansion of gases	D- Transfer to LP cylinder
3 (360deg-540deg)	C- 1st Expansion of gases	F- Exhaust of gases	A- Intake of charge
4 (540deg-720deg)	D- Transfer to LP cylinder	E- 2nd Expansion of gases	B- Compression
	A-F: fluid flow path of cylinder 1		A-F: fluid flow path of cylinder 2

Table 2-1: Porsche LMP1 V4 2.0-litre engine specifications

RPM Range	[1/min]	2000 to 9000	
Displacement	[cm3]	2000	
Number of Cylinders	[-]	4 – in 'V'	
Compression Ratio	[-]	11.0:1	
Bore	[mm]	90	
Stroke	[mm]	78.6	
Bore/Stroke Ratio	[-]	1.145	
Mean Piston Speed at 9000rpm	[m/s]	23.6	
Connecting Rod Length	[mm]	157.2	
Intake Valve Diameter / Max Lift	[mm]	33.4 / 13.50	
Exhaust Valve Diameter / Max Lift	[mm]	27.4 / 11.50	
Intake Valve Opening / Duration	[deg]	20deg BTDC / 260deg	
Exhaust Valve Closing / Duration	[deg]	15deg ATDC / 270deg	
Intake Plenum Volume	[L]	2.0	
Firing Order	[-]	Left bank C2-180deg C1-0deg	Right bank C4-540deg C3-360deg
FMEP	[bar]	2000rpm	9000rpm
		1.0	2.26
Crankcase Pressure [20]	[bar]	2000rpm	9000rpm
		0.433	0.968
Turbocharger	[-]	Garrett GT3582R	
Compressor : Trim – A/R	[-]	56 – 0.70	
Turbine : Trim – A/R	[-]	84 – 0.82	

Table 2-2: 1D engine simulation boundary conditions and fuel properties

Ambient Pressure	[Pa]	101245
Ambient Temperature	[K]	293.15
E20 LHV	[MJ/kg]	40.019
E20 A/Fstoichio	[-]	13.35

and equal, due to the kinematics of the piston. From a thermodynamic examination, a dissociation of these two ratios is favourable for increased thermal efficiency, and superior energy output is achieved with increased expansion ratio relative to compression ratio. The use of high compression ratio in a 4-stroke SI engine is limited principally by abnormal combustions (knock), mechanical and thermal stresses.

This is further pronounced when forced induction is used. Then, it is necessary to lower the compression ratio and by consequence, lower the expansion ratio too, leading to reduced indicated efficiency as shown below by the theoretical Otto cycle efficiency:

Equation 1: $\eta_T = 1 - \frac{1}{\varepsilon^{\gamma-1}}$

This introduces the need for dissociated compression and expansion events. The compression ratio would be chosen to be the maximum that enables the combustion of the mixture without knock under high pressure forced induction conditions, whereas the expansion ratio would be maximised to deliver more work to the crankshaft.

5-stroke success?

The five-stroke engine concept follows the cycle represented by **Figure 1-3** in association with **Table 1-1** explaining the gas flow path of each cylinder. As can be seen from **Table 1-1**, the two high pressure cylinders are phased by 360deg in the 4-stroke cycle, whereas the low pressure cylinder is proceeding a 2-stroke type cycle, hence producing work every crankshaft revolution from the second expansion. As a consequence, the exhaust valve in the low-pressure cylinder of the 5-stroke engine is opened once per crankshaft revolution, giving a camshaft rotating at the same speed as the crankshaft.

In addition to the greater overall expansion process, the 5-stroke engine is designed to use a high level of forced induction. In fact, by using a low compression ratio for the high-pressure cylinders, it allows a wide range of pressure boost levels.

This can be used to control the engine load via a closed loop control of the wastegate. This avoids the use of a throttle device, hence minimising the pumping losses, which is favourable for higher efficiency. The 5-stroke engine enables the use of a variable geometry turbocharger as the exhaust temperature after the second expansion is lower than the 850degC limit for VGT durability.

A sensitivity analysis, based on the maximum fuel flow allowed in the 6MJ category chosen by Porsche demonstrated that an improvement of 0.005 points (0.5 per cent) on the BTE level, considering a LHV of 40MJ/kg, led to a power rise of 4.97kW. According to Porsche, more than 370kW is developed by the engine, resulting at maximum fuel flow in a 37.2 per cent BTE or 242g/(kW/h) BSFC. The technical regulations put no restriction on engine speed and displacement. This can be used as a lever to increase power, but in reality is restricted by power losses due to friction and pumping losses. Then, downsizing, by the use of fewer cylinders with lower unity displacement, is possible as high inlet air density is achievable thanks to high pressure ratio allowed. Ways to improve fuel conversion efficiency can be by the choice of SI or CI engine, but also due to no limitations on compression ratio, injection type (PFI or DI), fuel pressure, and so on. The breathing quality is partially limited by the prohibition of variable valve systems, which could improve volumetric efficiency and reduce pumping losses. Finally, the fuel to air ratio can be tuned freely to match targets while staying within fuel flow and energy spent per lap limitations.

LMP1 technical regulations oblige the use of a fuel constituted of a blend by volume of 20 per cent of ethanol and 80 per cent of petrol, known as E20. E20 fuel differs from petrol by its lower LHV but also lower stoichiometric A/F ratio, which

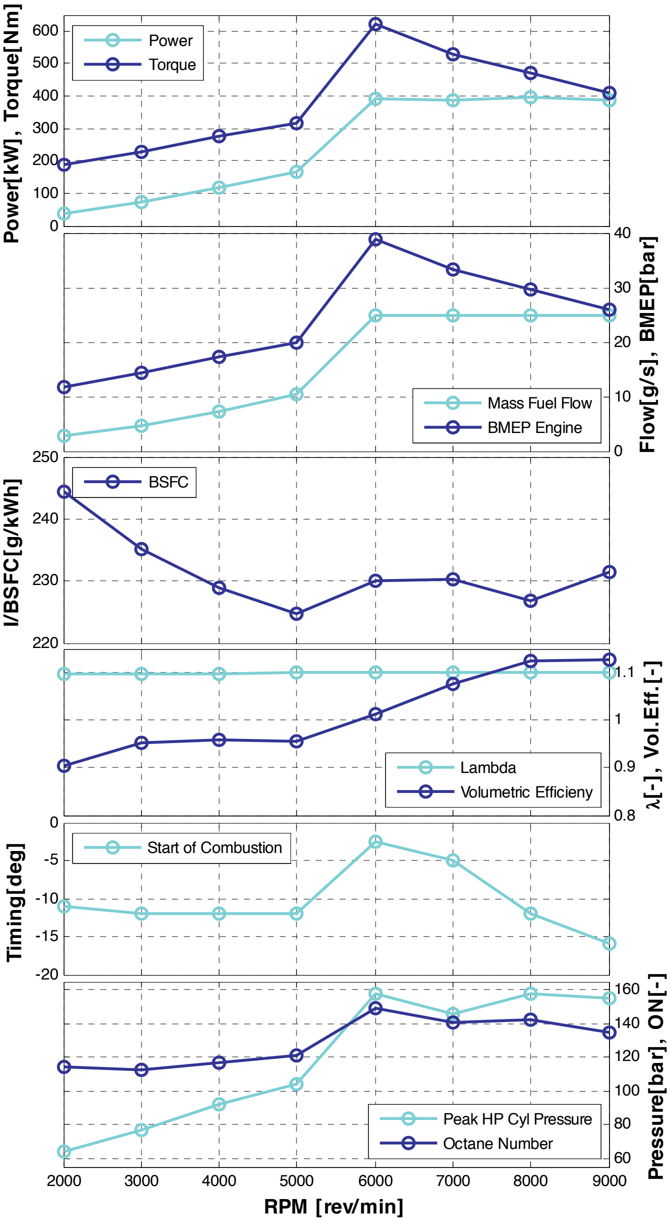


Figure 2-1: performance indicators of the Porsche LMP1 V4 2.0-litre engine

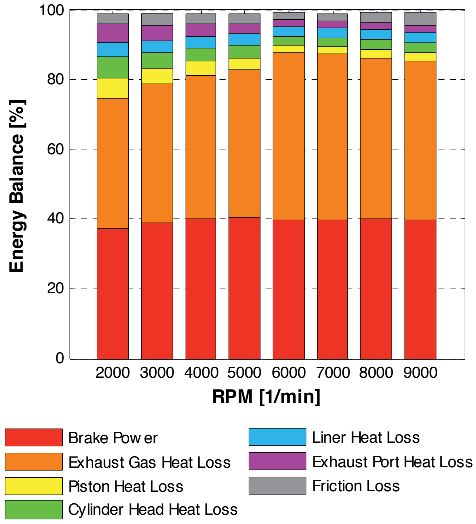


Figure 2-2: Porsche LMP1 V4 2.0L energy balance

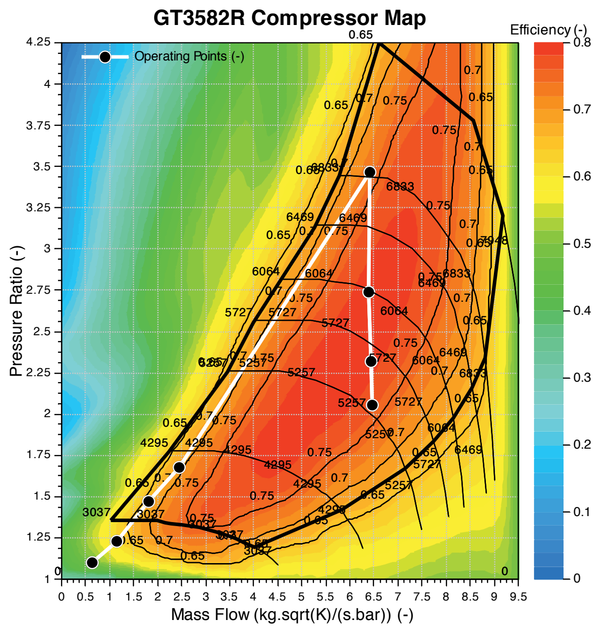


Figure 2-3: Porsche LMP1 V4 2.0-litre turbocharger GT3582R operating points

provides equal energy content per kilogram of the stoichiometric mixture. The heat of vaporization is 1.4 times higher and helps to cool the in- cylinder charge. It also has a higher RON. The last two parameters are beneficial to minimise knock occurrence and this enables the use of a higher compression ratio or boost level.

Comparison test

The pros and cons induced by the 5-stroke engine make sense only if a direct comparison is realised against a modern LMP1 racing engine. Therefore, it was decided to model the Porsche V4 2.0L turbocharged engine, which constituted the adequate baseline for benchmark. As for any recent LMP1 engine where no technical information was available, a pre-sizing was realised to determine the possible engine specifications. The relevance of the parameters used was discussed and confirmed with the support from Cosworth engineers, benefiting from their experience. However, most of the specifications used couldn't be confirmed and were by consequence the main assumptions of this work. An overview of the engine specifications used is presented in **Table 2-1.**

The simulations of the 4-stroke and 5-stroke engines were done with the same boundary conditions and the same E20 fuel, as shown in **Table 2-2**. Furthermore, the combustion and heat transfer models used were identical for both engines.

The simulation performed with AVL Boost at full load gave after multiple refinements the performance indicators presented in **Figure 2-1**. The results obtained were relevant as they matched with the performances announced by Porsche, and they followed the LMP1 technical regulations. In fact, the maximum fuel flow was 89.5kg/h and was exceeded at maximum by 0.09 per cent. The maximum pressure ratio was 3.5, which was below 4.0 as seen in **Figure 2-3**. The engine was operated at lambda 1.10 and peak cylinder pressures were below 160bar. As targeted, the engine showed constant power from 6000 to 9000rpm, with a peak value of 395kW, which was 25kW more than the minimum announced by Porsche. However, the BMEP level of 38.9bar at 6000rpm may be unrealistic as Mahle engineers obtained combustion instabilities and misfires at 36bar. Regarding efficiency, as represented in **Figure 2-2**, BTE of around 40 per cent were obtained as expected. However, the energy lost through exhaust gas as heat seemed overpredicted as it reached values comprised between 37 per cent and 48 per cent. On the other hand, heat transfer through the walls seemed underpredicted.

So the heat transfer model would require further refinement to obtain a correct energy balance correlated to experimental data.

Comparing 5-stroke

The previously sized and modelled 4-stroke engine was used as a baseline for the 5-stroke engine. The HP cylinders were kept identical, as well as the operating conditions and design constraints, in order to obtain relevant comparisons. Hereafter

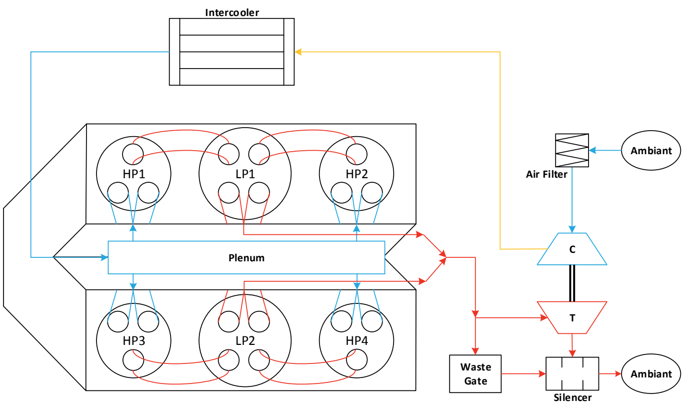


Figure 3-2: 5-stroke engine layout 1, with sideway transfer port, intake and exhaust ports inside the V

Table 4-2: AVL boost 5-stroke engine FMEP model used

RPM	[rev/min]	2000	3000	4000	5000	6000	7000	8000	9000
FMEP	[bar]	0.75	0.87	0.99	1.125	1.26	1.405	1.55	1.695

Figure 4-1:

$$FMEP_{5S}[bar] = \frac{4\pi \cdot T_{friction-5S}[Nm]}{100 \cdot V_{d-5S}[L]} = 0.75 \cdot FMEP_{4S}$$

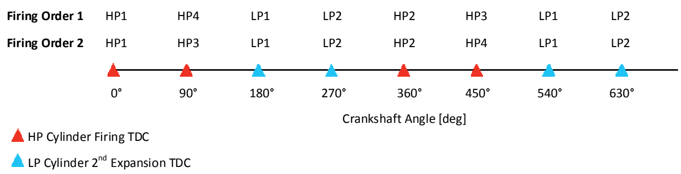


Figure 3-8: 5-stroke engine firing order for a V6 at 90deg with shared crankpin axis for two cylinders on the same 'V'

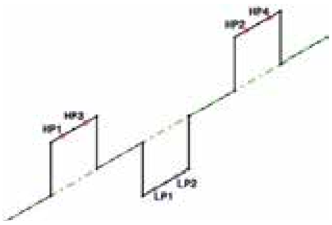


Figure 3-5: 5-stroke engine crankshaft architecture for a V6 at 90deg with shared crankpin axis for two cylinders on the same 'V'

Table 3-1: low pressure cylinder characteristic parameters

Displacement	[cm3]	1000
Bore	[mm]	127.28
Stroke	[mm]	78.6
Expansion Ratio	[-]	45.0:1
Connecting Rod Length	[mm]	157.2

are presented the engine design specifications selected and used for its modelling.

The 5-stroke engine designed was a V6 with banks inclined relatively at 90deg for the following reasons:

- **The specifics of the cycle steps of a 5-stroke engine (cylinder phasing)**
- **The most compact configuration allowing sufficient cylinders to achieve BMEP levels high enough for LMP1 application, compared with a I3, I5 or I6**
- **The 'V' structure is desirable for racing application as the engine is a stressed member, giving higher torsional stiffness compared with an in-line engine, where the V design also fits well within the chassis**
- **To keep the crankshaft design simple, with shared crankpin axis for two cylinders on the same 'V'**

The selected architecture was the sideways transfer port with the intake and exhaust inside the V angle of the engine. This was to have the shortest transfer ports, valuable to minimise engine dead volume, therefore gaining efficiency points, and allowed the fitment of the turbocharger inside the 'V', therefore minimising exhaust manifold lengths which was beneficial to feed the turbine with high energy exhaust flow pulses and to reduce heat losses and obtain the narrower engine configuration giving potential aerodynamic gain for the rear of a LMP1 car.

The drawbacks were the potentially higher CoG, the layout was less flexible packaging for piping, and the more complex thermal management of the engine bay as everything is confined into a compact block. The firing orders possible were dependant on the architecture of the crankshaft and 'V' angle.

For the purpose of this study, the crankshaft layout used was the one from **Figure 3-5** for its simplicity, compactness, and shorter transfer ports usable, at the expense of an odd firing order. Also, this would allow the manufacture of a simple crankshaft for an eventual prototype to be realised, hence minimising engine complexity and cost, while not reducing reliability crucial for endurance racing.

The firing order chosen was the ndeg1 from Figure 3-8 as a starting point as the balancing of the engine was not studied.

The LP cylinder parameters used in this study are presented in **Table 3-1**. It was decided to keep the HP and LP cylinder crankshaft throw, deck height and compression height equal, for packaging considerations and to give boundaries to the study. A LP over HP cylinder unity displacement ratio of 2.0 was used. The expansion ratio of the LP cylinder was one of the key parameter and a value of 45.0:1 was used, based on clearance volume measurements realised by a CAD model. The latter offered an ER potential over 150.0:1 due to the assumptions taken, but a closer value to the 30.0:1 ER used by Danielson Engineering seemed more realistically achievable.

The transfer port allows the HP cylinder to transfer the exhaust gas to the LP cylinder proceeding simultaneously to the second expansion. Its volume should be minimised to reduce the engine dead volume, while maximising its cross section area to allow high flow. The parameters from **Table 3-2** were used and obtained by CAD model measurements.

The 5-stroke engine FMEP values from Table 4-2 were lower than the ones used for the 4-stroke engine as the displacement of the 5-stroke engine was two times higher, but the friction torque assumed was 1.5 times higher as illustrated by **Figure 4-1**. The performance indicators presented in **Figure 5-1** may also be improved with further time and research dedicated to the project. Therefore, it should be reminded that they are not representing the absolute limits of the concept.

Firstly, it can be seen from **Figure 5-1** and **Figure 5-2** that the engine was operating within the LMP1 technical regulations of the 6MJ category and constraints decided with engineers from Cosworth. Indeed, the engine was run at lambda 1.10 and the maximum fuel flow didn't exceed the 24.9g/s limit, thanks to the PID controller, while keeping the boost pressure ratio below 4.0, with the same GT3582R turbocharger. Also, the ignition timing was set to maintain the peak cylinder pressure below 160bar, which was only exceeded at maximum by 0.84 per cent at 8000rpm.

The simulations suggested that the peak power attainable with this V6 5-stroke engine was 401kW (538hp) at 7000rpm, leading to a BSFC of 223g/kWh. This was also where the peak torque of 547Nm was obtained. Therefore, this may led to a peaky engine to drive, as the maximum power wasn't constant up to 9000rpm, but dropped down to 357kW. The operating range of the engine should be carefully selected in association with the number of gears and their ratios. Besides, even lower BSFC levels were achieved at lower rpm, down to 208g/kWh at 4000rpm, where the 5-stroke engine seemed to deliver the maximum of its efficiency potential. In fact, the BTE achieved at this operating point with E20 fuel was 43.1 per cent. It should be

This would allow the manufacture of a crankshaft for an eventual prototype to be realised, hence minimising engine complexity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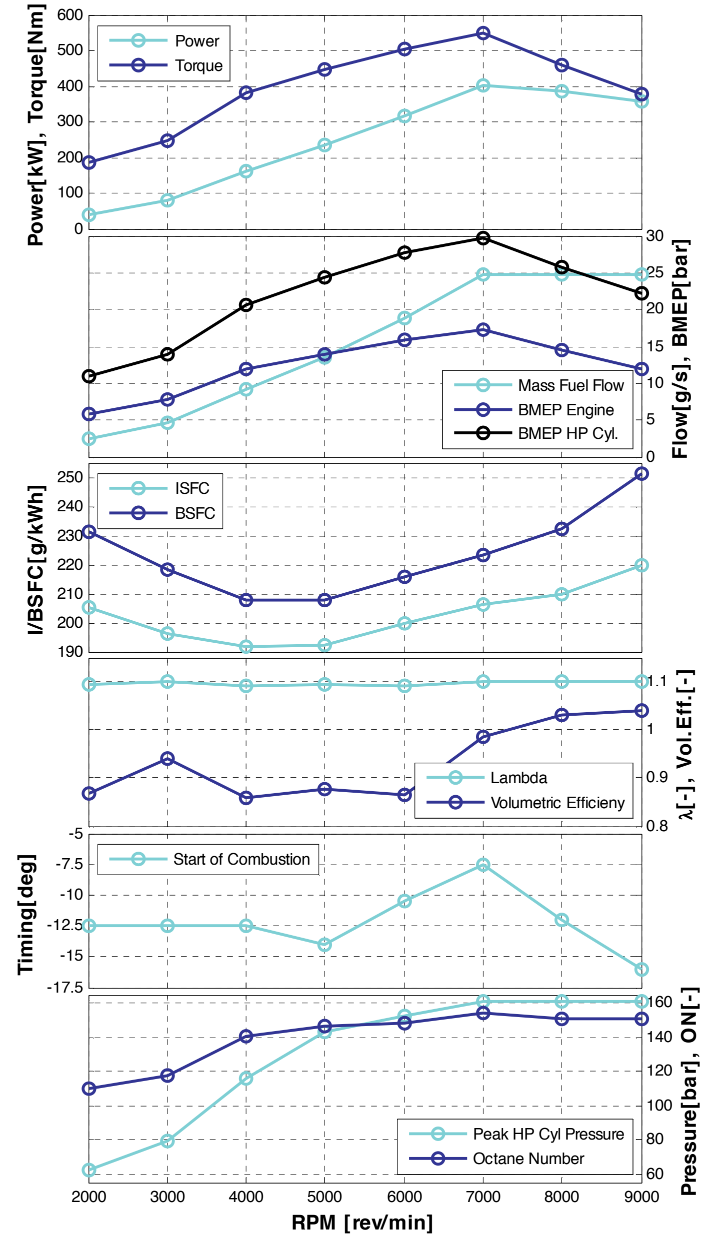


Figure 5-1: performance indicators of the 5-stroke engine V6 turbocharged

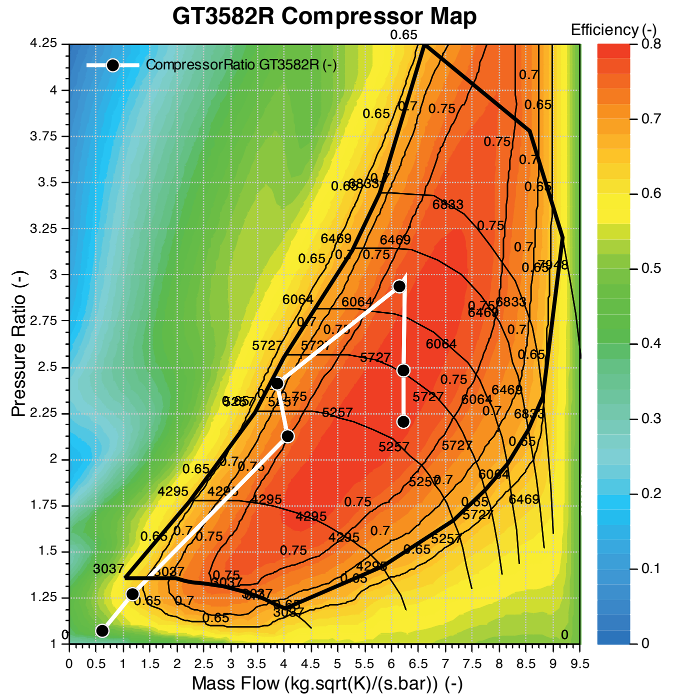


Figure 5-2: 5-stroke engine turbocharger GT3582R operating points

Table 5-1: comparison of benchmarked 5-stroke engine BSFC results obtained via simulations and dynamometer testing

	BSFC	RPM	Boost Pressure	Comments
Sources	[g/kWh]	[1/min]	[bar]	(*simulation)
G. Schmitz	192.9*	4000	3.9	Simulation, Own Code
ILMOR Engineering	232.5	4000	1.45	Dyno test
	217*	3750	-	Simulation GT Power Before prototype test
Danielson Engineering ID-MOTION	226	4000	1.632	Dyno test First prototype results
	203*	4000	1.75	Simulation GT Power After prototype test
Unknown German Car OEM	204*	-	-	Simulation GT Power
Author's Study	207.6*	4000	2.09	Simulation AVL Boost

mentioned as well that the BMEP of the engine was overall below 18bar, which seemed very low for this type of engine. This was because the displacement of the LP cylinders were also considered, giving a 4.0-litre engine, with only 2.0-litre of fired cylinders.

As can be seen from **Table 5-1**, information gathered for the benchmark were not fully explicit and therefore the comparison is not straightforward. The results obtained from the simulation at 4000rpm were close to the simulation results established by these companies. Moreover, the BSFC achieved was higher than Danielson Engineering and the undisclosed German car OEM. They both obtained more optimistic results than the BSFC realised by experimental tests.

Therefore, the 207.6g/kWh obtained using DI and E20 seemed to be a realistic value, also considering the much lower time, resources and experience used for this study compared with these companies.

In addition to BSFC results, work per cycle produced by HP and LP cylinders could be found, as seen in **Table 5-2**.

It could be observed that the work distribution obtained was in between the simulations from Schmitz and the experimental values from Danielson Engineering. Also, the total amount of work produced per cycle was much higher as it included four HP cylinders and two LP cylinders compared to respectively two and one for the benchmarked sources. Moreover, the engines were designed for less extreme operation than required by motorsport, where Danielson Engineering used its engine as a range extender for hybrid cars. All of this explained the high work per cycle obtained. Therefore, it was not clear if the simulation model performed well in term of work per cycle distribution between HP and LP cylinders, but from what it could be compared with, the results obtained were within an acceptable range.

Overall, the engine model seemed to predict reasonable results based on the previous comparisons realised with benchmarked data. Other studies showed that the LP cylinder displacement, the transfer port and valves diameters, and the FMEP were the most sensitive parameters. Unexpectedly, the LP cylinder expansion ratio was found to be the less responsive parameter.

Comparison test

The 5-stroke engine appeared more likely to be a promising concept for efficient operation, while maintaining performances relevant for motorsport applications, as illustrated by **Table 6-1** and **Figure 6-1**. The first noticeable element was the increase in performance level at speed below 6000rpm, but which were reduced where higher speed

Table 5-2: comparison of benchmarked 5-stroke engine work per cycle distribution results obtained via simulations and dynamometer testing

	WorkHP	WorkLP	WorkTotal	WLP/WTotal
Sources		[J/cycle]		[%]
G. Schmitz	531.6	200.3	731.9	27.4
Danielson Engineering	950	86	1036	8.30*
Author's Study	4340	860	5200	16.54

**Calculated from PV diagram of experimental test*

Table 6-1: best performance indicator values comparison between 4-stroke and 5-stroke engine at full load

		4-Stroke	5-Stroke	Difference (net)	Relative Difference
Power	[kW]	394.57 8000rpm	401.25 7000rpm	+6.68	+1.69%
Torque	[Nm]	619.64 6000rpm	547.38 7000rpm	-72.26	-11.66%
BMEP HP	[bar]	38.93 6000rpm	29.65* 7000rpm	-9.28*	-23.84%*
BMEP LP	[bar]	0	4.74 7000rpm	+4.74	N/A
BMEP Eq**	[bar]	38.93 6000rpm	34.39 7000rpm	-4.54	-11.66%
BSFC	[g/kWh]	224.82 5000rpm	207.60 4000rpm	-17.22	-7.66%
ISFC	[g/kWh]	209.01 5000rpm	191.79 4000rpm	-17.22	-8.24%

**The additional work produced by the LP cylinder isn't counted in this comparison*

*** BMEP Equivalent: BMEP considering the engine torque but only the HP cylinders displacement*

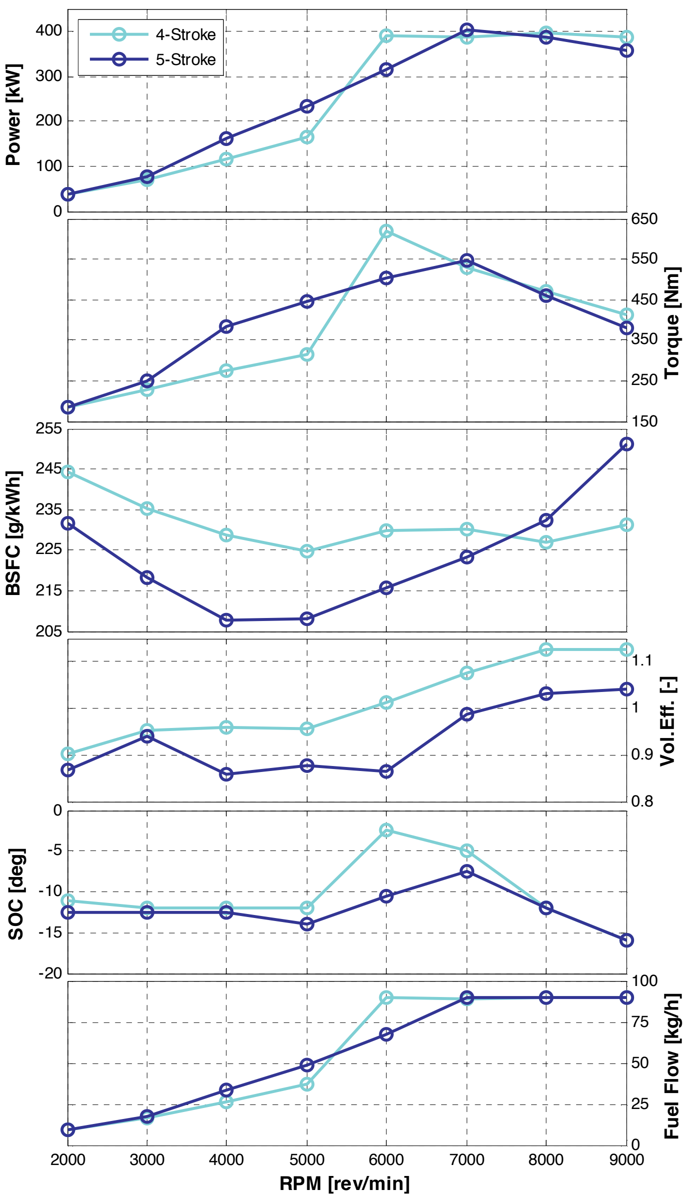


Figure 6-1: Comparison of 4-Stroke and 5-Stroke Engine Performance Indicators (both engines running at λ=1.10 at each rpm

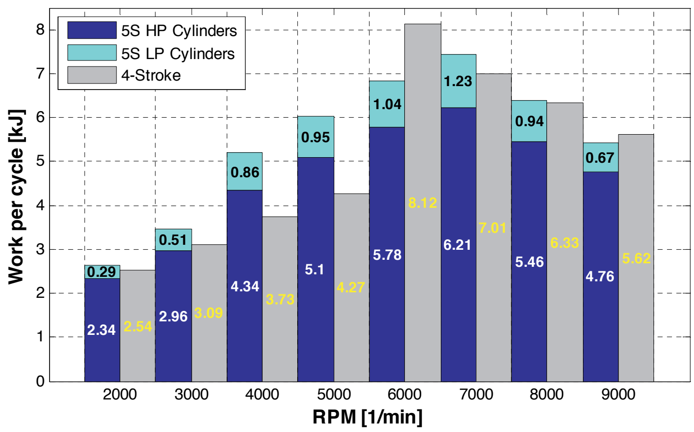
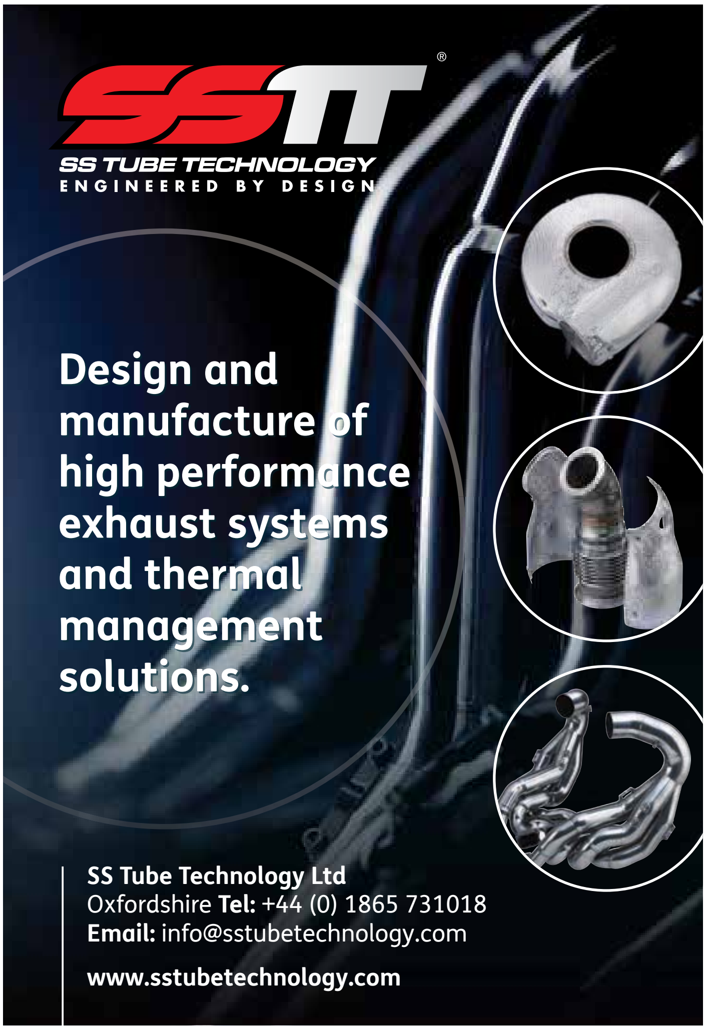


Figure 6-4: indicated work per cycles produced by HP and LP cylinders

was concerned. In fact, at and above 8000rpm, torque was reduced, and because the fuel flow was equal, BSFC increased. Therefore, from the simulation performed, the 5-stroke engine was more adequate for relatively low speed operation, up to 7000rpm where peak power and torque were obtained. The increase in power at 7000rpm was less than 2 per cent, therefore it was negligible as the simulation might have over or under estimated one of the engines. However, the power drop at 9000rpm compared to the 4-stroke engine may be manageable. In fact, as long as enough power is available to overcome the aerodynamic forces, running at 9000rpm would help to increase the car top speed for a given gearbox. However, the car acceleration potential would be reduced compared to the 4-stroke engine at this rpm Therefore, a compromise between engine operating range and the number of gear and their ratios should be found. The engine performance should also be balanced with all the transient operations, when accelerating from 5000rpm to 7000rpm, for example, where much lower fuel consumptions were achieved, with possible reduction of 7 per cent. All of this should be analysed in close collaboration with the vehicle dynamics and race strategy departments, in order to find which of the engines are the most suitable as a whole for the overall car performance over an endurance race.

Another element to point out was the much wider constant power band obtainable with the 4-stroke engine, where around 390kW was obtained from 6000 to 9000rpm. This was one disadvantage discovered for the 5-stroke engine. On one hand, very high rpm was penalised by the flow restriction introduced by the transfer port, by the reduced volumetric efficiency due to the different valve timings (used to cope with the interactions between HP and LP cylinders) and by the higher friction level. On the other hand, at 6000rpm, lower torque was attained as less energy was available to feed the turbine which led to lower boost level and fuel flow reachable. Therefore, the HP cylinders BMEP was degraded as seen in **Figure 5-1**. The lower energy available at the turbine inlet was due to the LP cylinder converting this energy into work by the second expansion, before exhausting the remaining. However, the amount of work produced by the LP cylinders was not high enough to compensate with the reduction in boost pressure, diminishing the HP cylinders work production. The difference in HP cylinders work production was higher than the work produced by the LP cylinders, which explained the reduced torque compared to the 4-stroke engine. This is also where the introduction of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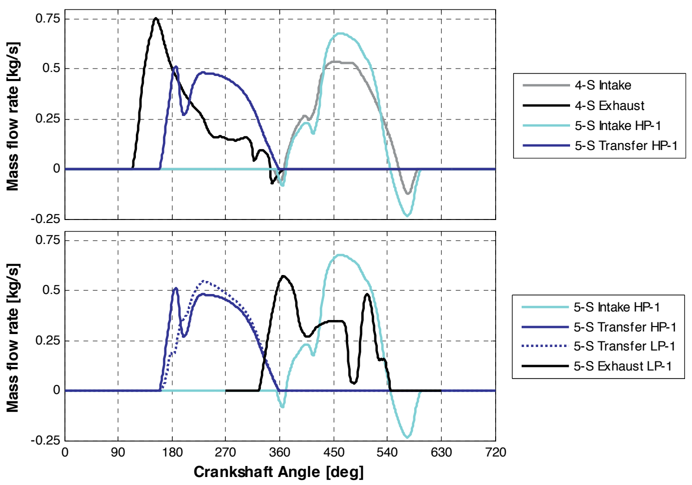

Figure 6-6: 4-stroke and 5-stroke engine valve flow comparisons at 7000rpm (top graph) and 5-stroke engine valve flows at 7000rpm (bottom graph)

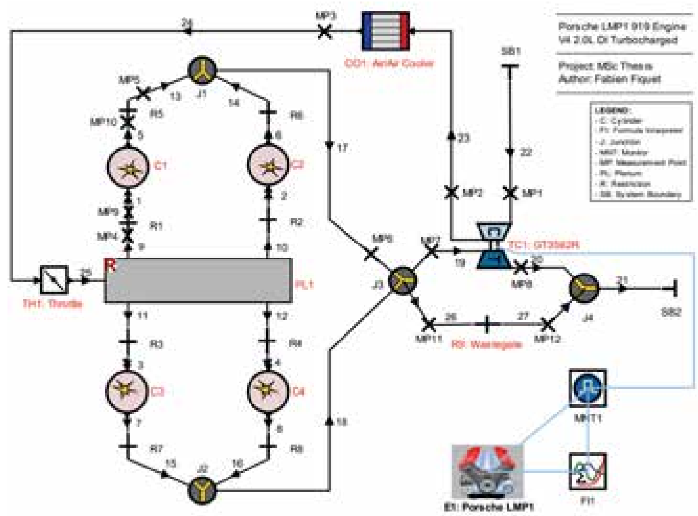

Figure 6-1: Porsche LMP1 V4 2.0-litre turbocharged – 1D engine AVL boost model

Table F-3: 5-stroke engine work per cycle distribution over HP and LP cylinders

	Work per cycle per cylinder & total [J]							% of Total Work	
RPM	HP1	HP2	LP1	HP3	HP4	LP2	Total	%HP	%LP
2000	586	584	148	586	584	141	2629	89.01	10.99
3000	729	729	253	751	751	257	3468	85.31	14.69
4000	982	1010	360	1170	1180	500	5201	83.47	16.53
5000	1191	1248	464	1340	1315	484	6043	84.32	15.68
6000	1415	1431	575	1486	1452	465	6824	84.76	15.24
7000	1520	1520	677	1586	1586	551	7440	83.49	16.51
8000	1392	1392	578	1337	1337	365	6401	85.27	14.73
9000	1222	1222	457	1159	1159	213	5433	87.66	12.34

Table F-4: 4-stroke engine work per cycle distribution

	Work per cycle per cylinder & total [J]				
RPM	HP1	HP2	HP3	HP4	Total
2000	660	609	659	609	2538
3000	758	789	757	788	3092
4000	911	957	909	957	3734
5000	972	1164	968	1162	4265
6000	1980	2080	1981	2081	8122
7000	1714	1789	1716	1790	7009
8000	1584	1580	1586	1581	6332
9000	1387	1419	1389	1420	5615

a Variable Geometry Turbocharger would benefit the 5-stroke engine as exhaust temperatures below 750degC were observed throughout the rpm operating range. Even so, the torque achieved by the 4-stroke engine at 6000rpm may not be physically possible as up to 38.9bar of BMEP was obtained, where instable or incomplete combustion would in reality probably limit the use of the 3.5 boost pressure ratio.

Between 3000rpm and 5000rpm, the volumetric efficiency of the HP cylinders of the 5-stroke engine was lower, and higher fuel flow was seen. However, the 5-stroke engine was still more efficient than the 4-stroke engine that had better breathing and used less fuel. Indeed, the BSFC level was reduced by more than 10g/kWh. This clearly illustrated the advantage of having the LP cylinders producing "fuel-free work". It was also noticed that the 5-stroke engine lowest BSFC was lower than the lowest 4-stroke engine ISFC, at least with the FMEP assumed.

The results presented in **Figure 6-4** illustrated clearly the higher amount of work produced at rpm below 6000rpm, where even higher HP cylinder work was achievable at 4000rpm and 5000rpm compared with the 4-stroke engine, as higher fuel flow could be obtained as seen in **Figure 6-1**. At 6000rpm, the indicated amount of work was higher for the 4-stroke due to higher boost level.

From **Figure 6-6** it could also be seen that the exhaust flow of the 5-stroke was really different from the 4-stroke engine. At the EVO of the 4-stroke engine, the cylinder pressure was much higher than the pressure at the EVO in the 5-stroke engine LP cylinder, which previously realised an additional expansion decreasing the cylinder pressure. Therefore, the exhaust phase didn't benefit from a high pressure ratio between the cylinder and the exhaust port, as usually seen on a 4-stroke engine. Finally, more sensitive and restricted valve timings were observed on the 5-stroke engine.

Conclusion

It was proved that the use of an additional cylinder realising a second expansion of the exhaust gases of a 4-stroke engine cylinder led to a BSFC reduction. The presently developed 5-stroke engine demonstrated a promising potential for motorsport application, but with limitations for the top-end speed range. It was also discovered that the control of the 5-stroke engine was more sensitive and less flexible than a 4-stroke, especially regarding valve timings. This is a consequence of the interaction between the HP and LP cylinders, leading to unusual HP cylinder valve timings, partly decreasing the HP work per cycle produced. So with the 5-stroke, a compromise has to be found between the control leading to the best performances obtainable for the HP cylinders and for the LP cylinders, to achieve the best combination overall.

A potential architecture for the V6 5-stroke engine was also developed. The turbocharger could fit well in the 'V' with its added benefits for the engine operation. The engine could be narrower, leading to possible rear car aerodynamic gains. But it was not possible to investigate all configurations. But it was revealed by the sensitivity analysis that the LP cylinder displacement and transfer port volume were the most sensitive parameters, in addition to the FMEP, contrarily to the LP cylinder expansion ratio. Improved performances may be attainable with different 5-stroke engine specifications. The next step would be to develop a prototype to validate the model and to further explore the 5-stroke capabilities. The engine architecture presented a 90 degree V angle. The intake manifolds were located as on a 4-stroke engine, whereas the exhaust ports were inside the V, feeding the turbine of the turbocharger which fit in the V, exhausting afterwards the gases in engine centreline direction.

For further information regarding Cranfield University and its extensive courses and programmes, please contact motorsport@cranfield.ac.uk
This article is an edited and reformatted version of the thesis the author completed while at Cranfield University

There were limitations at the top end speed range


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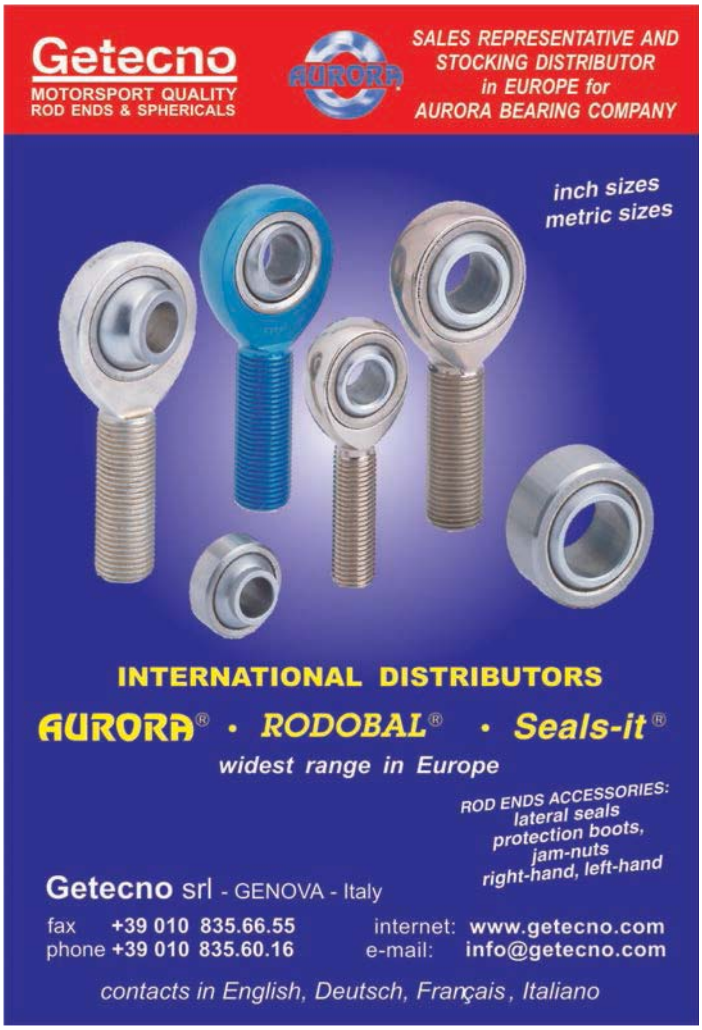
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Building energy

Exhaust gas recovery on a normally aspirated engine has brought application potential at Le Mans, WEC or on the commercial market

By SAM COLLINS

The laboratories of Tokai University contain many interesting projects for the motorsport engineer. Sitting on a four-post rig in one room, for example, is a 1990 Honda Formula 1 car, designed and built in secret by the Japanese firm's engineers. In recent years the establishment has risen in prominence by heavily re-working a Courage LC70 LMP1 car and entering it in the Le Mans 24 Hours in 2008.

The Le Mans project was headed by engine specialist Dr Yoshimasa Hayashi, who had designed and developed his own 4.5 litre V8 engine via his company YGK for use in the project. Once attempts to race the Courage had come to a close little was heard of the programme other than vague reports that it was being used to develop a new hybrid technology. The reports, it turns out, were true.

'I was looking at some basic details of the otto cycle one day and I noticed that there was no progress on working with the heat loss from the combustion process' Hayashi explains. The Otto cycle of the theoretical cycle, the ratio of gas specific heat:

Equation:

(Cp/Cv) = κ, compression ratio = ε

Then indicated thermal efficiency

η = 1-1/ε^κ-1.

'Looking at the values for κ-1, the exhaust loss, I thought why not use the energy recovered from such a big loss?' says Hayashi.

So a little under a year after the Tokai Courage had run at Le Mans, Hayashi, enthusiastically assisted by the engineering students at the university, started to look at ways of improving this. Of course this was something that had already been solved to some extent with the latest generation of competition engines, the four current F1 designs as well as the Porsche LMP1 all feature motor generator units on their turbo chargers, aimed at recovering some of the wasted energy heading down the exhaust pipe.

Notably the Porsche solution does not ever act as a motor to spin up the turbo – rather it is simply a generator unit (GU-H). This is the closest design in concept to what Hayashi was working on, but he wanted to apply it to his normally aspirated V8 engine. With no turbo to connect a GU-H to he had to come up with an alternative way of recovering the energy.

Very much a prototype, the V8 system developed by Dr Yoshimasa Hayashi and his students at Tokai University, in its Jaguar chassis

The YGK EER-Hybrid, as the Japanese concept has been branded, is at least on paper quite simple. A turbine is added to the exhaust pipe which is driven by the exhaust gasses up to 126,000rpm. This in turn drives a generator unit at around 18,000rpm via a reduction gear. But as this is a normally aspirated engine there is no compressor; the turbine is purely there to generate electricity. That electricity then passes via an inverter to a capacitor pack mounted in the passenger seat area of the cockpit. Unlike other LMP1 systems the energy store on the YGK solution is very compact, because the electricity is fed almost constantly to a traction motor mounted between the transmission and engine, though this could theoretically be positioned at the front or rear axle, though with this layout the electric motor acts on the engine's crankshaft, increasing rpm but not fuel consumption. The small size of the energy store is due to the fact that the energy is supplied constantly from the turbine at any point when the engine is running, while most hybrid systems used at Le Mans or in F1 rely on recovering brake energy then having to store it until needed.

The potential energy that can be recovered in such a system is much higher than that of a turbocharged engine due to the much higher exhaust gas velocity, but the lack of turbo in turn creates its own challenges, particularly in terms of thermal management. Hayashi will not be drawn on the exact details but admits that the generator unit runs at about 80degC while the turbine runs at 800degC or more.

Hayashi says one of the system's biggest advantages is its light weight and simplicity: 'The major components of EER-Hybrid are an exhaust turbine, a reduction system for ultra high speed revolution, an intermediate device,

"A turbine is added to the exhaust pipe which is driven by the exhaust gasses up to 126,000rpm. This in turn drives a generator at 18,000rpm"

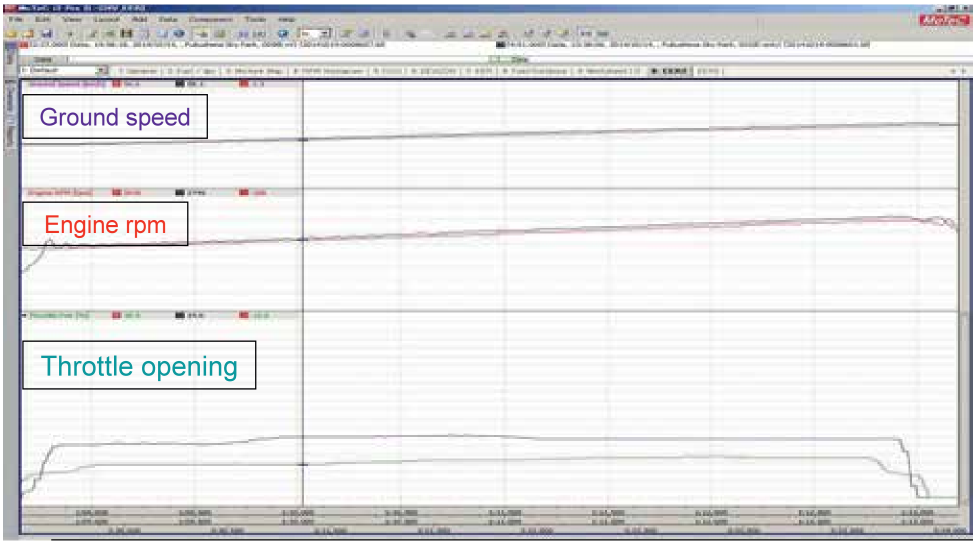

Figure 1: the same engine rpm and vehicle speed could be achieved with a smaller throttle opening. The black trace is from the run with the EER-Hybrid system deactivated and coloured traces are from the runs with the system switched on

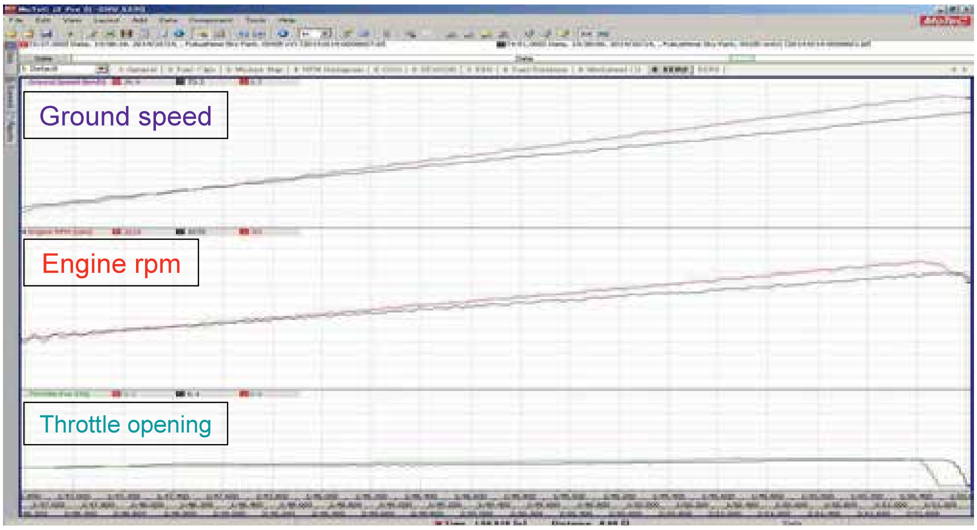

Figure 2: with a constant throttle position the Jaguar was notably faster with the hybrid system engaged

Figure 3: data from Fukushima airport shows the EER-Hybrid's power output and exhaust temperature

Hayashi has discussed the system with the ACO with an eye to it being used at Le Mans

a generator, an MGU, an inverter for generation and drive, and a capacitor, for the development of the test car project. Then we have specially developed the 2kg reduction system and the other parts are not really different from commercial products.'

After seeing early results from the test bench Hayashi decided to resign from his post at Tokai University to continue development of the EER-Hybrid, though still keeps a very close relationship with his former employer. After the bench tests were complete the next stage of the project was to run the system on track so the EER-Hybrid mounted to the YGK V8 was fitted to a Jaguar XJR-15 chassis.

'We had had the car for some time, it was used to for YGK's LMP1 engine 'YR40t' in 2005 for the Tokai University Le Mans project,' Hayashi explains. 'We have still got the LMP1 Courage, but this time we wanted to build the system into something that looked more like a production car. The XJR-15 is a classic car these days but it is still good enough for testing purposes.'

Test runs

During the test runs held at Fukushima airport the Jaguar completed over 100 miles of running and the hybrid system performed well. In the first runs the car was tested at a constant speed and rpm with the hybrid system turned on and off for comparison. These tests showed that the same speed and engine RPM could be achieved with a smaller throttle opening, suggesting an increase in range **(Figure 1)**. The second set of experiments saw back-to-back runs conducted with a constant throttle position, with the hybrid engaged this showed a notable increase in rpm and vehicle speed **(Figure 2)**.

'We found a 25 per cent improvement in efficiency at constant speed, powered by EER-Hybrid. You can make more improvement of fuel economy combined with KERS system using this,' Hayashi states.

Although it is very much a prototype Hayashi hopes the system will become commercially available. 'We will talk to potential customers about the reduction system for ultra high speed revolution. It costs less than 800 euros, but we estimate it will be going down to 10 per cent of the cost if it is put into mass-production as the other parts are similar to typical components,' Hayashi says. With no firm plans for its use in competition yet Hayashi has already discussed the system at length with the ACO with an eye to it being used at Le Mans or in the WEC.

'We do not have a plan for competing in races in 2015, but possibly we will do it the year after,' he says. 'We want to prove the system. It is not difficult to adapt EER-Hybrid to production cars. Nowadays, a Hybrid car already has MGUs, inverters, and batteries, and EER-Hybrid just provides the extra power from emitted exhaust gas energy by a N/A engine. We hope that it will be adopted by any interested world car and engine manufacturer.'


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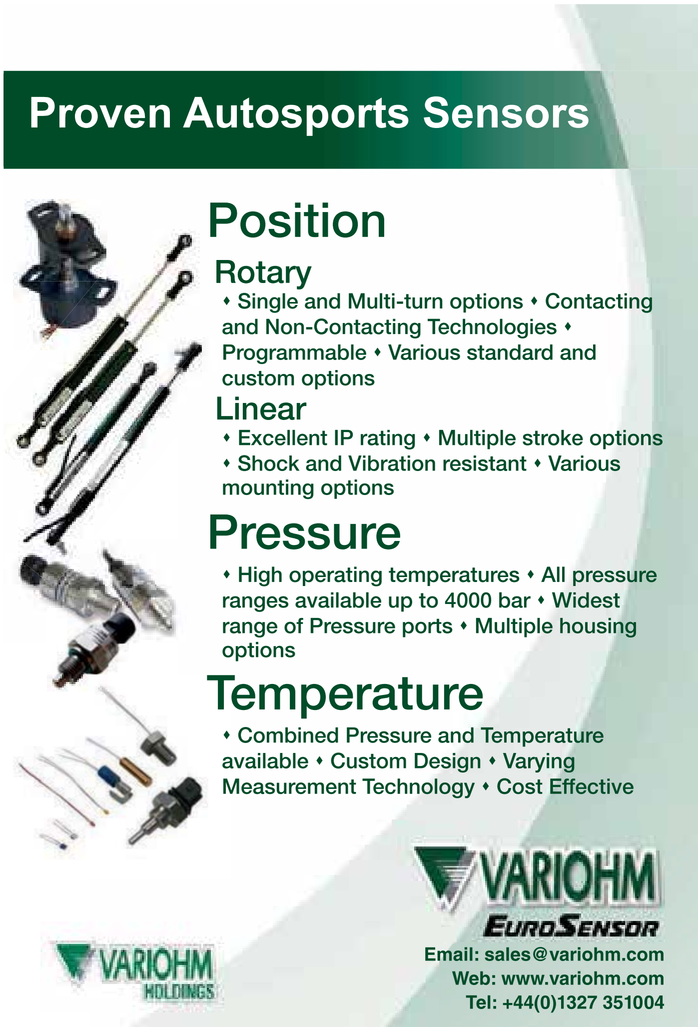
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When the going gets tough

If a car is easy to model you can work your way around calibration, but your engineering skill will be tested

By DANNY NOWLAN

From time to time as an engineer you will be faced with situations that are far from ideal. It's been a constant theme in many of my articles for the last couple of years because it is what truly defines engineering skill level. The following article I originally posted on the ChassisSim blog three years ago and it outlines one of the worst modelling situations I was plunged into. However the lessons learned back then are just as relevant as they are now. More importantly they can get you out of a tight spot.

One of the great myths surrounding race car and lap time simulation is that setting up a model and calibrating is way too hard for the average data and race engineer. It is not hard – it is just different to what people are used to and they don't have a lot of experience about how to do it. If the car is easy to model, for instance a well documented aeromap, with tyres that respond nicely and so on, then they can work their way around it.

Where people get into trouble is if they are dealing with poor documentation and/or tyres that are razor sensitive or are very non-linear.

The motivation for this article came in some work I have been doing for a colleague of mine. While I'm not at liberty to specify what this car is I can outline the challenge that was faced:

- The car's tyres are highly non-linear and very sensitive to adjustment.
- The aero documentation didn't present an accurate picture of the pitch sensitivity.
- For reasons I won't elaborate the data I had to work with was highly limited.

Consequently this forms the perfect case study about what to do because this particular example was an extreme case that illustrates the pitfalls that await and more importantly how to deal with them.

The first step that was taken with this racecar was to read the manual and enter all

This particular example was an extreme case that illustrates the pitfalls that await and more importantly how to deal with them

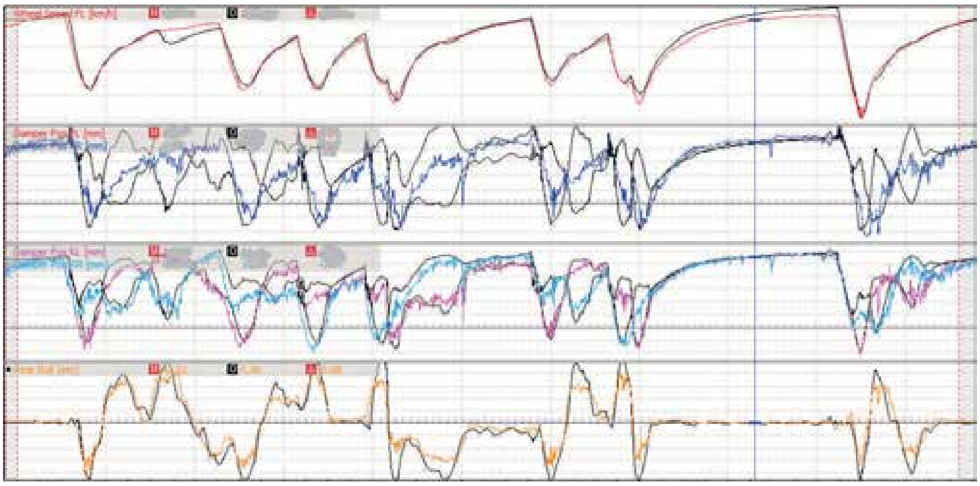


Figure 1: Initial correlation

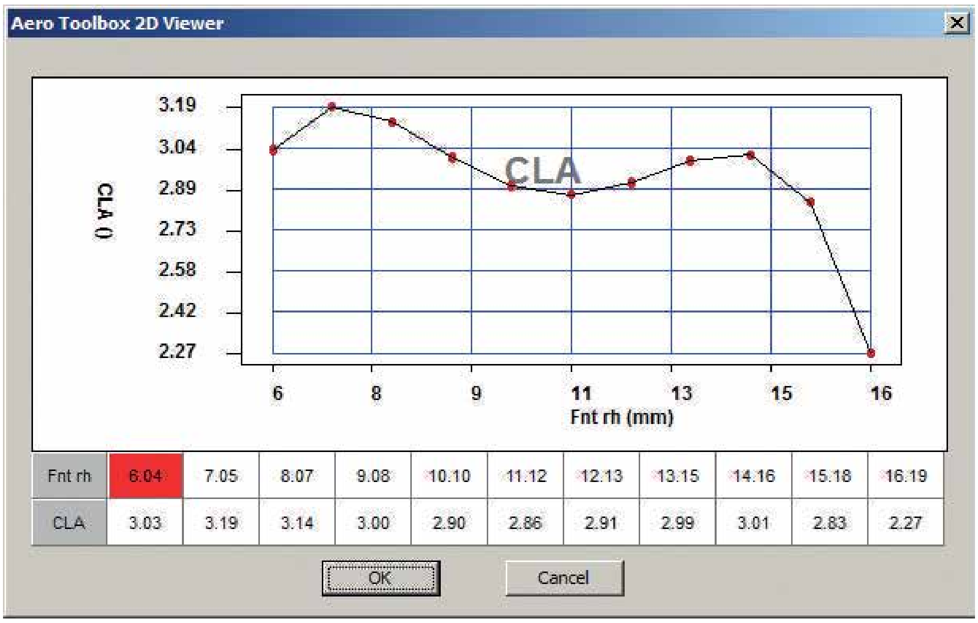


Figure 2: Actual pitch sensitivity from race data

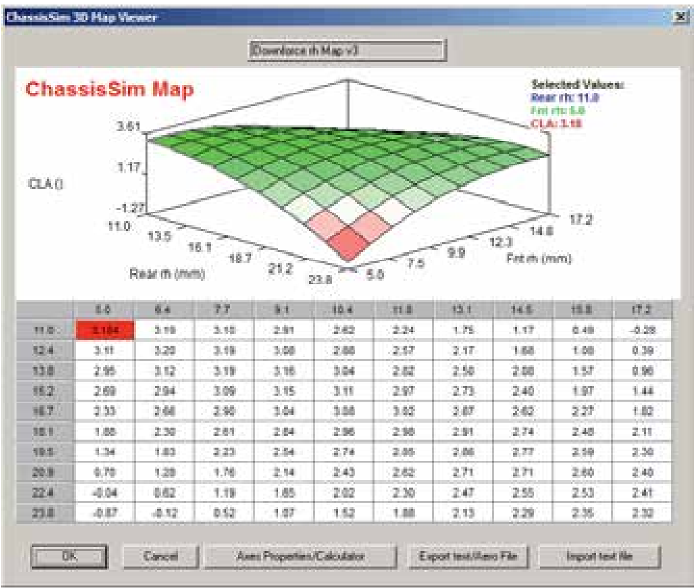


Figure 3: Initial aeromap

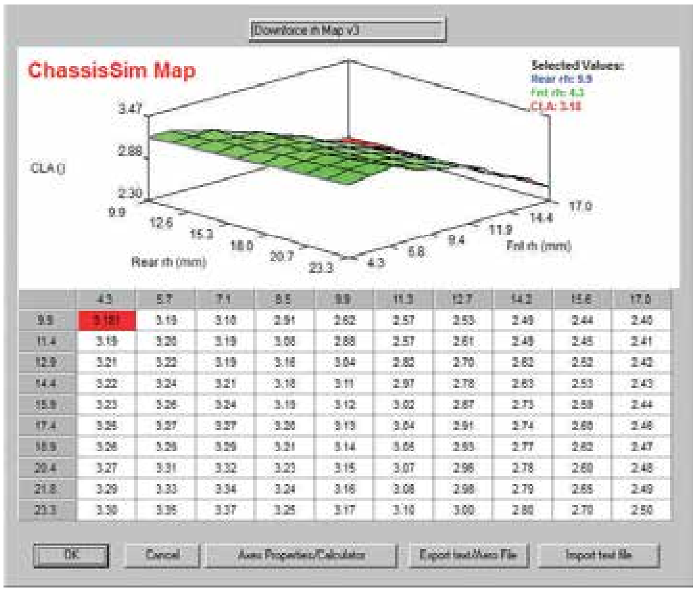


Figure 3b: Modified initial aeromap

the necessary parameters into ChassisSim. Fortunately I had a representative tyre model that could get the tyre forces into the ball park. The next step was to perform an initial simulation. The results of this simulation is shown in **Figure 1.** While it is obvious the speed traces needed a bit of work, the most striking thing was the rear roll. The simulated rolls were out by a nearly uniform factor of two everywhere. When you have something out that is this uniform then that is your cue to double the bar rates. What it's telling you is that you and the racecar manufacturer view the working of the bar differently. It's not saying either of you are wrong. You just view it differently. In this case we had to double all the specified bar rates.

The next step in the process was to dial in the aeromap. The issue that we were dealing with here is that, while the downforce and drag levels were in the right area, the drag levels in the map were validated by dropping the engine efficiency to approximately 80 per cent. This is a little low for an open wheeler but it is not ashow-stopper. But the downforce sensitivity was grossly understated. This was revealed in the fact the model was very insensitive to ride height changes.

Consequently we needed to come up with a ride height aeromap. The problem that we were dealing with is that we had only one set of data to deal with. This only gives us one slice of aeromap to deal with. In many of my articles for both my blog and for *Racecar* I have stated that to create an aeromap you need many of these slices. Consequently we were going to be in a situation where we needed to do some pretty good guess work.

The first step was to run the ChassisSim aero modelling toolbox. While the overall downforce

While the overall downforce levels were in the ball park of the manual, the car was much more pitch sensitive than indicated…

levels were in the ball park of the manual, the car was much more pitch sensitive than indicated in the manual. An illustration of this is shown in **Figure 2.** As we can see, a change in front ride height of 3mm can result in the CLA value dropping by 0.3! However the positive news is that there is a ride height sweet spot with the car as indicated by the peak at a front ride height of 7mm.

The next step is to use this exported data to create a ride height map. Using the ChassisSim aeromap generation utility the aeromap looked something like **Figure 3.**

The reason the aeromap drops off at the extremes is the fact we have no data for this range. However what is clear is that we can see the beginnings of our sweet spot range. What we now need to do is edit the bits that don't look right. The guiding principle here was:

- As rear ride height increases – downforce, drag and aero balance goes up
- As front ride height increases – downforce drag and aero balance goes down

Drag can sometimes be an exception to this but this is the basic model. The modified map looked something like **Figure 3b.** This was run in comparison to the data. The correlation that was achieved is shown in **Figure 4.**

As we can see from Figure 4, down the straights the correlation was excellent, with the damper traces being virtually on top of each other. This is in particular indicated in the front and rear pitch channel displays that average the two dampers. The biggest discrepancy, though, was in the low-speed corners. This is due to two reasons:

- The ChassisSim aero toolbox only looks at straight data
- We had ride heights of the front at 20mm and the rear at 30mm

However these two giveaways tell us how much the downforce drops off by.

So what was done was to modify the aeromap to reflect this? The modified aeromap looked like **Figure 5.**

All that was done here was to take the aeromap and export it to a spreadsheet and all we did was extract the ride height range to what was seen in the data. When we were out of ride height range we dropped the downforce down. While it isn't perfect it's all we had to go on from the data. You will also notice I accentuated the downforce drop-off range. The final aero correlation is presented in **Figure 6.**

While not perfect, most of our discrepancies in the low-speed corners have been resolved. I am not pretending that what we have here is ideal. But the point of this exercise is to show you how to get close with limited amounts of data, and we have demonstrated this.

The next step in the process was to model the tyres. These tyres were noted for their sensitivity despite a 100lbf/in rear spring change only producing a difference of 0.3 per cent of lateral load sensitivity. To illustrate the

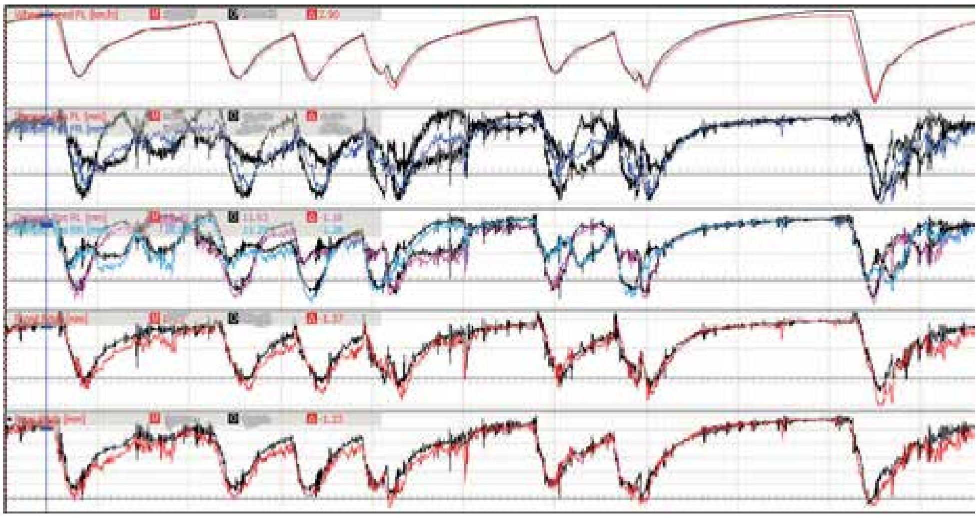
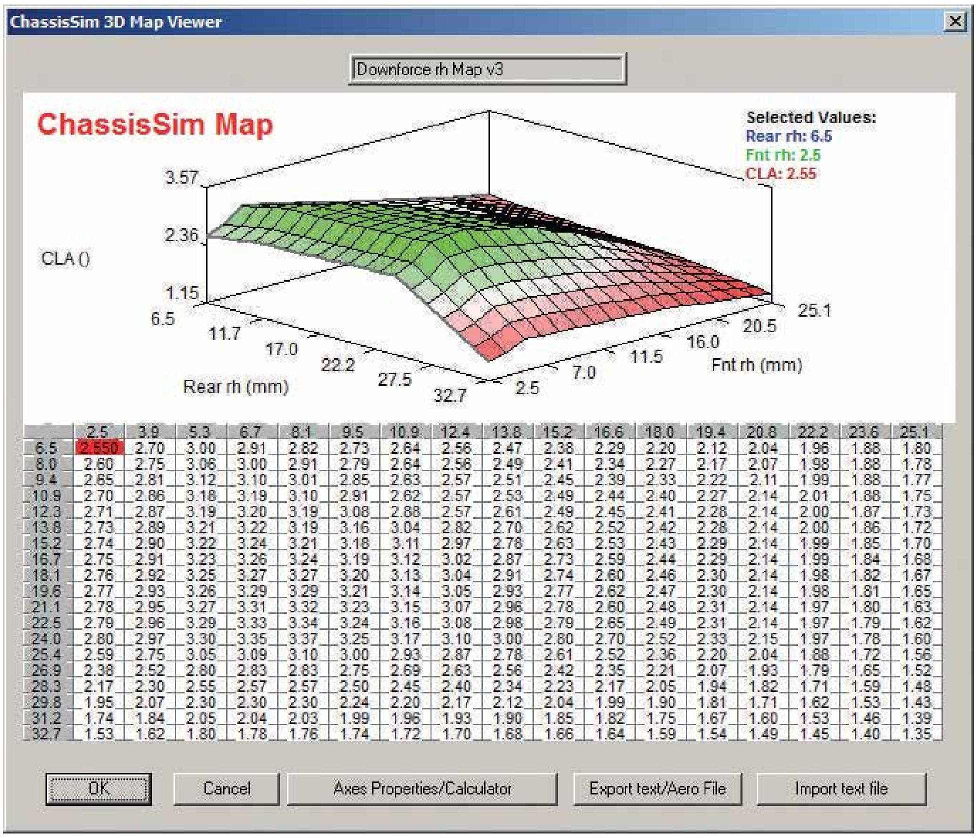


Figure 4: Initial aero correlation



	2.5	3.9	5.3	6.7	8.1	9.5	10.9	12.4	13.8	15.2	16.6	18.0	19.4	20.8	22.2	23.6	25.1
6.5	2.550	2.70	3.00	2.91	2.82	2.73	2.64	2.56	2.47	2.38	2.29	2.20	2.12	2.04	1.96	1.88	1.80
8.0	2.60	2.75	3.06	3.00	2.91	2.79	2.64	2.56	2.49	2.41	2.34	2.27	2.17	2.07	1.98	1.88	1.78
9.4	2.65	2.81	3.12	3.10	3.01	2.85	2.63	2.57	2.51	2.45	2.39	2.33	2.22	2.11	1.99	1.88	1.77
10.9	2.70	2.86	3.18	3.19	3.10	2.91	2.62	2.57	2.53	2.49	2.44	2.40	2.27	2.14	2.01	1.88	1.75
12.3	2.71	2.87	3.19	3.20	3.19	3.08	2.88	2.57	2.61	2.49	2.45	2.41	2.28	2.14	2.00	1.87	1.73
13.8	2.73	2.89	3.21	3.22	3.19	3.16	3.04	2.82	2.70	2.62	2.52	2.42	2.28	2.14	2.00	1.86	1.72
15.2	2.74	2.90	3.22	3.24	3.21	3.18	3.11	2.97	2.78	2.63	2.53	2.43	2.29	2.14	1.99	1.85	1.70
16.7	2.75	2.91	3.23	3.26	3.24	3.19	3.12	3.02	2.87	2.73	2.59	2.44	2.29	2.14	1.99	1.84	1.68
18.1	2.76	2.92	3.25	3.27	3.27	3.20	3.13	3.04	2.91	2.74	2.60	2.46	2.30	2.14	1.98	1.82	1.67
19.6	2.77	2.93	3.26	3.29	3.29	3.21	3.14	3.05	2.93	2.77	2.62	2.47	2.30	2.14	1.98	1.81	1.65
21.1	2.78	2.95	3.27	3.31	3.32	3.23	3.15	3.07	2.96	2.78	2.60	2.48	2.31	2.14	1.97	1.80	1.63
22.5	2.79	2.96	3.29	3.33	3.34	3.24	3.16	3.08	2.98	2.79	2.65	2.49	2.31	2.14	1.97	1.79	1.62
24.0	2.80	2.97	3.30	3.35	3.37	3.25	3.17	3.10	3.00	2.80	2.70	2.52	2.33	2.15	1.97	1.78	1.60
25.4	2.59	2.75	3.05	3.09	3.10	3.00	2.93	2.87	2.78	2.61	2.52	2.36	2.20	2.04	1.88	1.72	1.56
26.9	2.38	2.52	2.80	2.83	2.83	2.75	2.69	2.63	2.56	2.42	2.35	2.21	2.07	1.93	1.79	1.65	1.52
28.3	2.17	2.30	2.55	2.57	2.57	2.50	2.45	2.40	2.34	2.23	2.17	2.05	1.94	1.82	1.71	1.59	1.48
29.8	1.95	2.07	2.30	2.30	2.30	2.24	2.20	2.17	2.12	2.04	1.99	1.90	1.81	1.71	1.62	1.53	1.43
31.2	1.74	1.84	2.05	2.04	2.03	1.99	1.96	1.93	1.90	1.85	1.82	1.75	1.67	1.60	1.53	1.46	1.39
32.7	1.53	1.62	1.80	1.78	1.76	1.74	1.72	1.70	1.68	1.66	1.64	1.59	1.54	1.49	1.45	1.40	1.35

Figure 5: Final aeromap

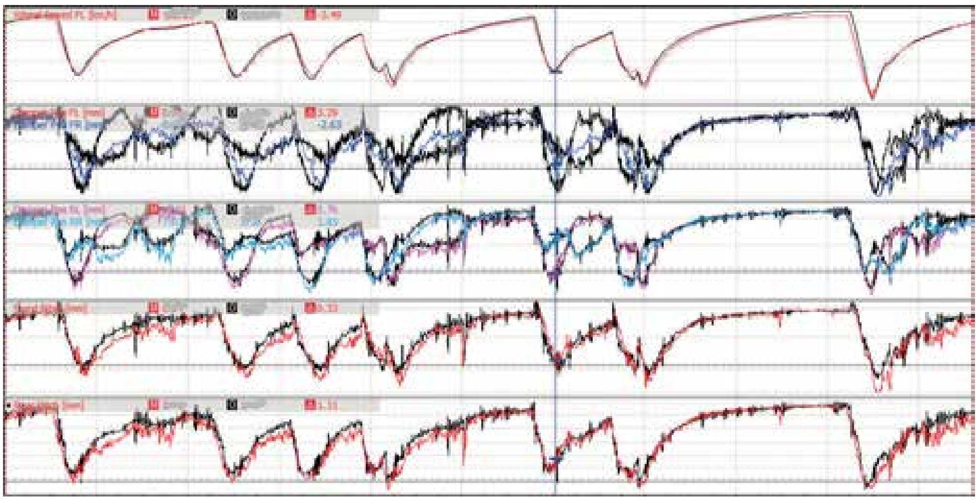


Figure 6: Final aero correlation

challenge that was faced let me illustrate some tyre performance parameters from the data – see **Table 1.**

The first column is speed, the second is lateral acceleration, and ds is the difference in steer from neutral. Negative indicates understeer and L1 to L4 are the four tyre loads. In an earlier article I articulated a way of solving the maximum tyre force vs Load function. To refresh the reader's memory see the **Equations** box below.

These numbers indicate that for this load range the tyres are highly load sensitive. If we extrapolate this curve fit to the high speed region, the tyre forces are significantly reduced. What this tells us is these tyres are both highly load and temperature sensitive.

The first step was to use the ChassisSim tyre force toolbox to reverse-engineer the tyre model. To start the process off we used a 2-D tyre model, or maximum traction circle radius versus load only. We did this for two reasons;

- To get an approximation of what to expect with the tyre loads
- To use it to dial in tyre temperature characteristics to pave the way for a 3-D model

This process was done and while the initial correlation was good the model was very insensitive to changes. This was traced down to a number of reasons:

- The tyre spring rates were about 10 per cent less than what they should be. A cursory evaluation of lateral load transfer distribution will show us this will give sensitivity. This was also confirmed by looking at projected ride heights and comparing this to what ride heights the car was being run at
- The initial tyre load range was too high. The load delta range was in the order of 900kgf. Looking at the simulated data the maximum load at the front was 600kgf and the rear was 700kgf

This second point was crucial. The lower your load range the more points you can put in to aid your sensitivity. This is a very key point to aid in the sensitivity of the model. The end result of all this was the correlation as seen here in **Figure 7.**

The actual data is coloured, unlike the simulated data. As you can see we have excellent correlation everywhere (with no grip factors).

What is particularly striking is how closely the steer and throttle traces correlate, particularly at the mid corner and initial throttle application. This is an indication that we have a very strong vehicle model.

In closing, I hope you agree that what we have just gone through was not particularly hard. It's just a matter of attention to detail, looking at data and using a lot of common sense. To recap this is what we did:

- Ensured all spring rates and bar rates were correct
- We then did our best to get the most accurate and representative aeromap we possibly could
- We then constructed the tyre model within our respective front and rear load ranges

Notice that all these steps built on each other and each leads to the next step.

We need to have the motion ratios and spring rates to construct the aero model. Once we have the aero model we can then construct the tyre model. The other thing to note here is that we have used the ChassisSim toolboxes to help us quantify what we are seeing in the data. We then use ChassisSim to help us fill in the details.

These techniques, while not perfect, will go a long way to quantifying the racecar's performance with even very small amounts of data. This will provide you with that crucial edge as you seek to get the most out of your racecar.

Table 1: Illustration of tyre sensitivity

Vx (km/h)	a_y	δs	L1 (kg)	L2 (kg)	L3 (kg)	L4 (kg)
55	2.19	-1.5	0.64	284.3	67.6	385.3
117	2.3	-1.5	7.4	320.8	125.2	453.9
230	3.6	0	501.3	125.3	691.2	222.5

EQUATIONS

For U/S

$$m_t \cdot a_y = fn(\alpha_{pf})(F_{y1} + F_{y2}) + fn(\alpha_{pr} - \Delta\delta)(F_{y3} + F_{y4})$$

For neutral steer

$$m_t \cdot a_y = fn(\alpha_{pf})(F_{y1} + F_{y2}) + fn(\alpha_{pr})(F_{y3} + F_{y4})$$

For oversteer

$$m_t \cdot a_y = fn(\alpha_{pf} - \Delta\delta)(F_{y1} + F_{y2}) + fn(\alpha_{pr})(F_{y3} + F_{y4})$$

For our maximum load function, assuming Load drops off linearly with friction, such that

$$F_y = k_a(1 - k_b \cdot F_z) \cdot F_z$$

$$L_p = \frac{1}{2 \cdot k_b}$$

Where,

k_a = initial coefficient of friction
k_b = drop off of coefficient with load
F_z = load on the tyre

Using the two low speed points as markers we have

	Front	Rear
K_a	4.311	6.5676
K_b	1.63 x 10¬-4	1.73x10-4

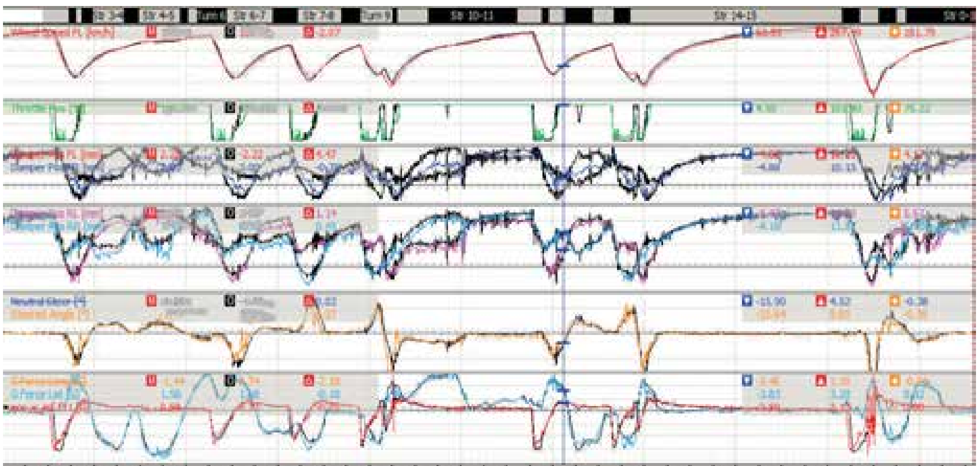


Figure 7: final correlation

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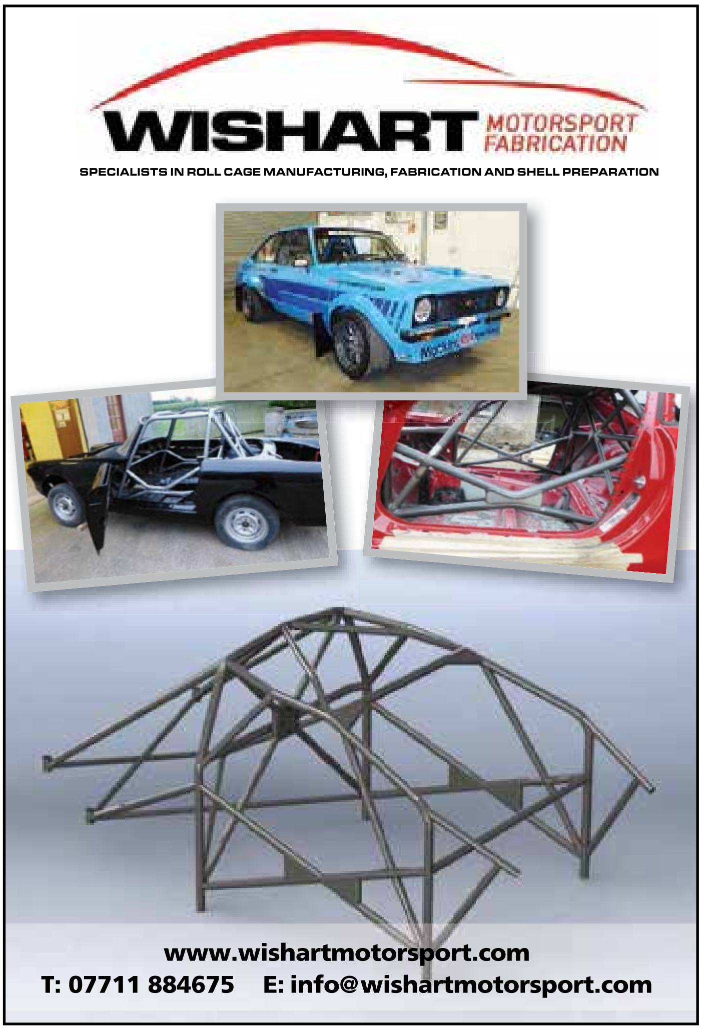

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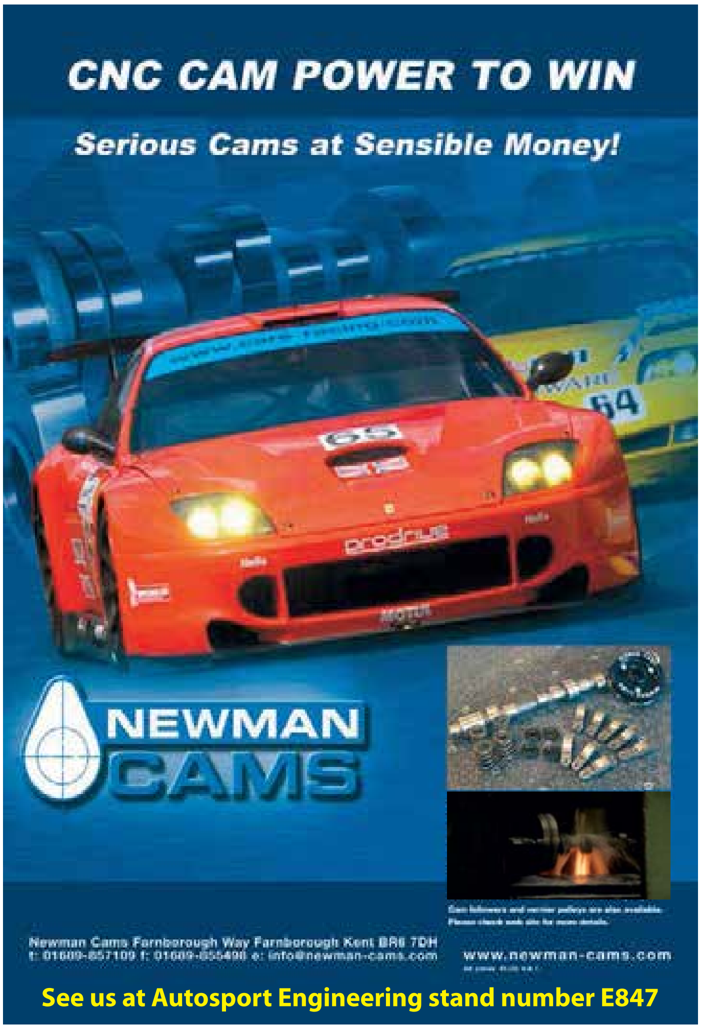

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Bianchi investigation

The probe into Jules Bianchi's accident at the Japanese Grand Prix found that it was not caused by one isolated event

An investigation by an FIA appointed panel into the crash of Jules Bianchi during the Japanese Grand Prix has found that human error was the major cause of the accident that saw the Frenchman suffer severe head injuries after his car hit a trackside recovery vehicle.

The findings of the panel showed that the accident was not one isolated event, but caused by a sequence of events that may have contributed to the accident. There is, according to the report, which has not been released in full, no single cause of the crash.

Towards the end of the Japanese Grand Prix the track conditions were very difficult. A weather system was passing through the area ahead of a typhoon and it was causing very mixed conditions, indeed heavy rain had seen the race red flagged at one point.

With just over 40 racing laps completed there was a semi-dry racing line in the S-Curves section of the Suzuka circuit. In the final part of the corner sequence, Dunlop Curve, that line abruptly narrowed due to water draining on to the track and flowing along it. On lap 42 Sauber driver Adrian Sutil hit this flowing water and lost control of his car, which hit the retaining wall on the exit of the corner. Sutil was unhurt but he was out of the race. The standard procedure of recovering a car in a position like this was carried out, a recovery vehicle or 'snatch tractor' was sent out to pick up the damaged Sauber and move it to a safe position behind the wall.

Marshals were also present trackside to clear up debris, repair the barrier and assist in the recovery of Sutil's damaged car.

To protect the course workers and to warn other drivers of danger ahead, double waved yellow flags were displayed. These flags mean that drivers must slow down and be prepared to stop if necessary. Overtaking is prohibited.

Jules Bianchi who had been just ahead of Sutil when the Sauber driver went off arrived back on the scene in his Marussia MR03 a lap later. He was shown the double waved yellow flags because at this point Sutil's car was in the process of being recovered. For reasons that may never become clear, and have already been debated elsewhere, Bianchi did not slow down enough under the double-waved yellow flags. It seems clear that from this point onwards an accident was highly likely, though it could still have been avoided or its severity at least could have been reduced.

When the Marussia arrived on the same piece of water that caught out Sutil just over a minute and a half earlier, Bianchi lost control of the car, just as Sutil had done. The Frenchman over corrected the steering of the car which had lost rear grip and ended up heading straight off the track to the point where the recovery operation was taking place. By now a crash was unavoidable, it was now a question of what would the Marussia hit, and how hard.

During the two seconds Bianchi's car was leaving the track and traversing the run-off area there was still time to avoid the recovery vehicle, and Bianchi attempted to do so. He applied the brake, but this locked the front wheels on the wet surface making it impossible to steer. Also, for some reason, he also applied the throttle (it is not clear if the throttle was already applied from the reports findings, but it probably was and Bianchi simply did not lift).

In this scenario the engine should have cut, as all 2014 F1 cars have a back up safety system called FailSafe. It is a software algorithm in the car's onboard computer that is designed to override the throttle and cut the engine in exactly this scenario, but on the bespoke Marussia brake by wire (BBW) rear brake design another sub system the Torque Coordinator which controls the the operation of the BBW prevented it from doing so. It transpired that the Marussia MR03 BBW system was incompatible

For reasons that may never become clear, Bianchi did not slow down enough under the double-waved yellow flags

The second Marussia did not take part in the Russian Grand Prix. A replacement tub was flown to Sochi and could have raced with another driver, but the team preferred to run a single car at the event

with the FailSafe settings used by all cars. This was probably the first time anyone realised this.

The report highlights this system failure, but points out that while FailSafe did not cancel out the engine torque requested by the driver, and that this may have affected the impact velocity, it has not been possible to reliably quantify this. It may be that Bianchi was distracted by what was happening and the fact that his front wheels had locked, and been unable to steer the car such that it missed the recovery vehicle.

If Bianchi had slowed adequately for the double waved yellows, had not over corrected the steering of the car and had lifted off in the final two seconds before impact, the accident could have been avoided or its severity reduced. The severity could possibly have been reduced if the FailSafe system had functioned.

Bianchi's car hit the engine cover and left rear wheel of the 6.5 (metric) tonne recovery vehicle with little reduction in speed. It did substantially damage his composite chassis car, tearing off the roll hoop and air box and hitting the Frenchman's helmet. The magnitude of the blow and the glancing nature of it caused massive head deceleration and angular acceleration, leading to his severe injuries.

Bianchi remains in a critical condition in a hospital in France.

Following the crash there were many inaccurate stories in the media, with many comments being published that a closed cockpit could have reduced the injuries suffered by Bianchi but the report rubbishes this suggestion. 'It is not feasible to mitigate the injuries Bianchi suffered by either enclosing the driver's cockpit, or fitting skirts to the crane. Neither approach is practical due to the very large forces involved in the accident between a 700kg car striking a 6500kg crane at a speed of 126kph. There is simply insufficient impact structure on a F1 car to absorb the energy of such an impact without either destroying the driver's survival cell, or generating non-survivable decelerations.

'It is considered fundamentally wrong to try and make an impact between a racing car and a large and heavy vehicle survivable,' read the statement. 'It is imperative to prevent a car ever hitting the crane and/or the marshals working near it.'

Other publications and websites, suggested that the safety car should have been deployed while the wreckage of Sutil's car was cleared, but the report disagrees. 'The actions taken following Sutil's accident were consistent with the regulations, and their interpretation following 384 incidents in the preceding eight years. Without the benefit of hindsight, there is no apparent reason why the Safety Car should have been deployed either before or after Sutil's accident. If drivers adhere to the requirements of double yellow flags, then neither competitors nor officials should be put in immediate or physical danger.'

Bianchi's crash and ongoing fight for life will continue to spark debate in racing circles but the report does seem to suggest that human error was largely to blame in this case. Many of the recommendations made by the report could not have been made before the crash at Suzuka, and racing should be safer going forwards.

Report recommendations

The report made a number of recommendations –some of which have already been implemented, others are under review and more again will reach into the 2016 international racing season.

1. A new regulation for double yellow flags:
Proposed new Appendix H Article (possibly under 2.4.5.1 b):

The Clerk of the Course will impose a speed limit in any section of track where double yellow flags are being displayed. It is proposed that a Working Group, made up of FIA Race Directors and Stewards should meet and draw up detailed regulations and guidelines for the application of this new regulation, in time to apply it in 2015 across international circuit racing.

2. Safety critical software:
A review of safety critical software and measures to check its integrity will take place.

3. Track drainage:
Guidelines on circuit drainage will be reviewed, to include drainage off access roads

.

4. Four-hour rule:
Article 5.3 of the F1 Sporting Regulations states that:

However, should the race be suspended (see Article 41) the length of the suspension will be added to this period up to a maximum total race time of four hours.

It is proposed that a regulation or guideline be established such that the Start time of an event shall not be less than four hours before either sunset or dusk, except in the case of night races.

It is also recommended that the F1 Calendar is reviewed in order to avoid, where possible, races taking place during local rainy seasons.

5. Super Licence
It is proposed that drivers acquiring a Super Licence for the first time should undertake a course to familiarise themselves with the procedures used by F1 in running and ensuring the safety of an event.

It is also proposed that new licence holders pass a test to ensure that they are familiar with all the relevant regulations.

6. F1 risk review
Consideration will be given to a review of F1 risk, in order to ascertain whether there are any significant holes in the safety defences, such that an unforeseen combination of circumstances could result in a serious accident.

7. Tyres
It is part of the challenge of a racing driver to drive his car as fast as possible given the track conditions combined with the characteristics of his tyres. Although the characteristics of the wet weather tyres provided by Pirelli did not influence Bianchi's accident or its outcome in any significant way, it is recommended that provision is made for the tyre supplier to develop and adequately test wet weather tyres between each F1 season, such that it is able to supply the latest developments to the first event.

Euro Commission set to scrutinise F1

XPB

The European Commission (EC) is looking into the possibility that Formula 1 has breached its anti-competition regulations.

Formula 1's finances were thrust into the spotlight in the wake of the collapse of Marussia and Caterham, which brought the gap between the richer and poorer teams into sharp focus. The redundancies that resulted from the failure of the UK-based teams led to British MEP (Member of European Parliament) Anneliese Dodds writing a letter to the EC raising concerns about F1, chiefly regarding the distribution of wealth among the teams.

Now it has been widely reported that Dodds has met with the EC's competition commissioner, Margrethe Vestager, on the matter. The EC has also confirmed it is now looking into it, although has not said whether there will be a formal investigation.

Dodds said: 'There was an agreement made between F1 and the European Union about competition some years ago and it seems that has not been stuck to. There does not seem to be true competition in the sport and the fears are not just for jobs, but for technology and the profile of the sport.'

It has also been reported that a dossier on Formula 1's finances had been written for the Commission as long ago as last June, but has yet to be acted upon. This is said to provide details of how the sport's finances are handled and to focus on the Strategy Group, which includes the FIA, FOM (Formula One Management), Red Bull, Ferrari, McLaren, Williams and Mercedes, and on whether this is in fact operating as a cartel.

The problems besetting UK-based teams Marussia and Caterham, both of which went into administration before the end of the season, were the catalyst for Dodds' letter.

Marussia has now closed its gates and laid off its staff, while Caterham is still looking for a buyer.

At the time of writing Caterham's administrator Finbarr O'Connell – who actually headed the team at the final grand prix in Abu Dhabi – said he was fairly confident a buyer would be found: 'I'm talking to some people who are interested in making a decision in the next few weeks and if that happens, they can take over the team as it currently stands,' he said.

NASCAR manufacturers praise selling-power of Gen-6

The motorsport bosses of the three manufacturers involved in the NASCAR Sprint Cup have said the change to the Gen-6 car has had a positive impact on customer interest and forecourt sales

NASCAR manufacturers are delighted with increased sales off the back of the Gen-6 cup car

The Gen-6 formula was introduced in 2013 at the behest of the manufacturers – Ford, Chevrolet and Toyota – as a way of giving the racecars product relevance by making them look more like their street car cousins.

Now each manufacturer has reported they are seeing positive signs in terms of interest and sales which can be tracked to their NASCAR Sprint Cup programmes.

Jamie Alison, director of Ford Racing, said: 'We generate a lot of leads for our dealers. We have generated 570,000 leads this year, up 60 per cent from a year ago. We track sales, match to leads generated from on-track activation, and our sales are up 90 per cent versus a year ago. These are gigantic swings in engagement, gigantic swings in fan affinity, and it translates all the way down to intention to buy. Success on the track translates into fan consideration and purchase intention.'

Jim Campbell, US vice-president, performance vehicles and motorsports at Chevrolet, agreed: 'We like that genuine connection from track to the showroom, and we see it in the numbers. The research numbers show that fans are relating to the car and making it relate more from what they see on the track to what they see in the showroom and on the street. We love that, and really one of the reasons why we race is to make that connection of relevance.'

David Wilson, president and general manager of Toyota Racing Development USA, which has recently launched its new Sprint Cup Camry, added that it was important that the manufacturers continued to keep the racecars aesthetically in line with the street cars: 'This is about relevancy, and when we undertook that project to bring the Gen-6 to the racetrack, we all knew that we were going to continue to evolve our production cars and that with that comes the responsibility to evolve our racecars.'

Silverstone Park development racing ahead


Silverstone Park plan viewed from the west

Work at the Silverstone Park engineering business estate is progressing well, with a brand new unit built and motorsport and other businesses moving in to units at the site.

Commercial property company MPEC took over the estate – which included 2.7 million square-foot of planning consent over 130 acres of land surrounding the grand prix circuit – from Silverstone's owner the British Racing Drivers' Club in September 2013.

Since then Silverstone Park has completed a major re-branding and marketing overhaul, while building work has also started, with the construction of a 15,000ft^2 unit.

Roz Bird, Silverstone Park's commercial director, says the project is now ahead of schedule and she believes it is set to become a leading global destination for high performance technology and motorsport.

'The rate of progress at Silverstone Park is extraordinary,' Bird said. 'We have got the community spirit back among the businesses on site, we've got new businesses coming in, we are in serious discussions with other very big and hugely influential companies and now we are starting to see land being cleared and new buildings going up.'

While the majority of the existing Silverstone Park site runs adjacent to the track from Woodcote back to Abbey – some 50 businesses are already housed here – the land MEPC plans to develop extends much further.

'The fields next to the Dadford Road opposite The Wing are earmarked for our development and next to that we're attracting new companies into the Buckingham Road [previously known as the Jordan Technology Park] units,' Bird said. 'They gave us another 82,500ft^2 of property when we acquired them as part of Silverstone Park.'

Ford restructures high performance division

Ford has restructured its high performance and motorsport divisions and created a single new corporate entity called Ford Performance. It combines Ford Racing, Ford SVT and Team RS to serve as an innovation laboratory and test-bed to create unique performance vehicles, parts, accessories and experiences for customers. This includes developing innovations and technologies in aerodynamics, light-weighting, electronics, powertrain performance and fuel efficiency that can be applied more broadly to Ford's product portfolio.

In addition to using racetracks around the world, the team will develop new vehicles and technologies at Ford's engineering centers globally and at the new technical centre in Concord, North Carolina. This state-of-the-art facility will help the team deliver racing innovations, as well as advance tools for use in performance vehicles and daily drivers alike. It is already equipped with some very high end simulation tools. The Ford Performance organisation is led by Dave Pericak, who has been appointed director, Global Ford Performance.

Over the next five years the new organisation will create and deliver a new range of at least 12 models, most of which will also have competition variants, though many details have yet to be announced.

'Ford still races for the same reasons Henry Ford did in 1901 – to prove out our products and technologies against the very best in the world,' said Raj Nair, Ford Group vice-president, global product development. 'The Ford Performance team will continue to pursue performance innovation, ensuring we can deliver even more coveted performance cars, utilities and trucks to customers around the world.'

Meanwhile Ford has announced that it is quitting the V8 Supercars series in Australia, although the rumour that Ford will enter Le Mans in 2016 with a Multimatic-built GTE car gained significant traction in December. While the company did not give its reasons for withdrawing from V8S there has been a question mark over Ford continuing in the series since it announced in mid-2013 it was to close its manufacturing plants in Australia by the end of 2016, and also that it was to cease production of the Falcon model that it campaigns in V8 Supercars.

The pull-out is not due until the end of the 2015 season but Ford will also reduce its current commercial commitment with works team Ford Performance Racing (FPR). The only other team set to race Fords in 2015 is the new Team Penske DJR outfit, formed after the buyout of Dick Johnson Racing by American motorsport mogul Roger Penske.

Ford Australia's decision comes against the backdrop of a run of bad financial results in recent years. Earlier this year it revealed losses had doubled from A$141m (£76m) in 2012 to A$276m (£149) in 2013, which took its losses over the past six years to A$800m (£431m).

Tim Edwards, CEO of Prodrive Racing (Australia), which runs Ford Performance Racing, said he was disappointed to hear the news: 'Ford Australia's decision to not extend its commercial relationship with our team beyond the end of next season is extremely disappointing for our large and loyal fan-base, but as a business this decision now allows us to concentrate on the long-term.'

Edwards added there was still a chance FPR might continue with the Falcon beyond 2015: 'We will run the FG X Falcon in 2015 as planned with support from Ford, and we'll possibly campaign the car in 2016 ahead of the major regulation changes coming from 2017.

'Now that we know where we stand we can further develop other opportunities,' Edwards added. 'We have a range of options, so we can now begin to explore these.'


Ford's new high performance facility in North Carolina

FIA opts for British Touring Car rules package

The British Touring Car Championship technical regulations are to be the FIA template for new saloon car racing national series around the world.

Two sets of technical regulations are to be published, with the BTCC regulations used for the higher level of competition, while the lower level will be based on those now used in Argentinean Touring Cars, which is production-car orientated and focused on low cost racing.

These technical regulations will be known as FIA TCN-1 and FIA TCN-2 respectively, and they are designed to make it easier and less costly for touring car series around the world to be set up from scratch, but the FIA has made it clear that the use of either package will not be compulsory.

Alan Gow, the FIA touring car commission president and also the promoter of the BTCC, announced the plans for a global rules package – such as the FIA has with Formula 4 in single seater racing – last April. Gow also told *Racecar* there was a possibility the NGTC regulations (which the BTCC runs to) could be chosen.

'It could,' he said. 'What we are going to do is have a look at the regulations of all the series around the world and see which is the most appropriate. Obviously NGTC would have to be fairly high up,' he said.

Meanwhile the FIA has approved the new global touring car series proposed for 2015, which was to be called TC3, but will now be known as TCR. Marcello Lotti, the former boss of the WTCC until 2013, has now been formally appointed as CEO of the company behind TCR.

Lotti said of the change of title for the series: 'The name TC3 [had] been chosen to introduce the technical concept of a global touring car category, based on production cars, that was affordable to private teams and drivers and inspired by the existing GT3 concept. We have decided on the change of name of the series to TCR that will create a strong and personal identity for the new series. In addition, the name change will avoid any potential confusion with other touring car championships and series that might suggest pre-arranged hierarchies.'

The above refers to the WTCC, which raced with both TC1 (cars built to current regulations) and TC2 cars (built to 2013 regulations) in 2014 but will run only TC1 cars in the series in 2015.

BTCC rules will now form the basis for a standardised FIA touring car formula, TCN-1

SEEN: Info Wing

This small carbon-fibre device was tried out on the airbox of a Force India VJM07 at the close of season Abu Dhabi Formula 1 test. The "Info Wing" is the brainchild of world champion Lewis Hamilton's father Anthony, and the idea behind it is similar to that used in the TUSCC, which is to relay information to spectators – such as driver name, race position, or tyre compound in use.

The trial was overseen by the FIA but it's not known whether the device will ever be used in F1.

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IN BRIEF

Force Windier

The Force India F1 Team is set to use the Toyota wind-tunnel for all its aerodynamic testing from 2015 onwards. The Cologne-sited tunnel enjoys a good F1 reputation – Ferrari used it while it waiting for its own facility in Maranello to be upgraded. Force India will now do all of its aero testing in the tunnel but its own tunnel facilities in Brackley will remain operational for hire.

Carlin Light

Crack UK single seater squad Carlin is to race in the US in 2015, running two cars in the resurgent Indy Lights category. Carlin will continue its operations in GP2, GP3, and F3 – as well as returning to Formula Renault 3.5 – from its Farnham, UK base in Europe.

Aussie probe

An independent report into the Australian motorsport industry has found that it pumps A$2.7bn (£1.4bn) into the Australian economy each year. The report, for the CAMS and compiled by Ernst & Young, found that in 2013 Australian motorsport generated A$2.7bn in direct industry output, A$1.2bn in direct value added, and 16,181 direct jobs.

Fire station

Motorsport fire protection company, Lifeline Fire and Safety Systems, is to relocate to new premises in its hometown of Coventry, UK. The firm also supplies to the defence sector.


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KPMG counting on McLaren expertise

McLaren is to supply its race-bred predictive analytics technology to well-known accounting firm KPMG as part of a new partnership deal.

The 10-year 'strategic alliance' between McLaren Applied Technologies (MAT) and KPMG's audit and advisory services will see the latter become an innovation partner of the McLaren Group, bringing together McLaren's expertise in predictive analytics and KPMG's extensive audit and consulting capability.

MAT and KPMG will jointly develop and deliver a unique range of advisory services, McLaren tells us, and it adds: 'companies will be able to draw upon a combination of KPMG's longstanding consulting pedigree and business insight, paired with McLaren's high performance culture and technical know-how'.

Simon Collins, UK chairman of KPMG, said: 'Our alliance with McLaren gives us the opportunity to accelerate the transformation of our audit and advisory businesses. McLaren has honed sophisticated predictive analytics and technologies that can be applied to many business issues. We believe this specialist knowledge has the power to radically transform audit, improving quality and providing greater insight to management teams, audit committees and investors.'

Ron Dennis, chief executive and chairman of the McLaren Group, said: 'We chose to establish this ground-breaking alliance to take our expertise into a whole new market and to continue the rapid growth of McLaren Applied Technologies. As well as being one of the largest audit and advisory companies in the world, KPMG has a deserved reputation for innovation.'

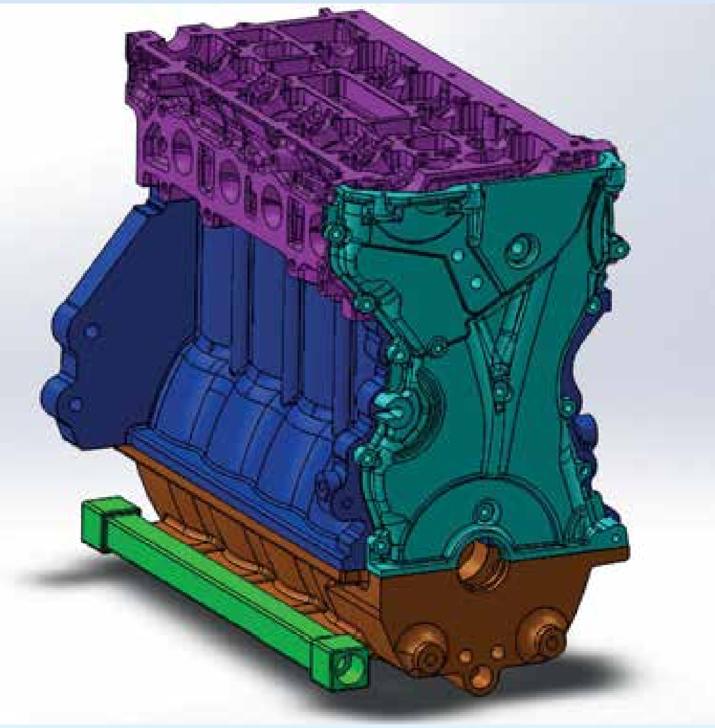
This is not the first time MAT's expertise has been applied to industries beyond motorsport. It has also helped with pharmaceutical R&D and manufacturing processes, created air traffic scheduling systems, and it has worked with oil and gas companies to optimise production processes.

SEEN: Composite Duratec engine

Matti Holzberg has presented to IMSA officials a plan to introduce a fibre glass engine for the Daytona 24 hours in 2016. The engine builder had plans to run the engine in a CN car rejected and now plans to run his polymotor in a larger prototype for the 24.

The lightweight engine, based on the Ford Duratec, is a development of the carbon unit that has been previously featured in Racecar Engineering but offers reduced cost and is just as strong. However, it is significantly cheaper even than an aluminium engine block, which Holzberg hopes will attract new customers once the technology is proven. While a carbon fibre moulding costs in the region of $6 per lb, fibre glass clocks in at $1.80 with a combination of fibre glass and a resing that Holzberg has kept secret. By comparison, aluminium is $2.25/lb. Fibreglass may lack the strength of the carbon, but is still well cabable of dealing with the stresses in engine bay. The fibreglass is capable of withstanding pressures of 35,000PSI and fluctual strength of close to 45,000PSI. Holzberg also says that there is no problem with heat. 'The first polymotor never ran above 70degC and there was a delta of 10 degrees in and out,' he confirmed. 'It is all in the design.'

Holzberg plans a six month dyno programme to ready the engine for competition in time for the 2016 season and he could build a hill climb version.



University boosted by new turbo research centre

A brand-new turbocharger research centre has been established within the campus of the University of Huddersfield in the UK.

The Turbocharger Research Institute (TRI) was opened by one of Britain's best-known engineers, Professor Isobel Pollock OBE, a former president of the Institution of Mechanical Engineers.

TRI has a staff of seven researchers, whose backgrounds are said to be evenly balanced between academia and industry. It is headed by Professor John Allport, whose extensive career in engineering has included key posts within the turbocharger industry.

The research team's work will cover the full range of turbocharger applications, from small vehicle engines to large, low-speed marine engines.

Collaboration is already under way with BorgWarner Turbo Systems to conduct a multi-million pound research programme into the engineering of turbocharger systems for future applications. This collaboration has recently been awarded a major Regional Growth Fund grant to establish a new Turbocharger Engineering MSc course and support research activities.

Professor Pollock said: 'The Institute brings together experienced professionals who have spent a significant amount of time working in the turbocharger and engine industries throughout the world. This gives it an unparalleled and unique insight into the field.'

CAUGHT

Mike Kelley, the crew chief on the No.17 Roush Fenway Racing entry in the NASCAR Sprint Cup, has been fined $50,000 and placed on probation for six months – from January until the end of June – after the Ford Fusion he tends was found to be running with suspension mountings that were outside the regulations at the Homestead-Miami season-closing round of the series. Car chief Patrick Magee has also been placed on NASCAR probation for six months for the infringement.

FINE: $50,000

SPONSORSHIP

Williams has poached two sponsors from F1 rival **Lotus**. **Unilever**, with its **Rexona** brand, was the first to switch teams, and then **Avenade** followed.

Force India is to continue its deal with **America Movil** – represented on the car by the brand names **Telmex, Telcel** and **Claro** – into the 2015 F1 season.

WSR has not retained its eBay backing for the 2015 season. eBay is to cease sponsoring the 2014 British Touring Car Championship-winning team after four years.

INTERVIEW – Stephane Ratel

Labour of love

Race series promoter Stephane Ratel tells why GT3 has been such a success, why British F3 has been such a failure, and how much he loves his work

By MIKE BRESLIN

XPB

"Bringing both our Sprint series and Endurance series under one name has been a fantastic success"

Just how much do you enjoy your work? As a reader of this magazine there's a strong possibility you're involved in the world of racecar engineering in some way or other, so chances are – for the most part – it's a job you adore. But do you love your work quite as much as this? 'It's my life, I absolutely love it. I would do nothing else. If you gave me 10 times the money and you asked me to run an insurance company, I don't care. This is what I do.'

Those are the words of London-based Frenchman Stephane Ratel, boss of the firm which bears his name – Stephane Ratel Promotions (SRO) – and a former supercar dealer who started in the race promotion game in a small way with the Venturi Trophy in 1992, before really coming to prominence with BPR Global GT mid-decade. It is GT racing he will always be associated with, too, running the top GT category under various guises for the last 20 years: from BPR through FIA World GT1 Championship and now Blancpain Endurance and Sprint Series.

It's not all been plain sailing. Ratel admits to losing money with FIA GT1, for instance, but right now things are looking pretty good, with both the Blancpain Endurance and Sprint series doing very well by any measure. 'It's more stable and it's stronger than it's ever been,' says Ratel. 'Bringing both our Sprint series and the Endurance series under one name [in 2014] has been a fantastic success. Our TV coverage has grown 500 per cent in one year, and we are now a truly professional format, which allows us to distribute prize money, not out of our own investment but out of what the series is generating.'

Strong grids

That prize money is in the region of €2.5m for the 2015 season which, Ratel tells us, comes mainly from TV, sponsorship and race promoter fees, and it should help to make sure the grids for both Blancpain championships remain strong in 2015. 'Many promoters in this business never know if they are going to have a grid next year,' Ratel says. 'It's always difficult, but we are at a point where we know we have the cars [up to 50 in Endurance, around 30 in Sprint] and we can fulfil our obligations towards a promoter; a TV distributor; sponsors and suppliers, and that's very important. Now I think we are in the process where the series is growing, not in terms of the number of cars, because it's not really what matters now, the product is there. What we're looking at is to commercialise it more; to have better TV deals, better events, growing sponsorship and growing marketing on site.'

The bedrock to this success has to be GT3, created by Ratel in 2005. It's a category that's not only revolutionised the world of GT racing, but changed the wider motorsport business in the process. Customer Sport is now a phrase heard beyond the race track; it's part of the lexicon of the board room, too, and the list of those sportscar makers currently involved is a long one. In fact, it's easier to say who's not involved: Lexus ('we know there is a Lexus GT3 out there somewhere,' says Ratel) Honda, Maserati and Jaguar.

It's part of Ratel's work to woo these manufacturers, and also to persuade them to choose GT3 over GTE, and the carrot of Le Mans the latter dangles. 'One of the hardest pitches I had was with Martin Whitmarsh,' he recalls, before explaining how he persuaded the erstwhile McLaren boss that GT3 really did make better business sense than GTE. It's a long anecdote, but the basic point is that manufacturers can make good money from GT3. This is largely down to the huge price difference between the two – Ratel says a GT3 is around €360,000, a GTE as much as €600,000 – as well as the cost of running them: 'To run a Ferrari in GTE is 29 euro per km, but it is 15 in GT3,' says Ratel.

Then, of course, a GT3 customer can race in one of a large number of championships right across the globe, and there is also the effective balance of performance SRO has developed, which means that someone buying a GT3 does not have to overly worry about its base performance level.

Little wonder teams and wealthy racers are keen to race these cars, then, while manufacturers have been just as keen to sell them. 'Before you had only Porsche and Ferrari with what we call customer departments. Now all these prestigious, sometimes large, manufacturers have customer racing departments,' Ratel says.

SRO is rightly famed for its GT racing and at one time it ran 12 series across the world. It also started all the main domestic GT championships apart from the Italian and British. Ironically it now actually runs the British championship, which is in rude health, but otherwise SRO mostly concentrates its efforts

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on the two Blancpain championships. It's not just GT racing at SRO, though. Ratel reminds us that he played a big part in the setting up of the WEC through his creation of the Le Mans Series from which it evolved.

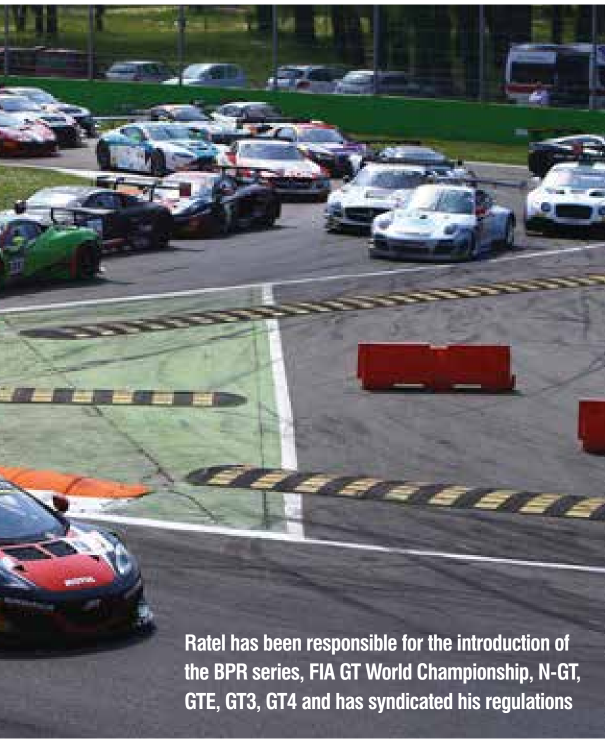
The company has also dabbled in single seaters, though this has proved to be less successful, with the folding of the UK Formula Renault Championship that was under the SRO umbrella in 2012, and more recently the collapse of the SRO-run British Formula 3 Championship, after many teams chose the Euro Championship and abandoned the fabled UK series. Ratel says this was largely down to the European series using F1 circuits, something enticing to young drivers – even if the budget is double that of British – while there was also a great deal of uncertainty over whether the British Championship would even be allowed to call itself F3 in 2014 (because it had decided to use the older engines in an effort to cut costs).

Three areas

'We tried our best,' says Ratel. 'I kept on saying we could not let something with 62 years of history go, and that's why I tried and tried. But when something really dies by itself – I mean we had five cars at the last race – you need to call it a day. 'The moment the FIA put its full weight behind Euro F3 it was difficult, especially with young drivers for whom FIA means Formula 1.'

British Formula 3's fall from grace is a harsh reminder of how things can change in the motorsport business, but how does Ratel envisage the racing world changing in the future? 'I think there are three things. You have heroes, and this is Formula 1. They are the heroes and they will remain so, I have no doubt about the future of F1. Then you have technology, and I think this is where Le Mans comes in. I think Le Mans will become again what it was years ago, the best place to prove new technology. Then there is the customer, who was always there. For example, in the '20s, the Bentley Boys: you have got the money, you buy your car, you go racing. So I think that in the end there are heroes, proving technology, and customers. If I had to bet on the future of motorsport these are the three areas where I see most chance of success.'

All of which leaves plenty of room for GT racing, of course. And despite some linking him to the top job in Formula 1, that is not a place for the Frenchman, who plans to continue enjoying his job in GT racing for a further 20 years.



Ratel has been responsible for the introduction of the BPR series, FIA GT World Championship, N-GT, GTE, GT3, GT4 and has syndicated his regulations

RACE MOVES

XPB

NASCAR engineer **Matt Borland** has been appointed to a new technical role which aims to bridge the gap between the new for 2016 Haas Formula 1 team and the related Stewart-Haas NASCAR operation. Borland's new job title is vice-president of technology.

NASCAR operation Stewart-Haas Racing has hired veteran engineer **Rex Stump** as technical director. Stump comes to Stewart-Haas after an 18-year spell at Hendrick Motorsports, where he worked as engineering manager and as a chassis specialist. Stump started his NASCAR career back in 1991.

Former Ferrari F1 team principal **Stefano Domenicali** is the new president of the FIA Single Seater Commission, taking over from **Gerhard Berger** who recently stepped down from the unpaid post. This will not affect the Italian's non-motorsport day job with the VW Group. The MSA's **John Ryan** is to be Domenicali's vice-president.

Keith Rodden has returned to Hendrick Motorsports, where he will be crew chief on the No.5 NASCAR Sprint Cup Chevrolet driven by **Kasey Kahne**. Rodden has plenty of experience working with Kahne, he was the lead engineer for him at Hendrick in 2013 and before that he had worked with Kahne at Evernham Motorsports, Richard Petty Motorsports and Red Bull Racing.

Ken Nicholls, the man behind the Nike racecar marque, has died. From 1961 Nicholls built everything from Formula Junior to Formula 5000 at his north Devon workshop, with his FF1600s proving particularly successful.

Marcus Haselgrove is the new director of competition at US GT and touring car championship the Pirelli World Challenge, the Briton leaving his post as Audi Sport Customer Racing North America's manager to take up his new position. He replaces **Geoff Carter**.

Matt McCall is to be the new crew chief on the No.1 Chip Ganassi Racing Chevrolet in the NASCAR Sprint Cup. McCall, a former Nationwide and Truck driver, joins the team from Richard Childress Racing.

Denny Darnell, the former sportswriter, track manager and PR man, has died at the age of 70. 'The General', as he was known, was the vice-president and general manager of Bristol Motor speedway in the 1980s and director of communications at the NHRA in the 1990s. He went on to become senior media man at former NASCAR sponsor RJ Reynolds before setting up Darnell Communications, which looked after Dodge Motorsport until 2013.

Chris Mitchum is the new director of race operations at United SportsCar Daytona Prototype-running team Action Express Racing. Mitchum has over 20 years of racing experience, as a crew chief, driver, team manager and owner.

Keith Johnson, the crew chief at USC team Action Express Racing, has retired and is to be replaced by **Chad Gordon**. Johnson now intends to focus on his indoor rock climbing gym project.

Howden 'H' Haynes has stepped down from his post as technical director at works WEC outfit Audi Sport Team Joest. Haynes had been connected with Audi's LMP programme for 11 years. He and business partner Dave Ward, now plan to build up his company, Progressive Motorsport, which recently moved into a 25,500ft^2 workshop in Brackley.

Legendary NHRA crew chief and engineer **Dale Armstrong** has died at the age of 73. Armstrong had a successful career in drag racing as a driver but he is perhaps best known for the many mechanical and technological breakthroughs he made while serving as crew chief for Kenny Bernstein, which included the development of the multi-stage clutch. He was also crew chief on the first dragster to break the 300mph barrier in 1992.

Xtrac scoops top manufacturing accolade

Renowned motorsport transmission company Xtrac has been crowned Manufacturer of the Year 2014 at a major industry awards ceremony.

The prestigious prize is given to the company which the judging panel believe to be the best all-round ambassador for competitive manufacturing in the UK, while also a role model for peers in the industry.

The awards ceremony, organised by *The Manufacturer* magazine and held at the International Convention Centre in Birmingham in December, attracted 1000 guests from manufacturing companies and supporting organisations, a record attendance for the event.

Both Peter Digby and the company he runs have picked up awards recently

Xtrac, which in 2014 celebrated its 30th anniversary, employs 280 staff at its 88,000ft^2 factory in Thatcham, Berkshire, and is recognised as a world leader in the design and manufacture of transmission systems for the motorsport, transportation, defence and marine sectors.

Peter Digby, managing director at Xtrac, said: 'It's a great tribute to our 280 employees and the shareholders back at Xtrac and our operation in America as well. [I'm] very excited. It has been a wonderful night.'

Meanwhile, Digby himself has also been recognised, this time at the Growing Business Awards, which is supported by the Confederation of British Industry in association with Lloyds Bank, where he was given an award for his work during 28 years with Xtrac.

Xtrac supplies a wide range of motorsport categories, from F1 to MotoGP, from its Thatcham base, while it also has design and logistics centres in North Carolina and Indianapolis in the US.

Arrivabene replaces Mattiacci as Ferrari team chief

Marco Mattiacci has left his post as team principal at Ferrari just seven months after taking control at the Scuderia, with well-known motorsport marketing man Maurizio Arrivabene stepping in to take his place.

The news of Mattiacci's departure from Ferrari came at the end of an unsuccessful season for the Maranello team, which failed to register a win in 2014 – the first time this has happened since 1993. His replacement Arrivabene was previously a senior executive at Philip Morris, the tobacco company which owns Ferrari's principal sponsor Marlboro.

Arrivabene joined Philip Morris in 1997 after a 20-year career in marketing and promotions. In 2007 he was made vice-president of Marlboro Global Communication and Promotions and, in 2011, vice-president consumer channel strategy and event marketing. He has been closely involved with Ferrari in Formula 1 during his time with Marlboro, while he has also represented all Formula 1 sponsors on the F1 Commission since 2010.

Ferrari chairman Sergio Marchionne, who replaced Luca di Montezemolo at the head of the legendary marque in September, said of the decision: 'We decided to appoint Maurizio Arrivabene because, at this historic moment in time for the Scuderia and for Formula 1, we need a person with a thorough understanding not just of Ferrari but also of the governance mechanisms and requirements of the sport.'

Mattiacci came to Ferrari's Formula 1 team from its North American road car operation, replacing Stefano Domenicali in the role of team principal in April.

Meanwhile, Montezemolo is now president of the Italian airline Alitalia, replacing Roberto Colaninno, who resigned following a deal last August with Etihad.

RACE MOVES – continued

XPB

Virgin Racing's **Alex Tai** (above) is now chairman of the Formula E Teams' Association, while Jean-Paul Driot of e.dams-Renault and Thomas Biermaier of Audi Sport ABT have been elected vice-chairmen. Heading up the technical working group will be Dilbagh Gill from Mahindra Racing

Oliver Weingarten, formerly of the Formula 1 Teams' Association (FOTA) and football's Premier League, has been appointed general secretary of the Formula E Teams' Association, a brand-new body set up to represent the teams involved in the FIA championship for electric racecars.

Darren Law has joined United SportsCar outfit Flying Lizard Motorsports as its programme manager. Law, a former race driver who once drove for the California-based team, was previously chief operations officer at the Bondurant School of High Performance Driving.

Speedworks Motorsport has welcomed **Geoff Kingston** to its British Touring Car Championship team. The race engineer arrives from the BMR VW squad, but has also worked in Formula 1 and sportscar racing.

NASCAR Xfinity Series outfit JR Motorsports has appointed two new crew chiefs: **Dave Elenz** and **Jason Burdett**, who both come to the team from Hendrick Motorsports. Meanwhile, **Ryan Pemberton** will now move from his post as crew chief at JR back to his former position as director of competition.

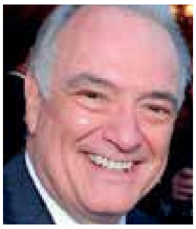
NASCAR Sprint Cup outfit Furniture Row Racing has promoted **Cole Pearn** from lead engineer to crew chief on its No.78 Chevrolet. Pearn, who joined Furniture Row at the start of the 2010 season, replaces **Todd Berrier**, who has been offered another key position within the organisation.

Joe Gibbs Racing has shuffled its NASCAR Sprint Cup crew chiefs. The new line-up will see **Darian Grubb** switching from **Denny Hamlin**'s car to that of **Carl Edwards**; **Dave Rogers** will move from Kyle Busch to Hamlin, while **Adam Stevens** switches from Edwards to Busch. **Jason Ratcliff** will remain with **Matt Kenseth**.

Racecar designer **Mike McDermot** has died at the age of 73. McDermot was well-known for his work with Mallock on its Clubman cars, but he also designed and built his own racecars, and was active in the motorsport industry right up until shortly before his death.

Veteran crew chief **Todd Berrier** has joined Joe Gibbs Racing in a role that has not yet been announced. Berrier started as a NASCAR crew chief in the Truck Series with Richard Childress Racing in 1997, progressing within the organisation as crew chief in the Nationwide and Sprint Cup Series until 2012 when he joined Furniture Row Racing as crew chief. **Cole Pearn** has been promoted to replace Berrier as crew chief of the Chevrolet.

◆ 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 **bresmedia@hotmail.com**



International market

Where to look globally if you want to increase your brand presence and increase sales

At this time of year, I always find myself reflecting on the potential of business for the year or two ahead. The information that is picked up during the show season informs that opinion. Working with the MIA allows me to have a wider perspective across the range, rather than focusing on a specific area of product or service. The two major economic areas of motorsport in all its guises would be the European block and North America. I keep my eye on movements in the general economy in these areas because the spending patterns of consumers, and the commercial health of these areas, definitely reflects, to some degree, on future commitment in motorsport.

With regret, the continuing difficulties in the Eurozone lead to a generally depressed overall european market. Nations such as Italy, France and Spain are going through very difficult times economically, and so the financial opportunities to invest in motorsport are severely limited.

There is no quick fix ahead for these economies, but the German economy continues to be the strongest in Europe.

Conversations at the PMW Show and beyond reveal this area as being robust, and the performance of Mercedes, BMW, Porsche, VW, Hyundai, Audi and many others, demonstrates their commitment to using motorsport to help sell their brands globally. This gives strength to their domestic supply chain, as well as great opportunities for other countries to approach that market. They are also moving quickly into alternative power trains, which produces good opportunities for research and development. As always, the close link between their automotive OEMs and their motorsport programmes mean these are very well funded and likely to last for some time in the future.

Automotive economies

Looking at the other nations in the Eurozone, it is hard to see real significant change occurring over the years ahead, as they must focus more on improving their automotive industry economies, upon which most of their motorsport relies. However, there are singular outstanding examples – Tatuus and Mygale enjoying the enormous immediate success of Formula 4. While not a vastly expensive programme, it shows that there is still wealth available to support entry level motorsport. However, in the wider scheme, these successes are unfortunately relatively minor.

The UK sits outside the Eurozone and prospers by being an independent currency. The strength of the British motorsport economy lies in its substantial international trade, so it is not relying on any particular nation's economic strength.

As difficulties occur in the Eurozone, then opportunities open up in South America and Asia, as well as the US, and so this counter balances.

The British motorsport industry is going from strength to strength and there is an unbroken growth record over the past five years since the economic difficulties of 2009. The new powertrain changes have helped the growth; the pursuit of energy efficient solutions is a bonus; and the recent substantial engagement between the mainstream automotive industry and the British motorsport industry, particularly in the area of R&D prototyping of hybrid solutions, has brought substantial strength. Added to this is new business along similar lines with the British defence industry which is the fourth largest in the world. These moves make the traditional British motorsport

The US continues to be the strongest national market in the global economy

Germany is a strong market, but if you want to go international, go to the US, says the MIA

industry far more solvent, secure and capable of rising to any motorsport challenges that arise.

The US continues to be the strongest single national market in the world, and with the economy improving – GDP at 3 per cent, similar to the UK's prediction, unemployment falling to unprecedented levels, just as in the UK, and house prices rising, soon to be followed by wages too. All these indicators provide confidence in the motorsport markets. It allows commercial concerns to sponsor races and cars, and private drivers to release some of their wealth to support their activities.

Corporate America is returning to motorsport, slowly but certainly. IndyCar is starting again from low beginnings, but is nevertheless on an upward trend – audiences returning, costs are being brought under control. This is also true of the sports car and GT market, in the US. Never underestimate the enormity of the project which NASCAR faced in amalgamating two major series, ALMS and Grand Am, in a continent as vast as the US. Scott Atherton and his colleagues at United SportsCar deserve our admiration for making this happen and keeping full grids and a growing spectator audience, allied with an enthusiastic TV and media package. That consolidation work is still underway for 2015, but from 2016 onwards, the amalgamation will be even more important and you will see the emergence of substantial business in prototypes and GT cars.

Looking at the other nations in the Eurozone, it is hard to see real significant change occurring although linking their technical future to the capability of racing at Le Mans will be an attractive cocktail for US sponsors and investors in sports cars, and even now, during this consolidation period, their grids remain consistently above 50 cars for each race, which is outstanding.

NASCAR has changed the rules subtly, but opening up great new business opportunities in simulation and aerodynamics. It could be said that this is an ideal opportunity for European F1 trained experts in these fields to turn their attention towards NASCAR, with the cutback in testing, forcing them to invest rapidly in sophisticated simulation techniques and modelling.

I always find it strange that those who wish to criticise NASCAR say they are slow to move, but in fact, they have a magnificent show which is appreciated by millions of fans and many sponsors that they must preserve and retain value. However behind the scenes of the last few years, they have made tremendous changes, and very courageous ones – the demise of the traditional carburettor was handled with great skill and did not affect the show, and now again, there will be a move towards more lightweight materials being allowed, and improved aerodynamics and simulation techniques. NASCAR produces the greatest spectacle in world motorsport, in my view, and this is borne out by the millions of fans who pay their $100 and enjoy the spectacle first hand. This is a different model from F1, which relies on TV audiences but fails to attract crowds who wish to pay the high price of enjoying the real thing.

My strong wish for businesses in 2015 and 2016 is "go international" and if you have to select a market to approach, go to the US. Good luck to everyone in 2015 and if you feel the MIA can help you in any way then please just contact us as we are here to help – www.the-mia.com.

AUTOSPORT INTERNATIONAL Engineering Show 8-9 January 2015 NEC Birmingham, UK In association with Racecar engineering

Show opportunities

Companies can use the shows to build a stable and solid future

Show season is an interesting time of year as suppliers race to launch their products in time for the new year, but by the time the shows come around development work is already underway. Porsche, for example, has already rolled out its 2015 919 Hybrid before Christmas, and the Formula 1 teams will hit the track at the end of January in preparation for the 2015 season. Even the Nissan LMP1 car has been running. Parts have already been evaluated, sourced and, by the time the trade shows roll around, component suppliers are vying for a small market...unless companies are looking further into the future and showing off already existing relationships. Brake manufacturer PFC had the 2015 Indy Lights car on its stand at the PRI show in the US, and is making the most of its relationship with Renault which is getting larger, and even more profitable.

There is a good reason why suppliers, manufacturers and teams return year after year - there is good value in the trade shows and the Autosport Engineering Show is a good place to do business, if not in the short term then keep an eye on the longer-term, and for trade growth. Did you know, for example, that more than 15 per cent of Autosport International exhibitors are based outside of the UK? A total of 16 countries are represented among the exhibitor list, led by 17 firms from the United States of America, 13 from Italy and 10 from Germany (correct at time of writing). Belgian, Czech, French, Greek, Lithuanian, Dutch, Portuguese and Swedish companies will also jet in from the continent, while those from Australia, Hong Kong, Malaysia, New Zealand and Taiwan are preparing for a slightly longer trek.

At the NEC, they'll be joined by motorsport professionals from around the world, with the Autosport International 2014 trade audience of 28,000 guests spanning 63 different nations. The group of international exhibitors includes industry leaders such as Brembo SPA, Bosch, Capricorn Automotive GmbH, Öhlins Racing AB and Sadev. Many will use the platform to launch new technology on the eve of the new season. This is an exciting time for racing suppliers and companies. The rapid development of new technology opens up new opportunities, while the emphasis on traditional race car engineering is still paramount for on track success. Make the most of the Autosport Engineering Show, held in conjunction with Racecar Engineering. We are both celebrating major anniversaries this year.

If you want to pass comment on the magazine to the editorial team, please do feel free to come and see the Racecar Engineering team in booth E580, where we will also have our latest show offers, both print and digital. You can also book advertising with the ad team which will be there in full strength, and look at how Racecar Engineering can help you to promote your business through our various platforms with the marketing team.

Mazak shows latest INTEGREX at Autosport 2015

Yazak has a long history of supplying CNC machine tools to the motorsport sector, most notably its relationship with McLaren Mercedes as the Formula 1 team's official supplier of CNC machine tools. There are currently 25 Mazak machines in operation at the McLaren Technology Centre in Surrey.

The latest variant of Mazak's flagship INTEGREX range, is cutting live on its stand throughout the show. It features a large machining area with compact ergonomic design and highly accurate performance. The machine is capable of machining both round and square workpieces from raw material with just one set up, one machine and one operator. It is also equipped with a new BARTAC S bar feed system, which offers integrated work unloading and conveyor handling of completed workpieces for lights-out and unmanned running.

Richard Smith, managing director UK & Ireland sales division, for Mazak commented: 'The Autosport Engineering exhibition is always a great way to kick off the machining year. Our INTEGREX i-100S is an exceptional machine perfectly suited for use across a wide range of applications within the autosport and automotive sectors, from small batch and prototype work through to volume production.

'What's more, the addition of the BARTAC S bar feed system enables continuous batch runs of workpieces which can increase productivity; an asset which cannot be underestimated in an industry where incredibly fast turn-around times are the norm.'

He continued: 'The i-series has proved to be highly successful in the UK market and across Europe since its launch and we are confident visitors to Autosport Engineering 2015 appreciated its capabilities during the live cutting demonstrations.'

Zircotec

Thermal management specialist Zircotec has created its first ever 'structural' heatshield, called ZircoFlex® FORM, and displayed parts at Autosport International. The new, more rigid and stainless steel heatshield provides Zircotec's ceramic coating protection together the strength and ability to form structures. Zircotec plans to launch in the coming months a number of hybrid derivatives, each able to solve multiple heat issues including both reflective and conductive sources, providing a compelling mix of strength, weight, structure and heat resistance. In addition to the heat benefits, initial testing suggests that FORM can also provide acoustic damping, ideal in GT and sportscar applications where unwanted noise can increase driver fatigue. Available from January, ZircoFlex FORM can be bent, cut and formed to shape, making it easy to fit to existing vehicles where heat is an issue. Visit stand **E962** in the Autosport Engineering Hall for more information.

Novel coating

A new plasma-sprayed coating that paves the way for increasing the use of lighter and more efficient materials in electronic applications has received the 2014 Innovation in Materials Award from the trade body for the UK composites industry, Composites UK. Zircotec's durable coating offers a considerably lighter solution than resorting to metal shields to protect the rising number of electronic systems housed in composite enclosures from electromagnetic interference (EMI).

Electromagnetic interference (EMI) can interrupt or degrade signals of transmitted data. Issues range from being simply a nuisance through to catastrophic failure that mandates legislation in sectors including automotive, aerospace and defence. With a rising number of engineers looking to make use of the lighter weight properties of composites in such applications, Zircotec's coating offers a robust solution without adding the weight penalty of using metal shields. Zircotec's EMC coating is already in use within motorsport, driven by a surge in electric hybrid powertrains, and is likely to transfer to similar applications within the automotive sector. The Abingdon, UK, based firm is now discussing applications for the new coating in future defence, aerospace and marine applications with projects set to start in the next 12 months.

Radical

British manufacturer Radical Sportscars launched its new flagship model, the SR8 RSX. The car is Radical's most advanced, powerful and aerodynamically-developed open racing car yet.

Founded in 1997, the Peterborough-based manufacturer has been one of the local industry's leading lights during the show's history and is now the world's largest constructor of racing and track cars, producing over 250 vehicles each year.

Priced at £109,950+VAT at launch and with a power-to-weight ratio of 558hp/tonne, the SR8 RSX is set to offer a value-packed dose of Le Mans Prototype-esque performance. A bespoke, 3.0-litre V8 engine delivers 440bhp and is paired with a new seven-speed, paddle-shift gearbox from Quaife, and an all-new carbon tubular steel spaceframe chassis.

In addition to sharing technology such as variable-assistance power steering, the SR8 RSX features design elements from the closed-cockpit RXC, crossed with Radical's SR9 LMP2 racer for a unique end product. The total package weighs 860kg, while larger cockpit dimensions enable a greater range of driving aids and functionality.

The new SR8 RSX will be eligible for Radical's premier international racing series, the 2015 Radical European Masters. Radical's Autosport International presence will be its biggest ever, with the SR8 RSX starring alongside the recently-revealed SR3 RSX four-cylinder track and race car, RXC V8 coupe and the entry-level SR1 Cup package. Over 600 exhibitors from the UK's renowned Motorsport Valley and beyond, spanning every aspect of high-performance engineering, are estimated attending Autosport International to start the 2015 motorsport season.

The new SR8 RSX, eligible for the European Masters

Xtreme Clutch kit for Focus RS

Xtreme clutch is a performance focused division of Australian Clutch Services, the market leader in clutch production and development in Australia. Xtreme produces a vast range of performance clutches, flywheels and conversion slave cylinders to suit thousands of vehicles for both road and track applications. Following frequent demands from both overseas and local customers, Xtreme Clutch decided to develop a unique clutch solution for the 2010-2012 Ford Focus RS. The new Xtreme Ford Focus RS kit is a 240mm single plate organic kit. The clutch replaces the original dual mass flywheel and pressed steel self-adjusting cover with a racing style alloy pressure plate and chromoly single mass flywheel.

The clutch was developed as a heavy duty street clutch for the 2010-2012 Focus RS 2.5L where the dual mass flywheel is not suitable for spirited driving.

The new racing style alloy pressure plate and chromoly flywheel provide a lighter rotating mass for the engine to work with. This kit is also an upgrade for late Focus ST and XR5 Turbo models running the same drive train.

For further enquiries on the Xtreme Clutch product range, please visit xtremeclutch.com.au or email sales@xtremeclutch.com.au

Brembo: GT products

Brembo enriches its range of Racing products with the 6 piston front GT caliper made in aluminium alloy and ready to fit the 390mm discs.

This GT caliper is the first one designed by Brembo specifically to work on discs with a bigger annulus, in other words with a 64mm radial surface, and it is designed to mount 30mm pad thickness instead of the more common 29mm ones, thereby granting longer life in endurance racing competitions.

An important feature is the innovative quick release system for pad replacement which allows the mechanics to change the worn pads as safely and quickly as possible. The geometry of the new GT caliper is optimised to reduce the overall weight of the braking system and to guarantee excellent performance. The caliper can also be fitted with a sensor that checks pad wear during the race.

Also introduced is a new 390mm front disc, a product specifically developed for GT category championships.

The 390mm diameter is a new size for Brembo, which until last year had produced racing discs with a maximum diameter of 380 mm; the braking surface, on the other hand, will be available both in the standard 53mm measurement and the 64mm wide annulus.

This disc, made from new raw material, has been designed with a different airgap that goes from the current size of 17 mm to 18 mm and with an innovative ventilation design in order to guarantee both significantly improved heat dissipation efficiency and a reduction in weight of the disc itself.

In the constant commitment to research and focus on innovation, decided to introduce on one of its Racing master cylinders the possibility to install a magnetic travel sensor. The travel sensor is a useful tool for analysing the brake system efficiency. Brembo also offers the possibility of purchasing the master cylinder and the sensor both as a set or separately.

Keating

Keating Supercars has designed the TKRS to be at the top of its class when it comes to performance and will unveil it at the Autosport show. Able to reach 60mph in just 1.67 seconds, the TKRS is built for speed. Aerodynamically tested using a full scale wind tunnel, the TKRS was the fastest car ever tested by the Centre for Advanced Performance Engineering at the University of Bolton.

Working with students from the university, the latest iteration is 20 per cent faster than the original

TKR and its creator has ambition to see his latest masterpiece attempt to break the production car land speed record.

Brembo: rally products

Rally drivers need to have more and more aggressive friction materials available, therefore Brembo has created a 32-38mm piston liquid-cooling caliper, made entirely from aluminium alloy.

The need for this type of caliper comes from the fact that, during WRC championship on Tarmac, standard calipers were unable to grant enough cooling of the system, reducing the driver control in the braking phase. This liquid cooling system aims to ensure a significant increase in braking performance. In fact, with this new caliper a drop in temperature of about 80°-100° is obtained with up to 45 per cent improvement on caliper temperature compared to air cooled systems.

The thermal drop allows the use of pads with more aggressive compounds that guarantee higher bite and a higher friction coefficient preventing excessive overheating of the calipers.

The liquid cooling 4 piston caliper is entirely machined from billet and has a particularly lightweight structure. In fact, it is similar in the design to a standard caliper with the addition of a few specific features such as the reservoirs and radiating surfaces for liquid circulation required for this type of cooling. This structure allows a only 0.2kg of weight increase than WRC air-cooling caliper which, added to the significant thermal gain, gives an improvement in braking system performance.

The WRC liquid cooling caliper was introduced for the first time last year in the German round of the World Rally championship with excellent results.

The Lightweight Rally disc is a type of disc designed for the most extreme competitions in the World Rally championship.

It is a cast iron disc that has been lightened by about 20 per cent with completely redesigned ventilation to allow significantly more efficient air circulation during the cooling phase.

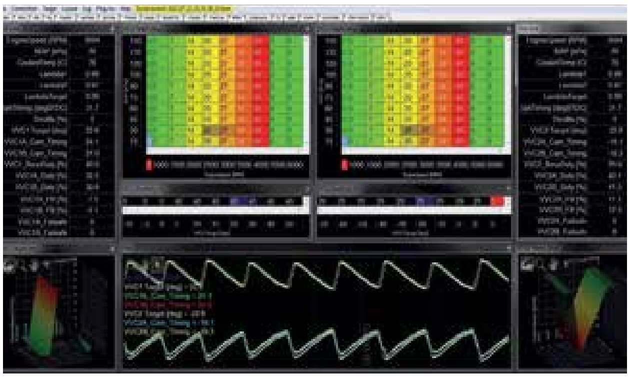
The disc is available in 300 mm or 355 mm diameter versions.

In order to supply even more complete car equipment, Brembo has designed a hand brake dedicated to four-wheel-drive Rally cars and a pedal box assembly to equip WRC and GT championship cars.

Advanced Engine Management

Advanced Engine Management has announced new software for the Infinity standalone programmable ECU at the show. The new supported applications include Porsche 997/996 Turbo, VW MKIV 1.8T with DBW, and 13B/20B Mazda rotaries.

New features added to Oil Protection and 3-step algorithms, enhanced DBW functionality, and added semi-sequential fueling strategy. The I/O set up page is more intuitive. AEM has also released its Infinity-6 (30-7106) and -8h (PN 30-7108) ECUs and Plug & Play Adapter Harness (PN 30-3903) for 2002-'05 Volkswagen Golf/Jetta 1.8T racecars. When combined with AEM's Plug & Play Adapter Harness, the Infinity completely replaces the factory VW 1.8T ECU and can be installed in about 30 minutes when using the factory sensors (MAP sensor required and sold separately). A base map for the engine is included.



Advanced Engine Management's new software

The Infinity ECU does not support the factory Mass Airflow sensor. AEM offers a MAP sensor adapter harness (PN 30-3903-00) for seamless integration that provides speed density fueling control and allows users to eliminate the factory Mass Airflow sensor (MAF).

The Infinity ECU makes state-of-the-art ECU technology affordable for both professional teams and amateur racers. Built around a latest-generation 32 bit floating point 200MHz automotive processor and Real Time Operating System (RTOS), the Infinity is capable of processing 400 MIPS (millions of instructions per second). This processing speed combined with a RTOS provides more accurate ignition timing for increased power, more responsiveness to truly custom tailor the driving experience to the driver, allows the Infinity to perform more computational features without a sacrifice in processing performance, and enables tuning of features and sub strategies without affecting other features and sub strategies. It allows you to do more, faster, in a more stable programming environment.

Schroth Racing

Schroth Racing introduces the Schroth Racing iNDi Seat. (Previously known as HANS Seat). The iNDi Seat is a race proven seat insert stemming back to the 1990's. The iNDi Seat has been used in all levels of Formula/Open Wheel and various championships and series for almost twenty years now. We are very happy and excited to be working with the originators of this system as an additional quality product option from SCHROTH Racing.

Over the years the iNDi seat insert has constantly been improved through research, testing and development, and today it leads the market for seat inserts.

We are very proud to be able to offer the best technical support and advice from our Schroth Racing iNDi Seat Team, offering not only the seat insert as a DIY kit to all drivers in all championships to make themselves, but we also offer a full Seat Fitting and Covering Service if you want to have your Schroth Racing iNDi Seat made for you.

Aquila's new car targets students

Aquila Cars has launched a new car project targeting universities and engineering students. Along with Birmingham City University, Aquila developed the Syndergy racing car, a one-seat open sports car prototype based on an aluminum monocoque and a 3-cylinder, 1-liter Toyota engine. Aquila sells Synergy in three packages. One for universities, one for colleges and one for privateers. The cheapest version of the Synergy, can be purchased for just £7990, an extremely reasonable price for a racecar with a low center of gravity, low weight and low maintenance costs. Synergy is the fourth car from Aquila, who in 2005 produced their first Formula Ford, followed by sports car prototypes CR1 and Adamo.

The idea is that universities and colleges buy Synergy kits. To assemble the set, they must use a donor car (Toyota Aygo, Citroen C1 or Peugeot 107) and use the engine, transmission and wiring to the Synergy kit. Students must first assemble the aluminum sheet monocoque, which afterwards must be reviewed and approved by Aquila.

Subsequently, the students assemble the rest of the car and thereby receive important training and experience in construction and manufacture of a racecar. In the College version of Synergy, the chassis is pre-assembled and the practical experience obtained by assembling the mechanical parts.

Tickets are on sale for the Autosport International Engineering show, held at the Birmingham NEC, on 10-11 January 2015. Advanced Adult tickets cost £32, children £21 (under fives go free). Group tickets are available. Paddock passes cost from £42, VIP passes cost from £120.

Paddock passes include general admission plus access to the Driver Signing Area, the backstage Paddock Area and a paddock guide.

VIP tickets include: access to the VIP enclosure at the Live Action Arena, complimentary champagne and canapés, a Club Lounge, free parking, access to Driver Signing Area and dedicated VIP signing sessions, fast-track entry to the Live Action Arena and access to the backstage Paddock Area.

For more information call +44 (0)844 581 1420 or visit **www.autosportinternational.com**

Trade stands are available for the Autosport Engineering Show, held in association with *Racecar Engineering*. Don't miss out on your opportunity to exhibit in a trade-dedicated area for two days ahead of the main show. To exhibit, please log on to **www.autosportinternational.com/trade**, or contact Tony Tobias; **tony.tobias@haymarket.com**

Fire safety
Lifeline takes up new home

After 20 years in Burnsall Street, Lifeline Fire has considered that it is time to move on to much larger premises – still in Coventry – where production will be streamlined, meaning a faster delivery service from stock and the ability to bring new products to market quicker. The company's new address is: Falkland Close, Coventry CV4 8AU, UK.
http://www.lifeline-fire.co.uk

Pedals
OBP introduces new pedal box

OBP Motorsport has taken its massively successful Universal Pro-Race V2 series of bias brake pedal box/assemblies and taken them to the next level. The Pro-Race V3 full aluminium billet bias brake control pedal box/assembly is aimed at pro-drivers and teams. Prices start at £800. Available Jan 2015 – pre-order today.
http://www.obpltd.com

Sensors
Variohm specialist sensors

Variohm EuroSensor supplies an extensive range of specialist sensors and transducers across the motorsport industry. The complete range includes pressure and temperature sensor solutions for fuel, oil, coolant and brakes as well as force, torque and position measurement sensors for suspension travel, steering angle, ride height, throttle and gearbox. Laser and infrared technologies are also supplied for ride height position and tyre condition.
http://www.variohm.com

Steering
Quick release from SPA

SPA's QR3 Steering Quick Release mechanism utilises a Deutsch 22 pin connector pre-wired with Raychem cable. The boss is manufactured from aircraft specification material and the inner splined hub is hard anodized for strength and durability. Shafts available in EN3B or 4130 steel either 5/8in or 34mm.
www.spa-uk.co.uk

Fire suppression
Total protection

SPA Design, a world leader in racecar fire suppression safety, is proud to introduce the first three-way activation head for this industry sector. This SFI17.1 certified extinguisher can be electronically activated, mechanically activated or automatically activated by the frangible bulb offering total protection to the driver.
http://www.spa-uk.co.uk

The International Journal of Motorsport Technology
Racecar engineering

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Subscription rates UK £66 (12 issues) USA $162 (12 issues) ROW £84 (12 issues)
News distribution Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT **Tel** +44 (0) 20 7429 4000 **Fax** +44 (0) 20 7429 4001 **Email** info@seymour.co.uk
Printed by Wyndeham Heron
Printed in England
ISSN No 0961-1096
USPS No 007-969

recycle

www.racecar-engineering.com

Flag complications

Following Jules Bianchi's crash in the Japanese Grand Prix in October, the FIA has issued a detailed report into the accident and the details are covered on page 80. What was also interesting was that the FIA considered a safety car system loosely based on that trialled at Le Mans and used subsequently in FIA WEC races.

The circuit at Le Mans is so large that multiple safety cars were required to slow the field within a suitable time. This year, that was replaced by a new system, where all cars ran through a specified 'slow zone' at the pit lane speed limit, 60km/h. This led to problems with drivers making up time through the slowing down zone. It took up to 30 seconds before all the cars slowed to the correct pace. Since then, that time has improved to 10-15 seconds, although clearly this can be used strategically.

The 60km/h limit also led to another problem; the cars are designed to run on the pit lane speed limiter for a short space of time and for a particular purpose before they stop, are switched off while refuelling and tyre changing takes place, and then restarted. The pit lane programmes run by the cars was set up for such routine but out on track, not only were the cars getting confused after running for 1km on the set programme, but the cars were not designed to run for such distance at such a pace, and damage was being done to the engines and clutches, while cooling was also on the limit. Then, the FIA went further and for remaining WEC races, the Virtual Safety Car was used around the full track. Lessons were learned from Le Mans, and cars were slowed to a more manageable 80km/h, allowing for a separate computer programme to be written, one that didn't confuse the cars and the speed was high enough that the cars were not damaged.

It is still not perfect. In Sao Paulo, the leader got stuck behind a car that was running around two seconds slower than the chasing pack, and lost time. And this points to another problem – those that have the speed absolutely on the limit down the pit lane and those that don't.

In the days following Bianchi's crash in October, drivers considered what might be a fair solution for Formula 1, and their conclusion was that the driver needed to be taken out of the equation altogether. A driver is expected to make up as much time as possible, and use every tool available to him, including the safety car. To exclude the driver, the speed must be dictated by technology, and that technology must be governed by race control.

So, Formula 1 has gone for its own version of the Virtual Safety Car (VSC), which may be initiated to neutralise a race upon the order of the clerk of the course normally when double waved yellow flags are needed on any section of track, and competitors or officials may be in danger, but the circumstances are not such as to warrant use of the safety car itself.

However, there are issues to overcome, including the time it takes to get down to the correct speed. The WEC cars achieve this in 10 seconds, but in a sprint race such as Formula 1 this is too long. However, asking for an immediate drop to the stated speed could lead to sudden mid-corner deceleration, which would lead to its own set of issues for the driver. Under the Formula 1 system, a delta time is set for each section of the track to ensure the cars are not too fast on track at any time that the VSC is deployed. The WEC had major issues with this until an accurate GPS system was adopted.

In races where there is no such technology, drivers are taught simply to respect the yellow flags to protect the marshals

Under section 41.4 of the rules announced by December's FIA World Council, 'No car may enter the pits while the VSC procedure is in use unless it is for the purpose of changing tyres.' That allows for the possibility that those closest to the pit entry when the VSC is called may be able to gain track advantage if they pit first, and so it could still hinder a competitor.

In short, racing is still trying to find a way of making the safety car work, such that the marshals are safe, the race is neutralised without risk to machinery and in the WEC at least, that no one can gain an advantage, or be made to suffer. However, in races where the last tenths of a second are critical, without a clearly defined regulation it is open to abuse. Personally, I like the American attitude which, for a long time, was that with safety cars making a regular appearance, sometimes it helped, sometimes it hurt, but over the course of a season it probably balanced out.

The other system that I like is that in races where there is no such technology, and drivers are taught simply to respect the yellow flags, and protect the marshals who are trying to help them in the event of an emergency.

ANDREW COTTON Editor


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