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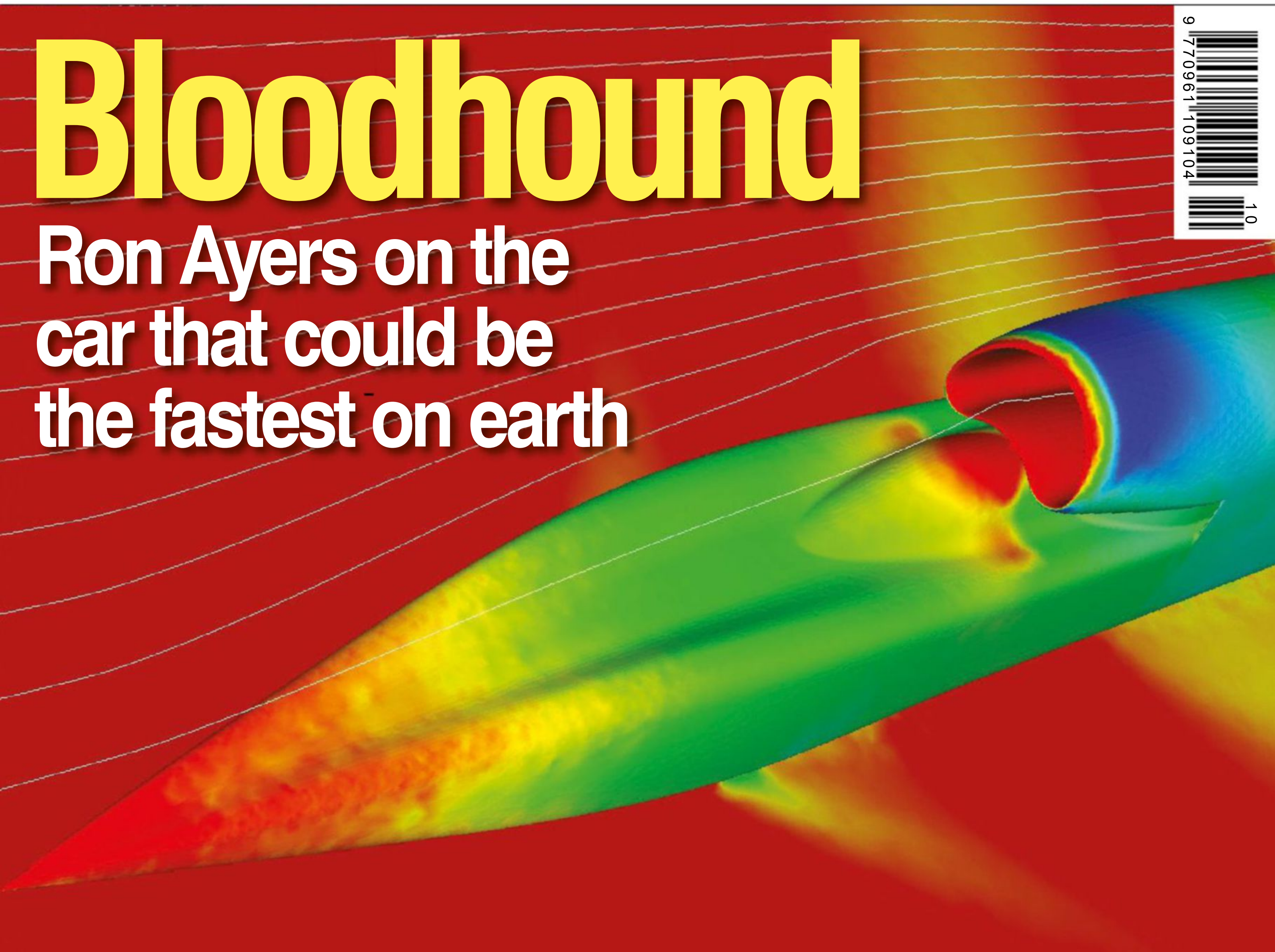
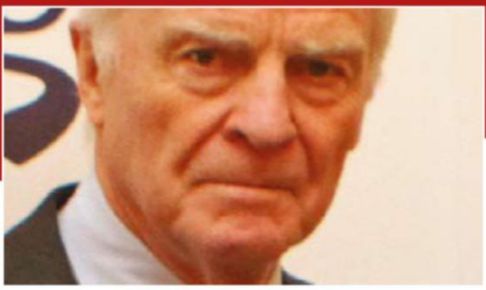


Bloodhound

Ron Ayers on the car that could be the fastest on earth



Max Mosley

Former FIA President speaks out about the future of F1

Secret LMP revealed

Exclusive pictures of Porsche's unraced Le Mans prototype

Birth of the cool

Simon McBeath on how to spec a race cooling system

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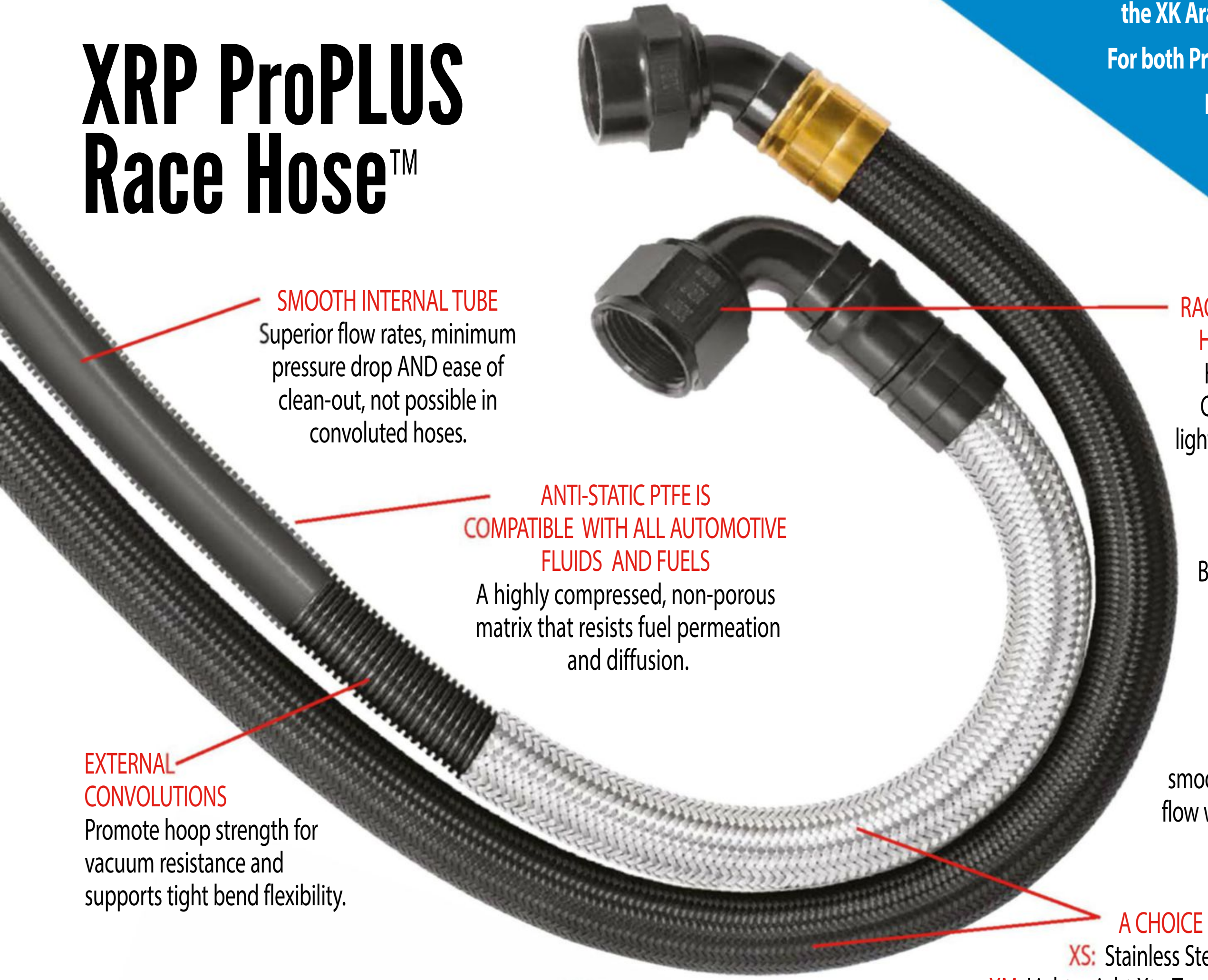

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The racecar that Porsche has hidden away for 16 years. Could this LMP have taken the fight to Audi at Le Mans throughout the 2000s?

Calculating risk

Is Formula 1 forgetting the fundamentals when it comes to risk management?

Motorsport is dangerous – it says so on the ticket. It always has been and always will be, just as descending stairs is dangerous. It's an activity which is right up there as a cause of accidental death with pedestrian road accidents, drugs and alcohol. Or, to put it another way, motorsport is remarkably safe; if you are going to have a high-speed crash in a car, make sure it is in a racing car. But this was not always the case.

The early races, city-to-city contests, had only been going a few years before nine fatalities during the Paris-Madrid caused the French government to halt the race in Bordeaux and ban all open road racing. Governments do not want to have to control any sport, let alone motorsport, and will only step in if sporting fairness or safety is compromised; instead they look for sanctioning bodies capable of doing the job properly. In international motorsport, that organisation is the FIA, with its affiliated member clubs acting as the national sanctioning bodies.

Explosive issue

High on the agenda of anybody responsible for any form of motorsport is safety. The sport is still inherently dangerous, because of the level of energy embodied in a high-speed car, the use of flammable fuels, high voltages in electrical energy stores, and the number of people involved in the running of the sport. The nature of the contest requires this concentrated energy to be conducted by a human at the limit of control – the kinetic energy of an LMP1 car at maximum speed is equivalent to over 1kg of TNT; while the full fuel tank is over 0.5 tonnes of TNT. And accidents will happen.

The job of the sanctioning body is to keep any sudden release of this energy away from humans. Track workers and spectators must be protected by the circuit layout and design, but officials, teams, marshals, and drivers are inevitably likely to be exposed. This is where the management of risk becomes necessary. Motorsport cannot be 100 per cent safe; there are always risks and they need to be understood and managed.

The instruments by which these risks are managed are the Sporting and Technical Regulations. The way the drivers, officials, marshals, teams and all engineers involved conduct themselves are laid down here. Also set out are how they will be policed and the sanctions for non-compliance. These regulations have been developed over more than 100 years, with variations for all the different forms of motorsport from bikes, to trucks, to dragsters, to rally cars, and to F1.

Four forces have shaped the evolution of these regulations: experience, technology, social pressures, and the nature of the competition. At any time they combine to form a set of rules that define and limit the risks. Those who participate in the sport, as opposed to watching it, know what these risks are and accept them. They volunteer to expose themselves to these risks and can always walk away if they believe they are unacceptable.

Experience and technology have been applied by the motorsport industry to steadily reduce the risks, but occasionally social pressures intervene and demand a further reduction in risk. Examples include: 1907 Paris-Madrid; 1955 Le Mans, and 1994 Senna and Ratzenberger at Imola.

Risk factors

Influencing this steady evolution of risk is the nature of the competition. Leaving bikes aside, the four main categories of wheeled motorsport are: Karts; open-wheel, open-cockpit, single-seaters; closed-wheel, closed-cockpit circuit cars, and closed-wheel, closed-cockpit rally and cross-country cars.

They do not have identical safety risks, so why is that tolerated? Neither do they have the same risk as racing motorbikes, downhill skiing, base jumping, cross-country horse eventing, scuba diving, or flying home-built aircraft.

They are all different, they all involve different risks, and participants understand and accept the risks, or at least they should do so, as their racing licence requires it. To try and unify risk in all forms of motorsport would result in closed-wheel, closed-cockpit cars on circuits, and would eliminate karting, rallying, and single-seaters. Nobody wants that.

Acceptable risks

What is an acceptable risk has changed with time. If we take the highest class of racing, initially road-racing, then grands prix, and now F1, in the early days the driver and his unfortunate mechanic sat on top of the car with little protection. In an accident they were usually thrown clear and hoped the car didn't land on top of them. Even after the occupants were lowered and surrounded by bodywork in the interests of performance, being thrown clear was the preferred option. Anything that inhibited the driver escaping from a car that was on fire was rejected. In the late '60s, aided and abetted by Jackie Stewart, F1 drivers started to *not* accept the unnecessary risks involved. Over the next decade, standards were established to completely change the philosophy of protecting a driver in an accident.

This resulted in the cockpit becoming a survival space, particularly by the installation of a roll over hoop. Also, the driver was restrained in this survival space using a full harness, he wore fire protection clothing, and fuel tanks were fitted with bladders.

Alongside these fundamental changes to driver protection, changes to the race circuits, the

The kinetic energy of an LMP1 racecar at maximum speed is equivalent to 1kg of TNT

XPB

While F1 is nowhere near as dangerous as it once was it still has its moments. This was at this year's Russian GP


XPB

Halo looks set to come in to Formula 1 in 2018 and is sure to be used on other single seaters too. But have the risk factors been properly assessed and is it worth diluting the essence of open cockpit racing if they have not?

emergency intervention, and the medical facilities at the tracks were also taking place.

Once the driver was strapped into the cockpit, he was subjected to the deceleration of the car if it impacted a solid object. These were steadily removed from the edges of tracks and replaced by impact attenuating barriers. Standards for the strength of the car chassis were developed and thought given to impact attenuating structures on the cars themselves. Unfortunately, at that time the sides of the car structure were mainly fuel tanks. However, the spaceframe and aluminium chassis of cars in the 1960s and 1970s would not hold up well in an accident and intrusion injuries became prevalent, for example with Clay Regazzoni and Ronnie Peterson. And so the driver was moved back to put his feet out of harms way and fuel was stored in a single, central fuel tank.

Driving change

Drivers drove these changes, new technologies enabled them, and there was little pushback against the changes, as they did not infringe on the F1, open-wheel, open-cockpit concept. The advent of CFRP monocoque chassis then led to the concept of the strong survival cell for the driver, surrounded by impact attenuating structures of regulation-prescribed performance.

The risks reduced dramatically as intrusion injuries became rare and deceleration injuries were addressed with better harnesses, helmets, cockpit surrounds, and HANS developments.

The cars were still open-wheel and open-cockpit, and fans could just about see and identify with the drivers. Drivers started to take more risks as the consequences of a mistake were reduced. Circuit design, run-off areas and barriers, race direction, and intervention protocols applied throughout motorsport meant that a new generation of drivers arrived in Formula 1 who had never experienced a fatality at a motor racing event. Until Imola 1994.

Three accidents involving two fatalities occurred where the injuries incurred could be attributed in part to the lack of head protection in an open-cockpit. Measures were put in place to reduce the risks, but none impinged significantly on the concept of the open-wheel, open-cockpit single-seater formula. The risks became acceptable again.

We are now in a new era following a number of accidents where loose objects have hit the driver's head, and the risks are being reassessed once again. This time there is a difference, as the only potential solutions affect the open-cockpit concept of motor racing's premier formula, and inevitably, all the rungs of the single-seater ladder up which the young drivers climb to Formula 1.

Risky business

How are the risks assessed for acceptability in a volunteer activity? How are the sanctity of a concept and the image of a sporting activity determined? Who decides these issues? Risk is usually analysed statistically as it relates to the probability of uncertain future events. Safety is a statistical science, with development normally being based on experiments rather than theory. Any safety feature introduced into an activity can only be assessed in a limited number of experiments, which will never cover all eventualities. Once sufficient confidence in the benefits has been established it can be introduced and the *actual* benefits, measured against the downsides, assessed statistically. In motorsport there is usually a competitive benefit from taking risk, which must be balanced. Unfortunately motorsport safety statistics are very hard to establish reliably. With one fatality in Formula 1 every 20 years the data is not statistically significant. Head strikes by loose objects occur about once a decade. However, drivers themselves are expert at assessing risk, they do it every time they brake into a corner at racing speeds: 'If I leave my braking later and enter the corner faster I will take pole. If I brake too late, I shall not get pole and may damage the car or myself, which will affect my chances in the race.'

It is the drivers who accept the risk. No one can do that for them. The problem comes when they collectively say the risk is unacceptable; something has changed. At this point they can walk away, as Niki Lauda did on occasion, or lobby for a risk-reduction technical or procedural solution.

Dangerous liaisons

Enter the other stakeholders; the fans ('something must be done' or 'I shan't watch F1 if there is no danger involved,'); the sponsors (Mercedes after Karl Wendlinger's accident at Monaco in 1994 'We are not in this for a driver to be so injured in a car with a three-pointed star on it.'); the sanctioning body (must regulate safety to a level such that governments do not step in); the Commercial Rights Holder (against anything that puts fans off watching); the teams ('tell us what the rules are in time to implement them.' And then there's the lawyers ('it is too complex to define; depends on which territories are involved in any resulting action').

The race drivers themselves are experts at assessing risk, they do this every time they brake in to a corner at racing speeds

Any proposed reduction in risk that also changes the nature or perception of the activity is bound to cause controversy. Safety doesn't work with clear, irrefutable numbers, and this is why the Additional Frontal Protection proposed for F1, is creating so much discussion; how much does the Halo reduce risk? How much does it increase it? Would a screen reduce it further? Or increase the risk? Is there an alternative? How much would it cost to apply to GP2, F3, and F4 etc.? How many people would it put off watching F1?

Risk management is possible when clear numbers exist, although the unintended consequence can still rear its head. Without firm numbers it is just a battle of opinions. It should be resolved by the drivers (the risk takers), and by the guardians of motorsport, the sanctioning body (the sport) and the CRH (commercial rights holder), but in a world dominated by social media, everyone believes they have a right to have their views heard. From risk management to democratic government, it is becoming harder and more complex to find the right path in such an environment.


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Desert storm

With just over a year before Bloodhound SSC is set to go for the Land Speed Record at Hakskeen Pan in South Africa its chief aerodynamicist gave *Racecar* an insight into the challenges of designing a 1000mph car

By RON AYERS

Photograph by STEFAN MARJORAM

Creating the shape of the first genuinely supersonic car presented severe initial problems

Designing a car that is capable of traveling at 1000mph undoubtedly presents unique aerodynamic, structural and mechanical challenges. However, the engineering requirements of Bloodhound SSC are defined just as much by the fact that the longest track available is a water-laid playa, a flat desert area, just 12 miles long.

The Northern limit of the track is defined by an embankment leading to a road, and the southern end is bounded by sand dunes – so there is no chance of any over-run. The rules governing the World Land Speed Record (WLSR) stipulate that the velocity should be measured over a distance of one mile, and that a return run should be made within one hour. The average velocity of the two runs then defines the record speed.

Thus, our 12-mile track allows us 5.5 miles for acceleration, followed successively by one timed mile (the 'measured mile'), then 5.5 miles for deceleration. If, for illustration, we assume constant acceleration to reach 1000mph in 5.5 miles, the acceleration required would be 1.15*g*. Similarly, a 1.15*g* average deceleration would be required to come from 1000mph to a stop. These are truly formidable numbers and show that the restricted space available has just as much influence on the vehicle design as does the headline velocity of 1000mph.

Of course, the acceleration and deceleration will not in practice be anything like constant. **Figure 1** shows relatively low acceleration until 0.4 miles (17 seconds) when jet re-heat is selected. When the rocket fires at two miles (35 seconds), acceleration peaks at well over 2*g*, but reduces as aerodynamic

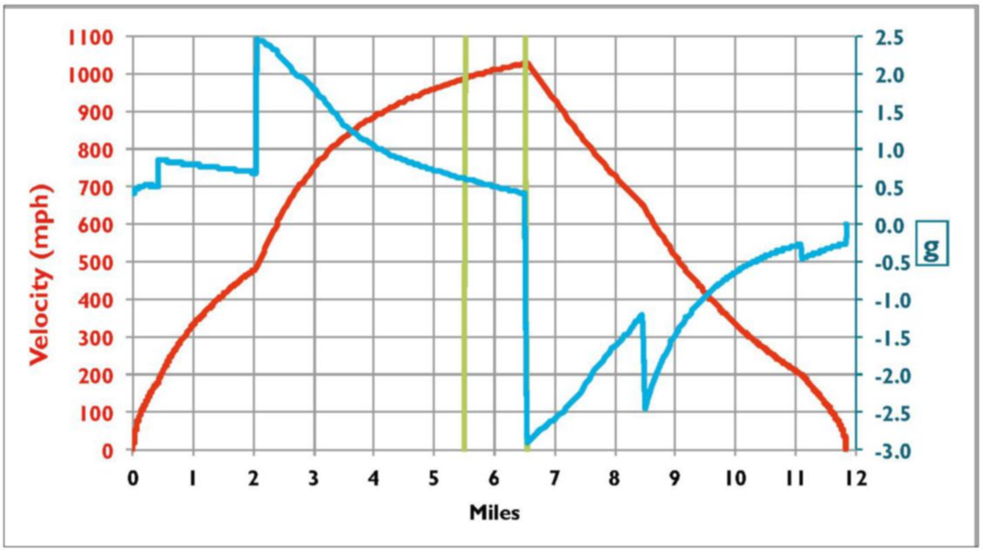

Figure 1: Note how there is relatively low acceleration until 0.4 miles (17 seconds) when the jet re-heat is brought in

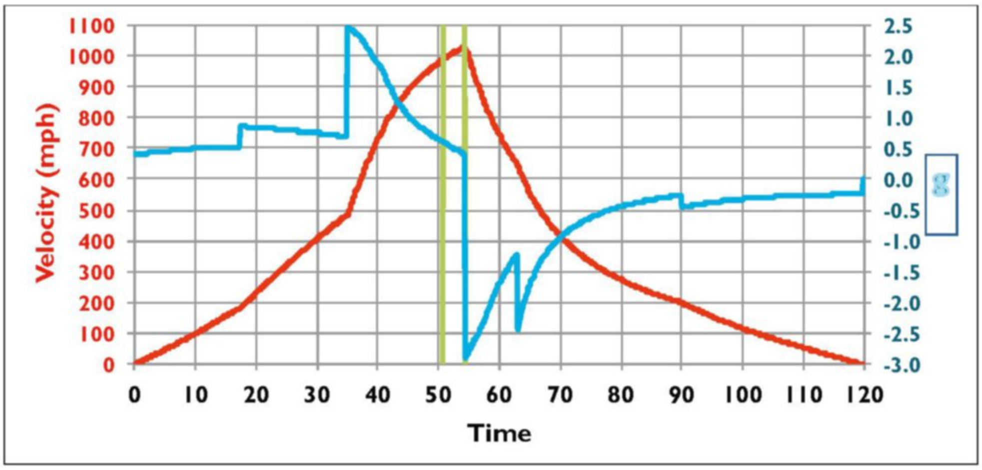

Figure 2: This shows the run over time. When the rocket fires at two miles (35 seconds) acceleration peaks at well over 2*g*

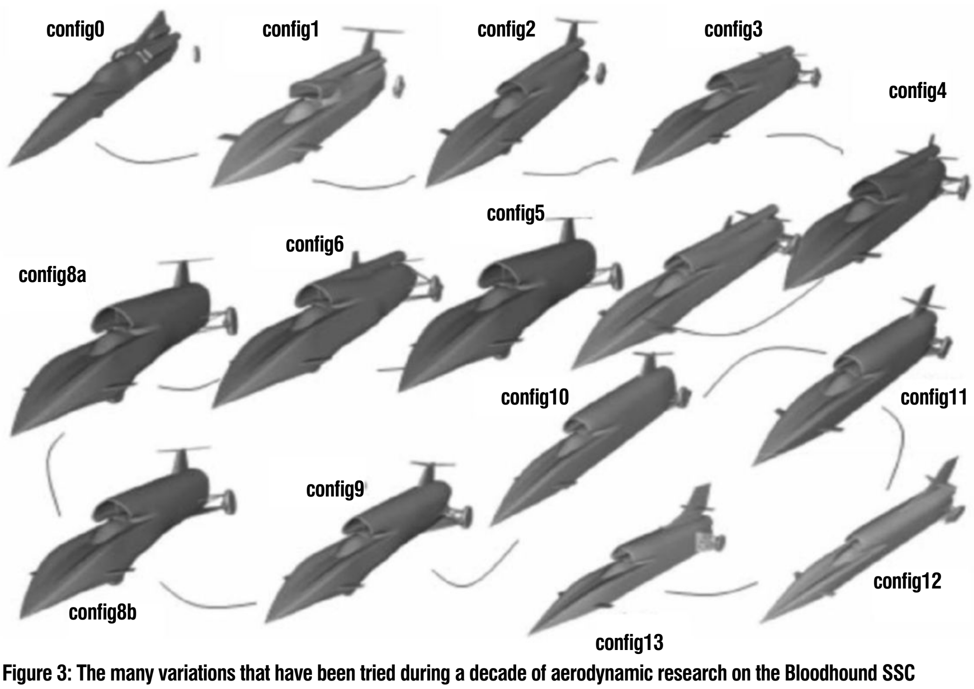

Figure 3: The many variations that have been tried during a decade of aerodynamic research on the Bloodhound SSC

Dynamically speaking, a hovercraft might provide a reasonable subsonic comparison

drag rapidly increases. Both the rocket and jet thrust are cut at the end of the measured mile. The **Figure 1** simulation shows a parachute deployment at 650mph and disc brakes applied from 200mph. This very same data is presented against a time base in **Figure 2**.

Even this simplified analysis enables us to identify the essential problems that must be solved. First there's the need for a high thrust/weight ratio propulsion system. Experience from Thrust SSC indicated that a jet-only solution would not be adequate, so an EJ200 jet engine, as used in the Eurofighter Typhoon, has been paired with a hybrid rocket motor. A 550bhp Jaguar V8 is used to pump nearly one tonne (800 litres) of concentrated hydrogen peroxide (High Test Peroxide or HTP) into the rocket chamber under 1100psi pressure, in 20 seconds.

Then there's the wheels to thinks about; these need to withstand a 50,000g radial force, combined with impact loads.

Aerodynamically, the car needs low drag shape, with pitch and yaw characteristics meeting very precise requirements at Mach numbers up to 1.4, while structural rigidity and the suspension also need to be considered.

Slowing a car from 1000mph is no easy matter, either. Airbrakes are used as primary means of slowing down. Capable of providing 10kN of decelerating force, rapid opening, but guaranteed to open symmetrically. Driver Andy Green has reminded us that the ability to stop reliably in the restricted space available is the one operational requirement that is not an optional extra. Back-up stopping power is provided by two parachutes deployable from 600+ mph, each able to stop the car, and disc brakes that can assist in stopping a 6.5-tonne (empty weight) vehicle from 200mph.

Then the car needs to be able to turn at the end of a run, be checked for damage or malfunction, refuelled with 960kg of concentrated hydrogen peroxide, the hot rocket casings have to be replaced with new ones, and then it must complete the second run to 1000mph – all within the hour. There is a lot to think about, then.

Aerodynamics

Creating the shape of the first genuinely supersonic car presented severe initial problems, for the obvious reason that there was no *prior art* to guide designers. The use of wind tunnels was rejected because tunnels capable of generating 1000mph are both wildly expensive and lack the necessary rolling road. Aerodynamic theory is also not very helpful. For instance, the well-known Sears-Haack optimum supersonic body shape ignores ground-effect and cannot accommodate the engineering necessities such as wheels, suspension, driver's canopy, jet intake, rocket and jet effluxes. However, experience with Thrust SSC in the 1990s confirmed that computational fluid dynamics (CFD) was now a sufficiently mature technology to determine

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Those wind tunnels that are capable of generating 1000mph are both wildly expensive and lack the necessary rolling road

pressures and evaluate the forces on a design. Dr Ben Evans of Swansea University has been responsible for all of our CFD analysis. Turn to **Figure 3** on the previous page for the range of variations that have been tried during a decade of research. Discussed below are some of the principal geometric variations:

Jet intake position

On the initial design, shown in **Figure 3** as **config0**, the jet engine was fed from bifurcated intakes with one part on each side of the driver's canopy. This led to unsatisfactory flow into the jet so a single top-mounted intake was selected instead. Careful positioning of the intake relative to the driver's canopy enabled a multi-shock compression of the flow into the intake, resulting in a significant gain in intake recovery factor (**config1**). **Figure 4** is a pressure image representing the flow at M =1.3, with the red area representing high pressure. The high pressure indicated at the front of the canopy indicates the presence of the shockwave that formed the first stage of the multi-shock system to decelerate the flow into the intake as efficiently as possible. Supersonic jet aircraft, such as the English Lightning, had significant conical centre-bodies in the jet intake to provide the same effect. **Figure 5** shows the same effect, but here the high pressure region – the shockwave – is shown in dark blue.

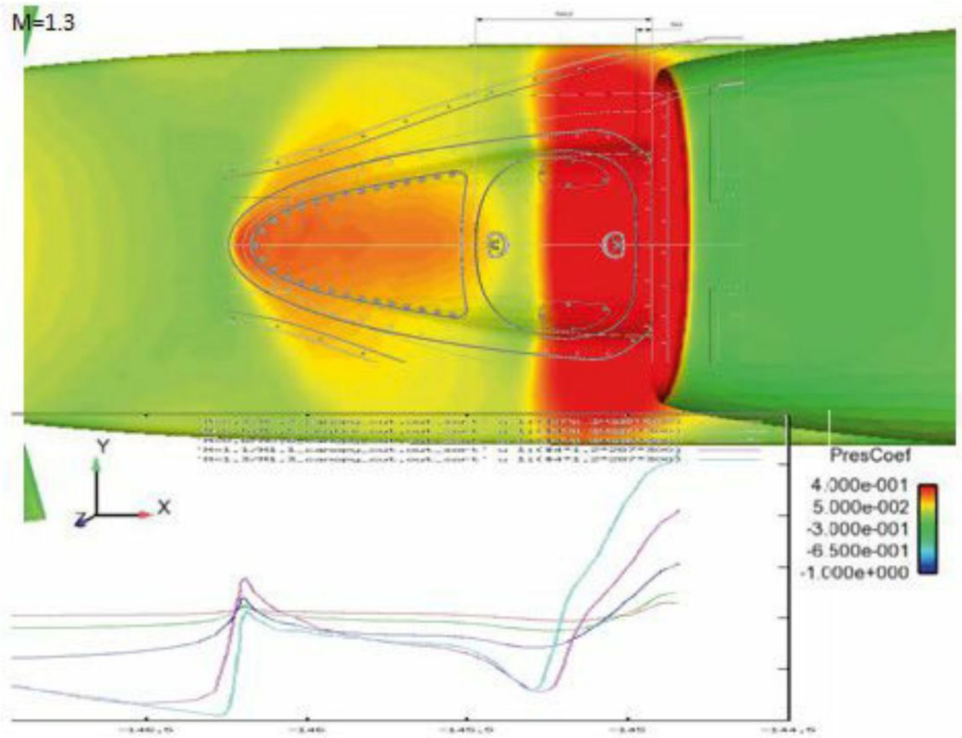

Figure 4: The high pressure (red) at the front of the canopy indicates the presence of the shockwave, decelerating the flow

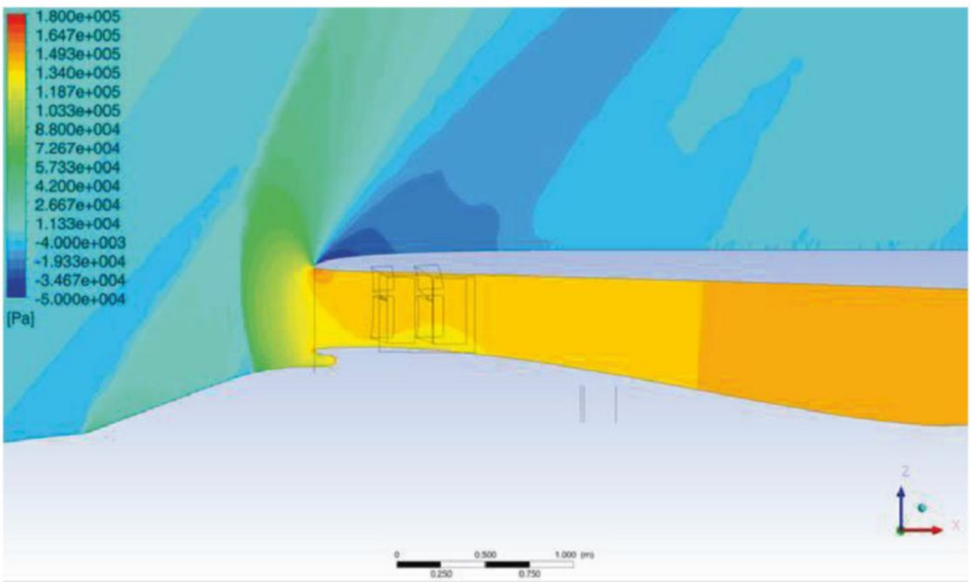

Figure 5: This shows the same multi-shock process as above but in this instance the shockwave is shown in dark blue

Area rule

In an initial attempt to minimise aerodynamic drag the frontal area had been kept as small as possible. Subsequent application of the area rule showed that the vehicle cross section near the front wheels was unnecessarily narrow, and that by increasing the width at that point we actually reduced the total drag. This nose widening (**config1**) also enabled the front wheels to be spaced further apart, which improved roll stability and simplified the mechanical design of the front suspension and steering mechanism. Subsequent configurations illustrate detailed evolutions of jet intake and nose shape.

On top or bottom?

Having a low centre of gravity sounds like a good idea, so putting the heavy jet engine under the much lighter rocket combustion chamber seemed obvious. Unfortunately, that meant that the line of action of the rocket was now too far above the vehicle centre of gravity. Thus, the rocket thrust (more than 100kN at a distance of about one metre above the vehicle centre of gravity) pushed the nose down and it was not possible to adequately counter this pitching moment by aerodynamic means. Such considerations led to **config5**, which reversed the positions of the jet and the rocket. This had the added advantage that it simplified the design of the jet intake duct, and provided suitable positions for the parachute cans, one each side of the rocket nozzles.

Mach sensitivity

In addition to minimising drag it was necessary to keep strict control over vertical forces. For structural reasons the maximum download per wheel was set at 25kN. To ensure safety/stability it was also agreed that the wheel load must never be less than 10kN. Keeping vertical aerodynamic forces within these limits proved to be extremely challenging as the vertical force coefficients proved to be very Mach number dependent. These, combined with the enormous dynamic pressures associated with supersonic velocities at ground level, resulted in unacceptable vertical loads. For instance, a configuration could easily have crushingly large downloads at one Mach number and 5*g* wheels-off-the-ground uploads at another Mach number. A rethink was needed.

After much analysis it became clear that the problem was caused by our initial (and


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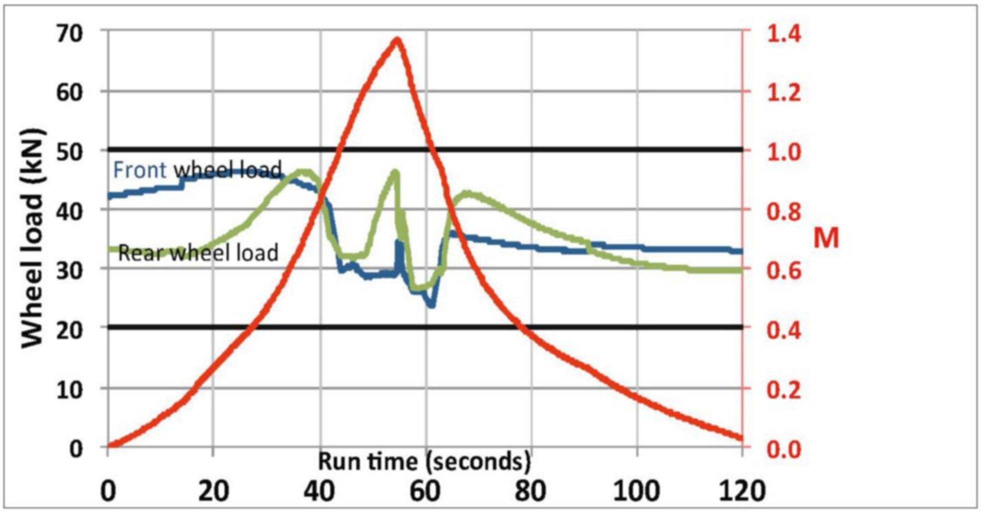


Figure 6: Predicted wheel load during a 1000mph run – in early development a quest for lower drag led to some issues

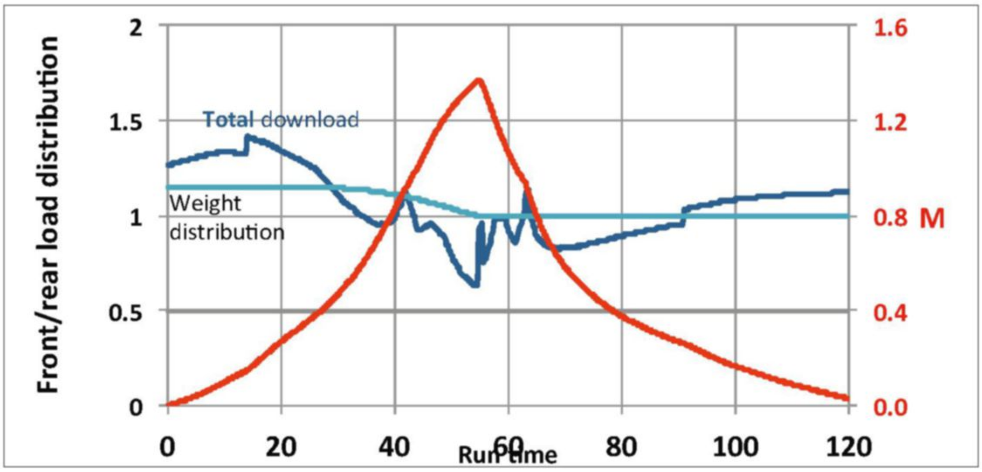
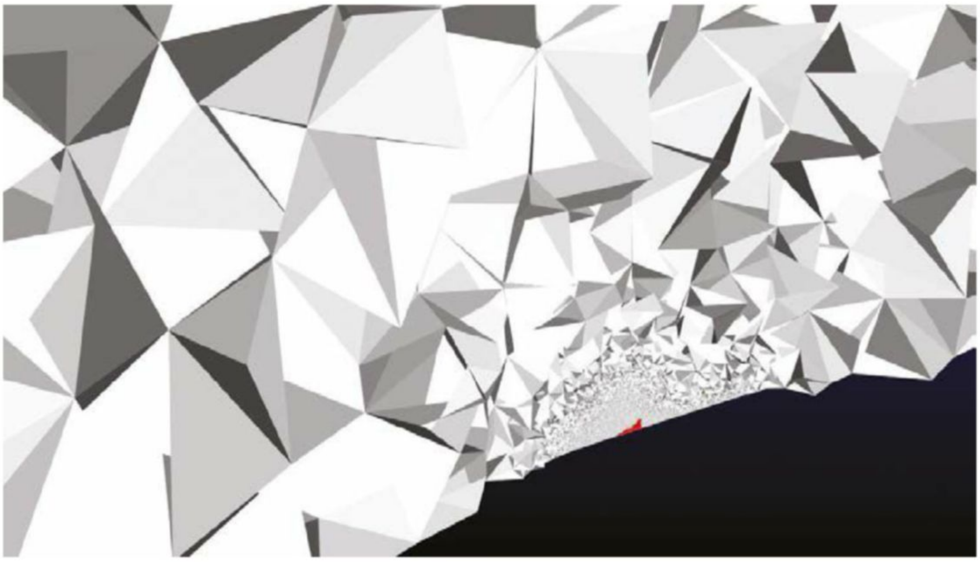


Figure 7: The download on the front wheels is still greater than on the rear wheels but the car's long enough to soak this up



With no wind tunnel up to the job CFD has been a vital tool for Bloodhound. This image shows the shockwave around the car

Careful positioning of the intake relative to the driver's canopy enabled a multi-shock compression of the flow into the intake

understandable) wish to minimise drag. This had led us to try aircraft-type body shapes with tapered after-bodies to minimise base area. It was these very shapes that introduced the Mach number sensitivity into the vehicle's lift characteristics. By changing the rear of the car to a simple parallel-sided, flat bottomed configuration (a bit like the rear of a single decked bus) we substantially solved the problem. **Figure 6** shows the currently predicted wheel load during a 1000mph run, taking account of the differing lines of action of the jet, the rocket and of drag – as well as the constantly changing position of the centre of gravity, for a run to 1000mph and back to a stop.

Although much better, the wheel load distribution still presents problems during acceleration. The download on the front wheels is clearly greater than on the rear wheels, as shown in **Figure 7** – a characteristic that is normally associated with instability.

However, jet powered cars have been successfully running with this characteristic since the early 1960s. As they always have a very long wheelbase (for Bloodhound it is 7.9 metres) the divergence time for such instability is long enough for the driver to be able to retain control and even be unaware of it.

Also, at high velocities the fin takes charge of yaw stability, so download distribution becomes of secondary importance. Despite all of this, our run programme will still carefully explore the yaw stability. Too much yaw stability may be just as dangerous as too little, as gust sensitivity at 1000mph could be an issue on our wide open playa in the desert.

Base drag

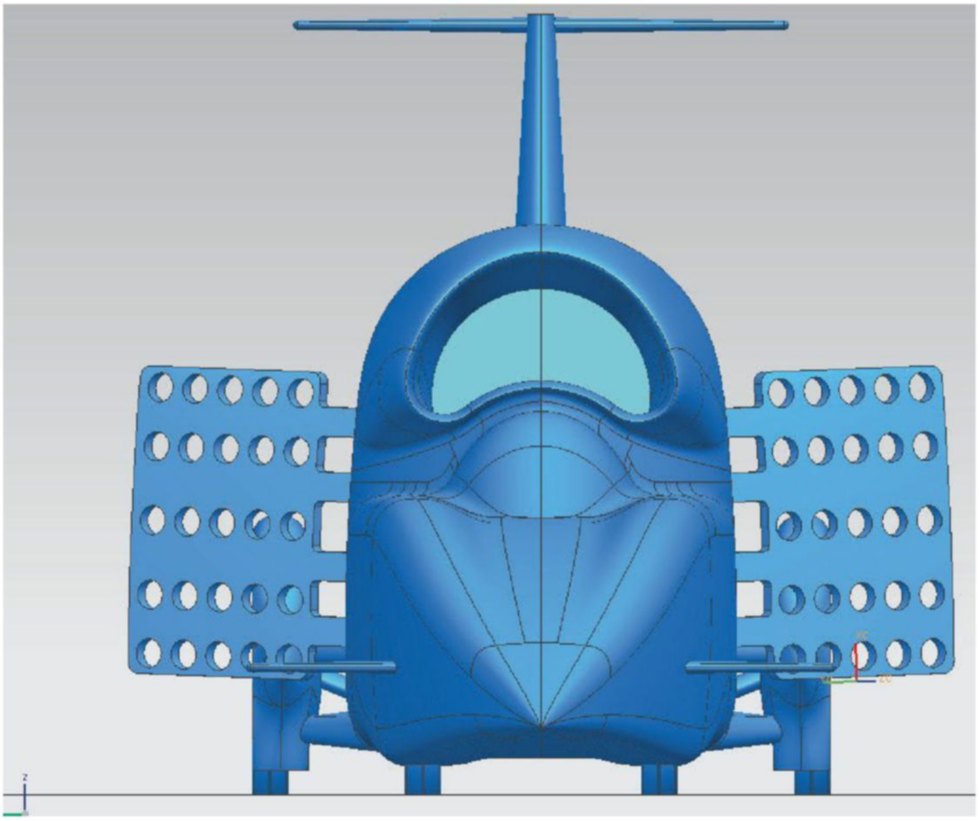
The change from rocket-over-jet to jet-over-rocket, and the use of parallel sides, effectively overcome one problem, namely, downloads. However, another problem is introduced as these geometric solutions constrain the vehicle to have a large base area.

Base drag coefficient reaches a maximum in the transonic region so a large base-drag results, aggravated by the presence of the jet efflux and rocket efflux. This can have serious impact on performance so we intend to use our first visit to our desert race track on the Hakskeen Pan, in South Africa – during which we hope to reach a speed of 800mph – to research the problem.

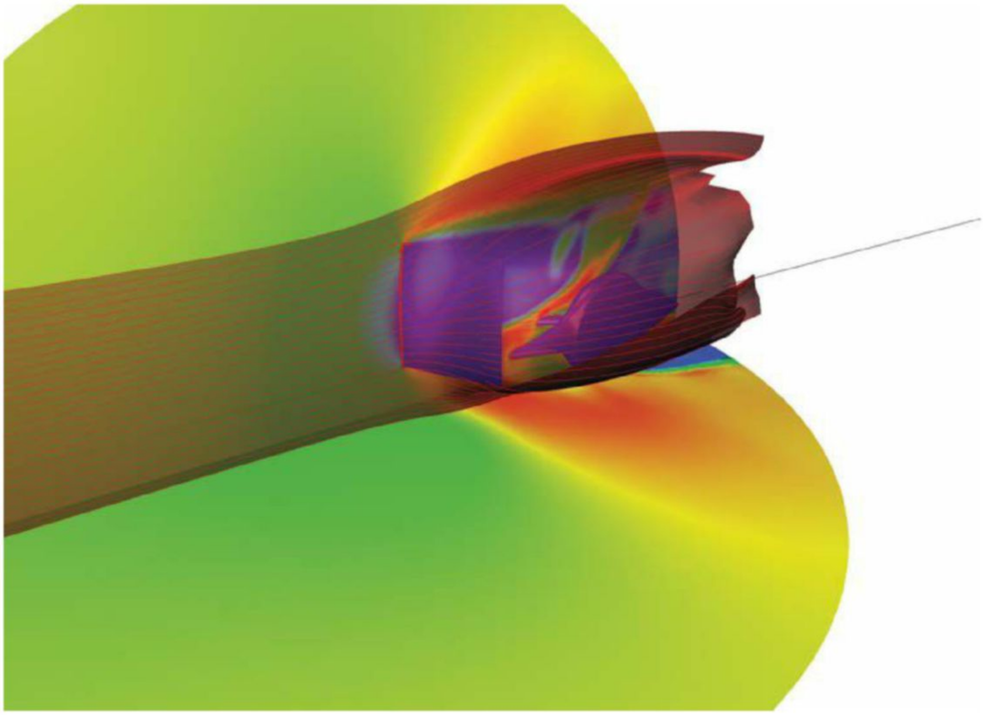
Meanwhile, the rear wheel assembly accounts for about one half of the vehicle drag and the fairings are still a work-in-progress.

Horizontal surfaces

During testing we may need to adjust the download on front wheels or rear wheels. This will be achieved with the aid of two pairs of horizontal surfaces, one near each end. These are intended to be fixed before a run, but if the vehicle characteristics differ substantially from those predicted by CFD, there is room to install



The huge airbrake doors are perforated with fist-sized holes to stop strong vortices developing in the air around them



Swansea University has conducted much CFD analysis of the unsteady airflow around the airbrake doors

Driver Andy Green has reminded us that the ability to stop reliably in the restricted space available is the one operational requirement that is not an optional extra

control motors so the download on each pair of wheels can be adjusted through the run.

In the groove

The convex profile of the wheels will encourage them to fit within the groove they create. However, the desert surface is frangible, and experiments have shown that the maximum lateral force achievable, even at low velocities, is only about 0.4*g*. Although this will enable Bloodhound to be steered at very low velocities, very soon the aerodynamic side-force due to steering will dominate over wheel/ground force. Experience from Thrust SSC showed that by 600mph the ground surface under the wheels has fluidised. One effect of this is that the wheel rotation does not match vehicle velocity, there being an under-speed of the wheels by about five to ten per cent. By now it should be clear that the car is both stabilised and controlled by aerodynamic forces and not by wheel/ground interaction. Dynamically speaking, a hovercraft might provide a reasonable subsonic comparison.

As for the dynamic stability of the car, at these very high velocities, dynamic instability would be disastrous. Both 'heave' mode and 'porpoise' mode must be considered.

Slowing from 1000mph

Getting up to speed is arguably the easy bit. Slowing the car safely from 1000mph in the 5.5miles of desert left available has, however, presented Bloodhound's engineering team with a real challenge. Bloodhound SSC has three discreet braking systems which offers redundancy should one fail, as it did on Thrust SSC. So there are airbrake doors, a pair of high speed drag chutes, and also conventional AP Racing 6-pot disc brakes on the front wheels (used to slow the car from 160mph).

At 1000mph Bloodhound will have 20 tonnes of thrust propelling it across the desert and 15 tonnes of drag working against it. As soon as Andy Green shuts down the jet engine and rocket, the car will decelerate at a rate of 3*g*. Once he reaches 800mph he will begin to deploy the airbrake doors, easing them out into the airflow to maintain the 3*g* deceleration, losing 60mph per second – most people would call this a crash, and it's sustained for 20 seconds.

The carbon fibre airbrake doors are operated by twin hydraulic pistons which drive a single slider plate, that in turn mechanically deploys them out into the airflow evenly both sides, this almost doubling the cross-sectional area of the car and increasing the drag. Both hydraulic pistons have their own separate accumulator that maintains pressure in the system should the main hydraulics fail.

Swansea University has spent a great deal of time modelling the unsteady airflow around the airbrake doors in CFD. The risk of creating strong vortices in the air as it rolled over and under the doors has been mitigated by perforating the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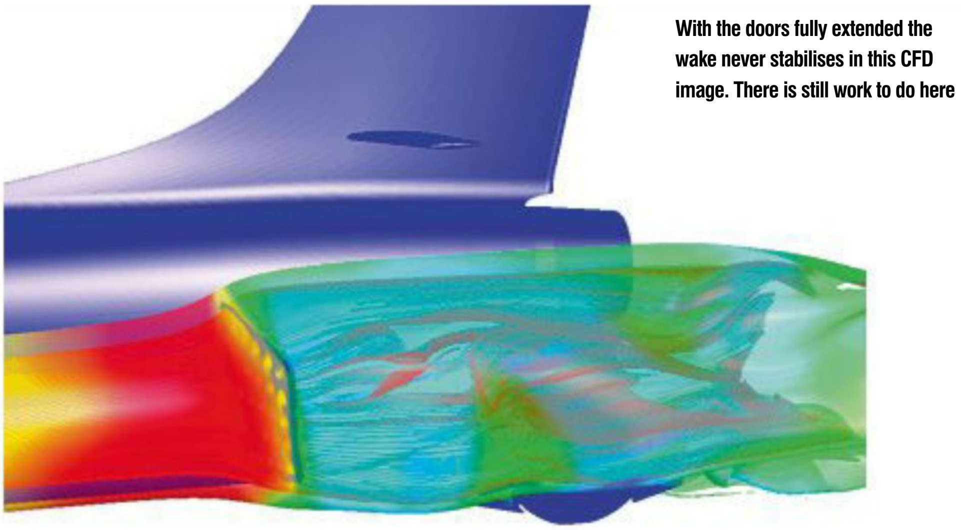
It is probable the airbrakes are the most powerful ever designed, as no-one else would need to deploy at 800mph at ground level



With the doors fully extended the wake never stabilises in this CFD image. There is still work to do here

doors with a dozen fist-sized holes. This reduces the strength of the vortices so there is no risk of them damaging the rear wheel assemblies.

It is probable that the airbrakes are the most powerful ever designed because no-one else would need to deploy such devices at 800mph at ground level. They are the largest that it is possible to install on Bloodhound. Their opening rate is 50deg/second initially, but panel force limits (50kN per panel) and vehicle 3*g* limit, slow their deployment, so the complete opening to 60 degrees takes about four seconds. The holes are placed to ensure that large vortices are broken into smaller vortices, and to reduce the effect of these on the rear suspension.

Despite the above precautions, much research will need to be conducted on the vehicle itself. To this end, the rear of the car is instrumented by a battery of strain gauges, accelerometers, pressure sensors and means of measuring the spectral density of the turbulence. Of particular concern will be to ensure that the structural response frequencies of the rear suspension are not forced by the turbulence.

Theoretical analysis of the airbrake wake has been attempted by Dr Ben Evans from Swansea University, but even with the biggest computer cluster available, the solution takes some weeks to stabilise. The image on the left is taken from such an analysis. This is not much use for a rapidly opening, and rapidly decelerating, airbrake as the wake never stabilises, so we are left with the need to conduct a cautious, highly instrumented, experimental programme.

Not just the air brake, but the whole vehicle is highly instrumented, with over 500 readings; instruments recording all relevant stress, pressures, and temperatures, for condition monitoring purposes and for research. These will be transmitted live by 500 HD channels, even when Bloodhound SSC is travelling at around 1000mph. It's not something you would want to miss, after all.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Four-sight

Manufacturers are now embracing GT4 in a very big way. We spoke to SRO boss Stephane Ratel and other major players in the GT world about the future of the category

By ANDREW COTTON

One year on from announcing that he would be developing the GT4 concept, Stephane Ratel has unveiled big plans for the category in 2017, starting with a two-region European series, stretching to three in 2018. Meanwhile, around the world, the concept is considered to be complimentary to the still-growing GT3 class and a viable national series alternative to the TCR touring car initiative.

With the Blancpain Endurance Series enjoying entries of more than 60 cars the Sprint series also with a robust grid, and with the Pirelli World Challenge and Creventic series gathering strength, it is hard to see how GT3 can grow in strength. With new GT3 cars from Ferrari, BMW and Porsche this season, and with new cars coming over the next few years including Honda, the number of new GT3 cars is once again on the rise following a drop in 2015.

The international GT3 grids are now reaching capacity although there is a big hole emerging in national series, and this is where Ratel sees the growth of GT4. GT4 follows the original concept of GT3, developed for lightly modified sportscars, and the idea has taken hold. Cars from Porsche, Lamborghini and McLaren have already been announced for next year, while it is clear that manufacturers such as Audi and Nissan will have to join in alongside the established competitors from Aston Martin, Ginetta and Lotus that are already competing.

At Spa in July, Ratel announced a European schedule for northern Europe and southern Europe. The Southern series will be called the Championnat de France FFSA GT and features races in Nogaro, Pau, Dijon, Magny Cours, Barcelona and Paul Ricard. The Northern Cup will evolve from the existing 102 GT4 European Series and will race at Misano, Brands Hatch, Zandvoort, Spa and the Nurburgring. In 2018, there is a plan to introduce a third series in Europe, the Alps Cup.

Meanwhile, in the US, Ratel is planning two series, East and West, following a concept

Cars from Porsche, Lamborghini and McLaren have already been announced for next year

already proposed for the F4 series. 'We are putting a lot of effort into GT4,' says Ratel. 'You have a good number of cars available, and we are pleased that Porsche [has introduced the] Cayman GT4 Club Sport and we are sure that there will be a number of teams interested in the car. BMW will introduce an M4 GT4 next season, and we are waiting for announcement of another two prestigious manufacturers.

'There is no doubt that GT4 will be the next big thing, but I don't want anyone to believe that GT4 will replace GT3. It is the right partner next to GT3 on the global GT scene.'

Global ambition

'We will spread the series, and multiply the series,' adds Ratel. 'The Pirelli World Challenge has adopted GT4 to replace GTS, and will run full GT4 spec next year. In the British GT Championship, half of it is GT4, and SP10 in the VLN is in contract with the SRO for GT4.

'Before, in America, you have a big gap, which is the budget of a one-make GT series, and running in GT3. In GT3, you either need $1m to do the Pirelli World Challenge or $2m to do IMSA. IMSA does endurance racing, but by having five events [in] Sprint [format] with one driver, and five with the format of the Blancpain Sprint series, we think you can do GT racing for the $230,000 that many of the drivers contribute in Europe. In this way, we should greatly improve the number of GT3 cars in America. The same will be done in GT4. Instead of one race series, we propose two smaller series of five races each, one on the West Coast, one on the East Coast, and if the teams, and drivers, have the money, they can do all of the 10 races.

'Instead of going into national championships, which is a bit of a risk, that structure with these three regional series in Europe is the right approach, and it will develop over two years and it will work. GT4 is 40 per cent of the cost of GT3, so the logistics should also be 40 per cent of GT3. Instead of moving all around Europe, you are just in one corner and it makes financial sense.'

TCR rivalry

Hans Reiter, who was behind the Xbow GT4 car, the Lamborghini Gallardo GT3 and Murcielago GT1, says that there is no reason to be complacent regarding GT3 numbers around the world, and that GT4 could be a direct rival to the TCR series. 'We are sitting here [at the Spa 24 hours] and it's fantastic, but the rest of the world is not fantastic,' says Reiter. 'We don't have a Spanish GT Championship, or a Portuguese, British GT3 cars are 12 or 13 on the grid, we lost the Brazilian series and Asia is on the way down.

'The FIA GT doesn't exist anymore, and while Germany is strong and Australia is still okay, most of the championships went away. Stephane's has gone well, so I am not worried about him for the next five years, but on a national level it is either GT4 or TCR. I cannot foresee which is the stronger market but I would normally think GT4 is more attractive for drivers, a Mercedes GT is better than a SEAT front-wheel-drive car.'

American market

Reiter has already found an impressive market in the US for his GT4 cars. 'America was impressive, we pumped seven cars into America,' says the German. 'America is not the ideal championship for GT4, because they are going America-wide, which is a big country and a lot of travelling costs, and the cost reduction of half the cost as GT3 is not so relevant because of the big transport costs. Everyone wants the GT3, but if you are not able to afford it, you have to look at the costs everywhere, and not just the car purchase costs.'

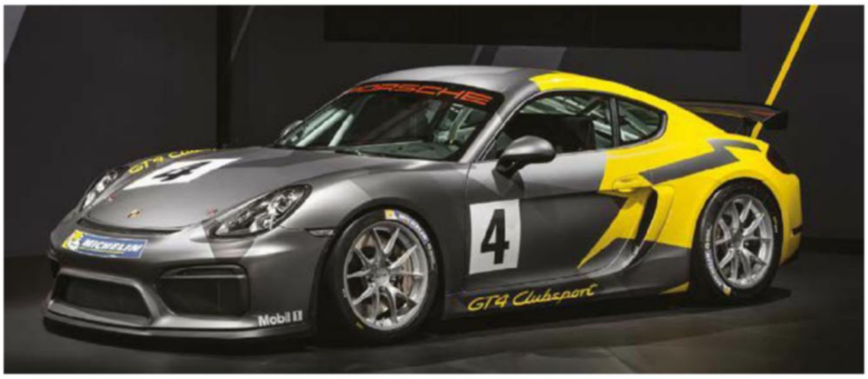
McLaren is similarly looking at GT4 and has had to increase its initial build order book before even starting production of the 570S. 'We are building a lot of cars, and selling a lot of cars, but we haven't as yet announced our motorsport dealers around the world,' says Andrew Kirkaldy, managing director of McLaren GT. 'We know that they are sitting there with a lot of people wanting to buy cars but can I say that we have a firm number of orders? Yes, we sold a number

'I don't think that GT4 is a GT3 replacement. Fundamentally the manufacturers want to see GT4 as purely a customer situation'

‘I would think GT4 is more attractive for drivers than TCR, a Mercedes GT is better than a SEAT front-wheel-drive car’

directly, which is healthy, but if the dealers get involved, it could be more than we are ever going to build. It is a good thing, but I don’t want to be in a position where you promise the earth and cannot deliver anything. There is a huge amount of work on production.

‘I really don’t think that GT4 is a GT3 replacement,’ Kirkaldy adds. ‘Fundamentally the manufacturers want to see GT4 as purely a customer situation, and I think that we are getting a lot out of GT3 as it stands now. I see that a lot of the national based championships could end up being GT4. GT4 costs half as much as a GT3, and a lot of people want to do this for fun. Will people who have been driving GT3s love driving GT4s? I don’t know the answer to that but I suspect not. [But] GT4 is a healthy thing, and it could bring down the GT3 costs a bit.’



Porsche has jumped on the GT4 bandwagon with its Cayman customer car, which has proved hugely popular

One of the more unusual GT4 creations is this funky X-Bow racecar which has been developed by Hans Reiter

Servicing issues

One of the major issues for manufacturers is the servicing for the GT4 cars. It is not that they are complicated, more that they will use production parts that are not normally in high demand, such as headlight clusters that could easily get broken during the course of a race. The production schedules will need to be altered in order to supply enough parts to service a racing category from the production lines.

‘We have a good network now, but it is the amount of space that you need to store this stuff,’ says Kirkaldy. ‘Also, you have to work closer with the road car network because the road car network has never had to supply parts to the degree of GT4. The reality is that the road car network is not set up to deliver parts in days. It is set up for weeks and sometimes months. We will be ordering bits that they don’t have a large stock of. It is different if you start with 10 [cars], than if you start with 40 or 50.’

Ratel believes that the future of GT4 is extremely bright. ‘It hasn’t exploded yet, but it is going to,’ says the Frenchman. ‘We have others coming, too. I felt that it would be this big. The record number of orders that Porsche received motivated the other manufacturers that have developed large customer racing departments to use the structure. Once you have the people, the stock management, the assistant truck, you have the hardware, you can just put more activity into it. That is what GT4 is doing at the moment, with success.’

The technical regulations


The interior of the Porsche Cayman GT4 racecar. While the technical rule book is quite open there are strict regulations on a car’s body shape and dimensions

The technical rule book for GT4 is pretty open. Telemetry is forbidden, and each car must carry an SRO data logger to ensure that parameters can be accurately measured. All bodywork dimensions and shape must remain original, including the front and rear overhangs, while material used for bonnet, boot lids, bumpers, doors and wings must be original. Soundproofing may be removed from the doors, but there are no other modifications allowed in this area.

The minimum weight of the car must be more than 1000kg, and the series will retain the success ballast model to balance the performance. The engine location, make and type must remain original unless the manufacturer is granted a waiver by the SRO. The internals of the gearbox are free to develop, while the gear selection grid pattern homologated on the series model must be retained.

The suspension must be original, though manufacturers may fit an anti-roll bar and shock absorbers may be modified. The braking system may be upgraded and brake bias may be controlled by the driver.

A car may be shared between a professional and an amateur driver, two amateur drivers or one amateur driver can contest a 50-minute sprint race.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Pulled Porsche

Porsche's LMP 2000 might just be the greatest sportscar that *never* raced. Here's the inside story of the prototype that could have changed the history of the Le Mans 24 Hours

By MARKUS EBERHARDT

Many who were there remember the 1999 Le Mans 24 hours as one of the truly great races. BMW was victorious after a wonderful battle with Toyota, while Mercedes made headlines with its CLR – examples of which flew spectacularly on three occasions during the course of the race weekend. Audi started a new era of its racing heritage with the new R8R and R8C models that year, too. But there was a name missing from the line up that many had expected to be there: Porsche.

In 1998 Mercedes turned up with a mid-engined CLK, a ground-up racing car, and used it to win every round of the FIA GT Championship. Never the less, Porsche won at Le Mans, the jewel in the crown. However, a radical re-think was necessary if Mercedes was to be beaten in 1999. Porsche evaluated the potential of a GT car and an all-out prototype, and settled for the latter, eventually creating an all-new racecar powered by a 5.5-litre V10 engine for the 2000 season. But the programme was cancelled on November 22 1999 by Porsche's CEO Dr Wendelin Wiedeking. Wiedeking's philosophy was to make money, and endurance racing was, in his eyes, a drain on finances. The racing department no longer had a top-line factory programme and it was not until the RS Spyder campaign in 2005 that Porsche returned to prototype racing.

The burning question is: could the stillborn Porsche have taken the fight first to BMW's V12 LMR in 1999, and then to Audi's R8, which went on to dominate endurance racing between 2000 and 2005? Perhaps so. Certainly, the indications are that the car had enormous potential.

Open 24 hours

The car was designed from the ground-up as a racing car by Porsche, for the first time since the 956 and 962 era. The legendary Norbert Singer guided the process, working with Wiet Huidekoper, who was responsible for the design of the Lola T92/10 Group C car and who was also involved in the LM-GT car – based on the Dauer 962 road car programme in 1994 – and the 911 GT1 programme in 1998. The LMP 2000 project was green-lighted in the October

A version of the V10 engine was later used in the Carrera GT. Porsche's existing race engine, the flat six that had seen service in its GT1 98, was thought to be too heavy for this application

The project had already been cancelled by the time the car was given a run at the Weissach test track. Bob Wollek, pictured in cockpit, believed he could have won Le Mans with the LMP 2000

The aerodynamics were developed by Norbert Singer with 1:3 models in the rolling road model wind tunnel at Weissach. It was old tech but Singer knew it well and could get useful data from it

of 1998, with the CAD design work on the racecar starting that very same month.

The project focused on an open-top design, as this had several advantages in terms of the regulations. Open cars ran wider tyres, which generated more grip, while there was no requirement for a windscreen which could lead to visibility problems, as well as needing extra functions such as a windscreen wiper. The cockpit of the car could be kept cooler, too, while open cars also tend to have better overall aerodynamics.

In 1999 Audi ran the open R8R and the closed R8C to establish which was better, and it was no surprise to see that it, too, opted to develop the open car. The closed R8C ran narrower tyres which helped straight line speed, was more aerodynamically slippery thanks to the smooth lines over the cockpit, but problems with the doors was a major issue during the test weekend, and motorsport director Dr Wolfgang Ullrich was clear that, even with the limited running of the R8C, the way forward for Audi was with an open car.

Formula 1 power

So, Porsche had made the correct decision on the chassis, but what of the engine? Here there was a choice between the 3.2-litre water-cooled twin turbo boxer 6-cylinder engine that powered the 911 GT1 98, with around 550bhp at 7200rpm and 630NM at 5000rpm, or a new Formula 1 based V10 engine. The 1998 engine was heavy, at 210kg, and required more cooling compared to the typical V8 race engines, and by the end of November, 1998, a V10 development of a never-used 1992 Formula 1 unit was chosen instead, a lighter and better design later developed for road use in the Porsche Carrera GT.

The engine was designed by Herbert Ampferer (1998 head of motorsport) and his team under the direction of Horst Marchart back in 1991, as a 3.5-litre which was to be used by Footwork in F1.

The unit was quite capable, with an output of at least 700bhp and a weight of only 170kg – without the use of any exotic materials. This included the intake-manifold, exhaust, secondary pipes, end-pipes and the clutch. This power unit was never

The tail of the LMP 2000 was not quite as low as on some of the LM900 cars of the time. Its Le Mans aero package was never revealed

The indications are that the car had enormous potential

The suspension was conventional at the rear with double wishbones and pushrod operated spring/damper units horizontally arranged on top of the gearbox. The front was the same but with the spring/dampers located vertically in the bulkhead

The engineers were allowed to finish one car and do a small two-day test at Porsche's own test track at Weissach

used by Footwork and the full race version has been kept under wraps ever since.

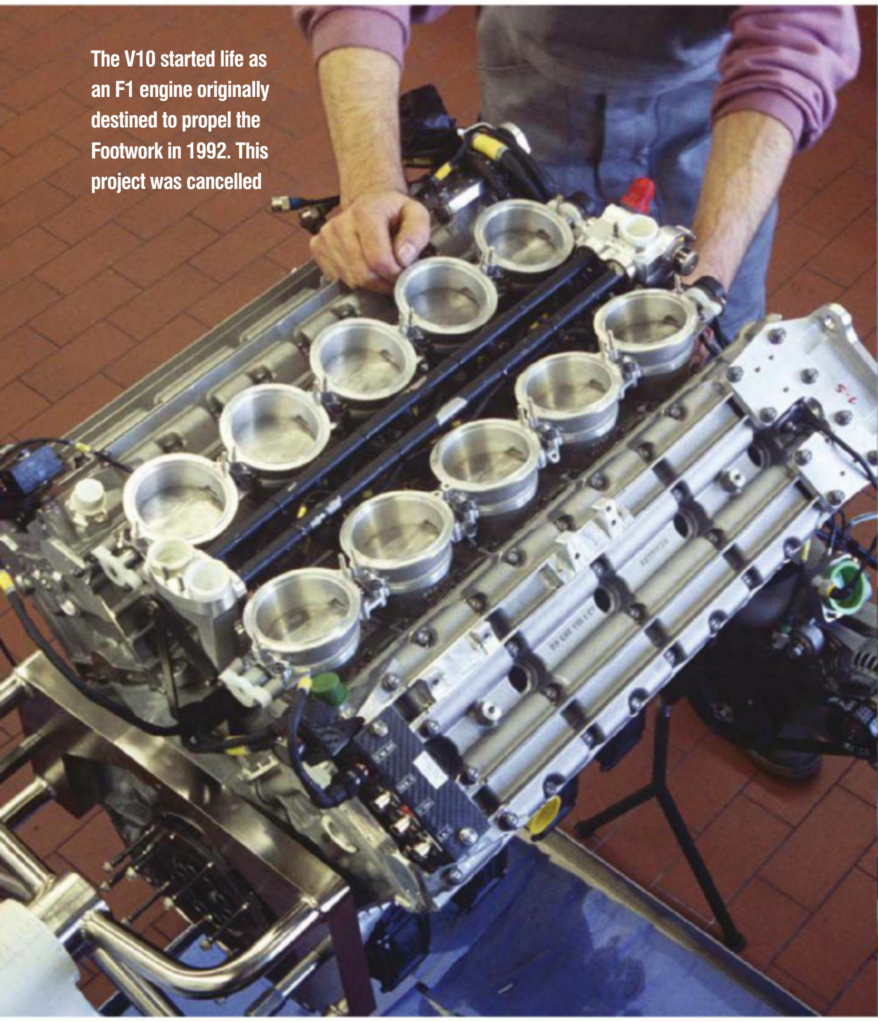
Singer had already talked with Herbert Ampferer and made some calculations, to see whether or not this engine was usable for the new LMP car and, with development, they considered that it could be suitable.

But for endurance racing the pneumatic valve system was not right, the engine needed more torque. After discussions with the engine department it was decided to up the capacity from 3.5-litre to 5.5-litre by increasing the stroke. The pneumatic valve system was replaced with a conventional layout, but the engine largely retained its architecture.

Mounting rescue

The decision on which engine would be used was taken just six weeks after the programme was given the go-ahead, and this meant changes to the car's design, including the engine installation – which mainly meant changing the mounting points, which had been designed with the flat six in mind. The bellhousing was narrower for the V10 than the flat six, and the cooling layout was very different, with intercoolers not required for the V10 as they had been for the turbo 911 GT1-98.

A new transmission was required due to the lower crank height of the V10 engine, although the front and rear suspension layout



The V10 started life as an F1 engine originally destined to propel the Footwork in 1992. This project was cancelled

Air was split by a raised and wide centre section towards cooling ducts on either side of the cockpit. Unlike Audi Porsche did not opt for an F1 style nose

The monocoque and bodywork was supplied by Lola Composites while the twin element rear wing was made up of a main blade and an adjustable flap

remained largely unchanged. The old style gearbox was too slow, anyhow, and had to be redesigned – Porsche opting for a longitudinal transaxle 6-speed sequential.

The new LMP 2000 (internal code 9R3) was designed with a carbon fibre monocoque with aluminium honeycomb cores. It was a high-sided design, with a fully raised floor at the pedal area, pushing everything up as the minimum footbox requirement dictatated minimum height and width inside the monocoque. It consisted of a lower and upper half bonded together. The car featured a narrow roll cage ahead of the driver, as was common among the new generation of LMP900 cars. Unusually, the airbox was integrated into the roll over structure. The monocoque, as well as the carbon fibre bodywork, was supplied by Lola Composites.

The suspension was conventional at the rear with double wishbones and pushrod operated spring/damper units horizontally arranged on top of the gearbox. At the front there were also double wishbones with pushrod operated spring/damper units. But the arrangement was quite unique as the spring/dampers were located vertically on the front bulkhead, which gave advantages in the aerodynamic packing as well as lowering the centre of gravity.

The aerodynamics were developed by Singer with 1:3 models in the rolling road model wind tunnel at Weissach. Compared to other facilities, the Weissach wind tunnel was not the most up to date, but Singer knew it well and was able to get meaningful data. He opted for a limited front overhang length and a raised splitter in the middle section to get a more stable aero platform and to avoid pitch sensitivity.

Splitter difference

The LMP 2000 also featured a front splitter with only a small overhang to the bodywork with radiused edges and a raised middle section. The difference to all other cars at that time was that the top of the middle section was wing-shaped with two deeper venturi tunnels on either side of the centre. The splitter in front of the front wheels was low and flat but rounded off with an upward radius in front of the front wheels. This radius connected nice and smoothly to the inner front wheel arch surfaces.

The rest of the underbody was completely flat as required by the regulations. At the rear axle the rear diffuser swept upwards at an angle of nine degrees. The first version, as on the CAD screen in April 1999, was full width with several strakes inside. After more wind tunnel tests the diffuser was narrowed by using fill-ins closing the outer sections. This should have reduced the negative influence of the tyre wake (turbulent air) into the diffuser. It now featured only two strakes inboard. The outer walls of the rear diffuser were not vertical but curved outside, which was then also a feature not seen on any other racecars at that time.

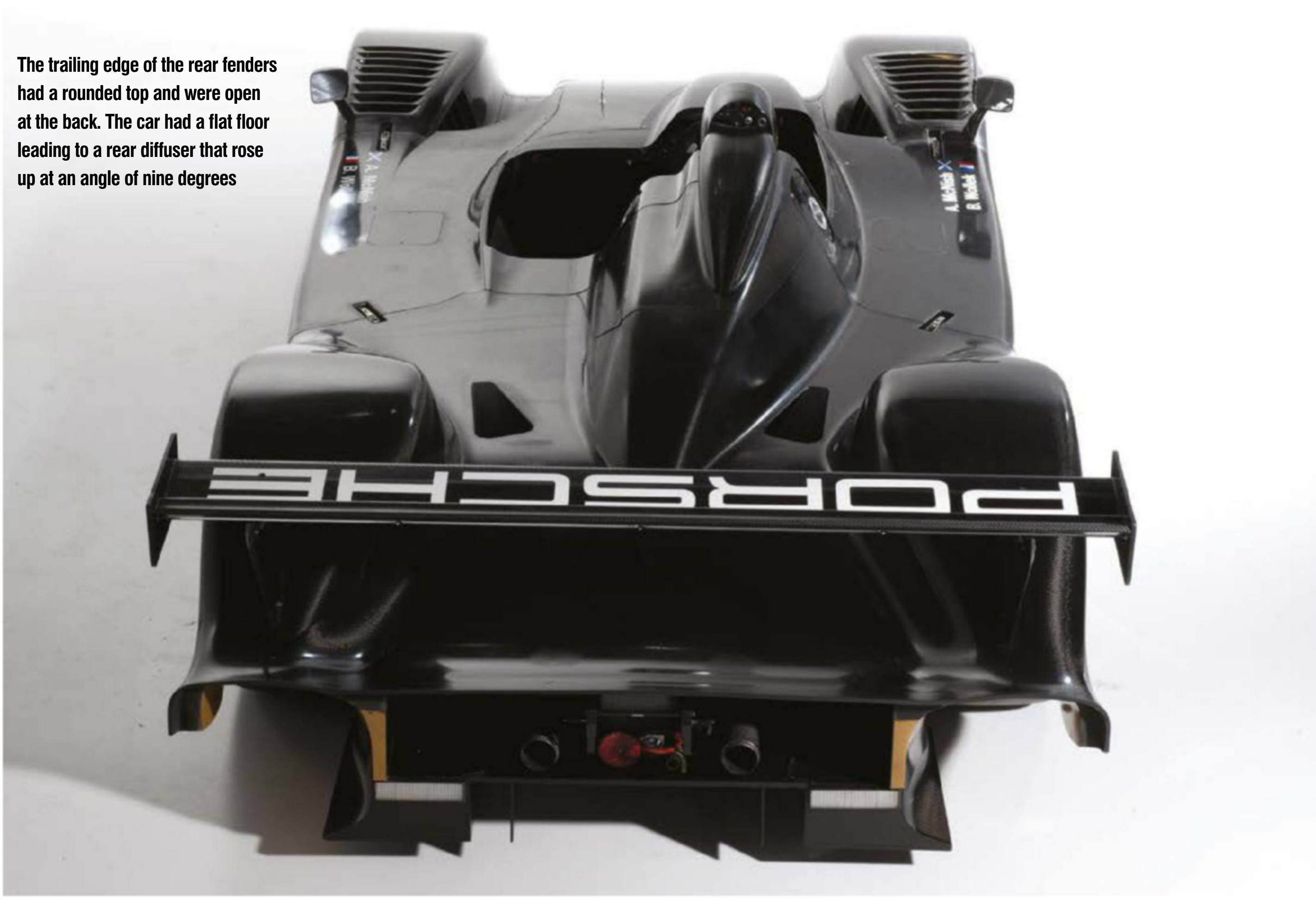
The tail was not as low as on some rival racecars and the trailing edge of the rear fenders showed a rounded top shape and were open at the back, although the Le Mans configuration was never seen. The twin element rear wing with a main blade and an adjustable flap overlapped the tail trailing edge and was fitted on two struts at maximum height. Small end-plates were fitted to the wing.

The front of the car did not feature an F1 style nose as the R8 did in 2000. The air was split by a raised but much wider centre section of the nose towards the cooling ducts located on either side of the cockpit. The water cooler was arranged in a V-shape (pointing forward) on either side of the engine with the hot air directed out of the car at the back.

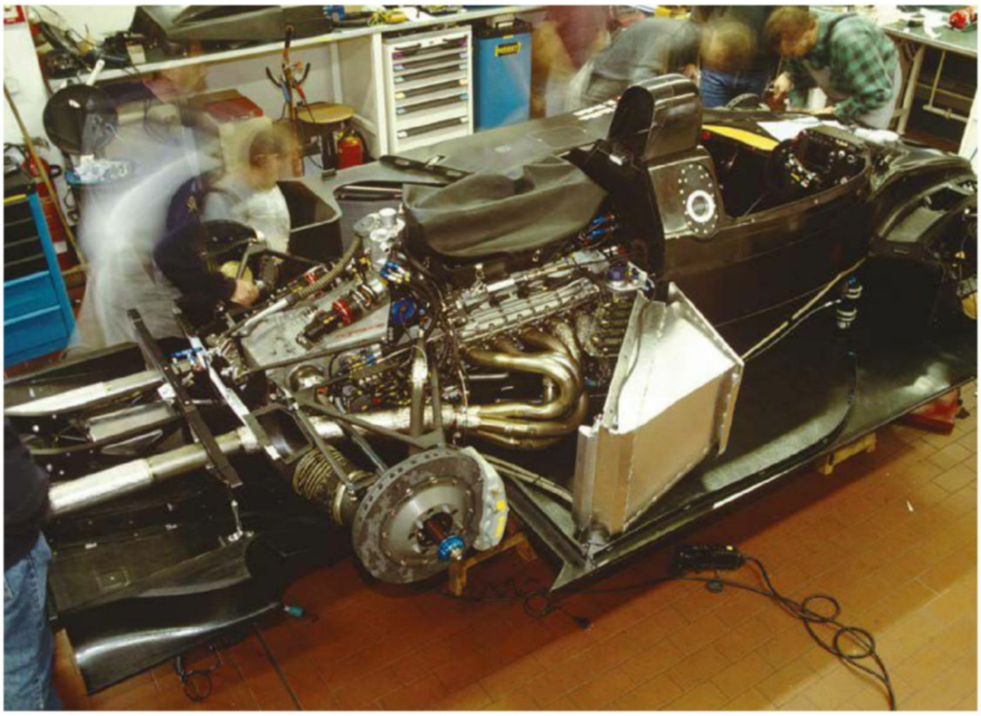
Pulling the plug

The car was further developed until the end of 1999, when the then Porsche CEO Wendelin Wiedeking stopped the programme definitively. He wanted to transfer the money and the engineers to the first Porsche SUV project – the Cayenne – although this was not known at the time. It was just stated in the press releases then sent out that Porsche needed the development capacities, such as the people and the money,

IMAGES COURTESY OF ULLI UPIETZ AND PORSCHE ARCHIVE



The trailing edge of the rear fenders had a rounded top and were open at the back. The car had a flat floor leading to a rear diffuser that rose up at an angle of nine degrees



A new transmission was required due to the lower crank height of the V10 engine and Porsche opted for a traditional longitudinal transaxle 6-speed sequential layout. Its older gearbox, as used in the GT1 98, was deemed to be too slow

After discussions with the engine department It was decided to up the unit's capacity from 3.5-litre to 5.5-litre by increasing the stroke

to move to production cars, which in the end turned out to be the truth!

However, none of the LMP 2000 engineers then worked on the Cayenne programme, and so the rumour took hold that Audi simply didn't want a fellow VW company to compete at Le Mans. But it is more likely that Wiedeking simply didn't see the economic value in competing against Audi, or maybe a high up decision maker – perhaps Ferdinand Piech – saw the advances that Audi was making with its programme, with the development and introduction of technology such as TFSI?

Untapped potential

Whatever the truth, the Porsche engineers were at least allowed to finish one car and do a small two-day test at its own test track at Weissach with Bob Wollek and Allan McNish at the wheel.

The car proved to be quick out of the box and Wollek later said that Porsche had taken from him his last chance to win Le Mans. The car was stored in a hall under the Weissach facility after that, and Porsche quietly hoped that interest in the car would fade over time. Some in Weissach still believe that the car should be kept a secret, others that the details should be made public. But without even racing, the car has reached a legendary status, and could be regarded as one of the greatest racecars never to compete. Of course, we'll never know for sure if it could have beaten the Audi.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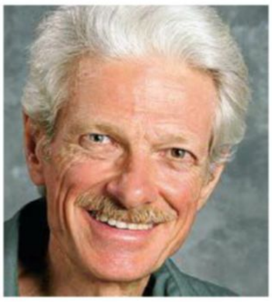

Lotus links and the magnificent Seven

The suspension of the original Lotus Seven examined

QUESTION

The other day I was looking at ads for racecars and I saw one for a very competitive SCCA GT3 car which I believe said it had a Winters solid axle and incorporated a Lotus link. Is this a type of four-link with side location, unlike either a Panhard bar or watts-link? Anyway, what is a Lotus-link configuration? What is the complete configuration, how does it work, and what are advantages or disadvantages compared to regular three- and four-link set-ups for a car with a solid/live axle?

THE CONSULTANT

I haven't seen that exact term used before, but I would assume this is the layout used on most versions of the Lotus Seven.

There are two trailing links above the axle and an A-arm, or wishbone, below the axle, with a single pivot at the bottom of the diff housing and two widely spaced pick-up points on the frame, typically below the forward pick-up points for the trailing links.

The wishbone provides both longitudinal and lateral location. The roll centre is approximately at the pivot under the diff.

The layout is simple, provides good location, and is compatible with spaceframes. The low roll centre reduces lateral tyre scrub on one-wheel bumps and requires that the rear suspension has a higher share of the elastic roll resistance than it would if the roll centre were higher. This reduces the effects of driveshaft torque on wheel loads.

However, the layout is not compatible with strategies that compensate for driveshaft torque – at least not without changing things considerably. I guess it would be possible to retain the lower wishbone and combine that with an offset torque arm and birdcages carrying the brake calipers at both ends, each with two trailing links. Of course, that would only somewhat resemble the Lotus design and would be considerably more complex.

One problem with the design in the original Lotus application has been that there are very high point loads at the pivot under the diff. With 1950s era tyres and the modest engine power that the car originally had, the system holds up reasonably well, but when people add modern racing tyres and a stout engine, the axle housing becomes prone to structural failure at that point. Partly to eliminate this problem, the last version of the Lotus Seven, the substantially redesigned Mark IV, had a different rear suspension design

However, the original design can be made to work if the parts are beefy enough, and placing the wishbone closer to the ground and the trailing links up higher certainly helps here. Two separate diagonal links can be substituted for the wishbone.

When considering purchasing a racecar with this type of suspension, it would be prudent to ask the seller whether there have been any reliability problems with the system, especially if the racecar has a lot of power, tyre grip, and downforce.

A Winters axle will probably hold up to the demands, provided the bracketry is well designed. Another thing to look out for is use of adjustable rod ends (Heim joints) on the wishbone, particularly for the pivot under the diff. It's bad practice to load the threads on these in bending. It's especially bad when just one of those threaded shanks has to resist all the lateral forces that way all by itself, and the axle has no lateral location if it breaks.

One problem with this suspension design in the original Lotus application has been that there are very high points of load at the pivot under the diff

Many Lotus Sevens used a suspension configuration sometimes referred to as a Lotus link. Pictured is Caterham's recreation of its own early Seven-like car

Power-on push in a Porsche

Returning to the problem of on-throttle understeer in 911s and, in this case, a 914

QUESTION

I have some thoughts relative to throttle-on understeer during corner exit on a Porsche – your July column (V26N7). My view is a lot of throttle on/off steer during cornering is due to roll angle change caused by the trailing arms being at different angles (power causing roll angle change). In this regard roll stiffness increase would be helpful. Also, a readjustment of elastic roll stiffness to make the front and rear as equal as possible taking into account the front and rear weight ratio (perhaps not totally equal). Then steady state balance brought back by adjusting the roll centres. Perhaps there is not enough variance possible to do this, though. At any rate the main thrust of this argument is that the relative contribution of the elastic *vs* r/c to the anti-roll affects the power on/off steer. I had a Porsche 914/6 that was impossible to drive fast on a track due to corner exit power-on understeer. Increasing roll resistance solved the problem

Also, about adjusting roll centres etc. I believe roll change with power is the culprit. I believe the base problem with a Porsche is that the trailing arms are too short.

Suppose one were to hook up a big lever to a body so a pure torque could be applied. Would the car roll and jack about the conventional roll centre or would it be different? Suppose the springs were replaced with a Z bar and roll was resisted by torsion roll bars only and a torque was applied and the roll and jack noted. Then the Z bar and the roll bars were removed and the springs were put back in but with the same roll resistance and the torque re-applied. Would the motion be the same? What I am getting at is: does the per cent roll resistance between the springs and roll bar affect where the body rolls and jacks? If it does, this would affect the angles of the trailing arms. I forgot to mention that on my 914 I also added solid bushings. I could do this on a 914, but I don't think you can on a 911.

THE CONSULTANT

First, we should note that the original question was with a Porsche 996, not a 911 or 914. The 996 has a multi-link rear suspension, not the trailing arms of the earlier designs. However, it is interesting to consider the effects of the earlier designs on power understeer.

The geometry of the 911 and 914 is pretty similar

The July piece was about thrust roll, my term for the effect we're discussing. I won't recap all of it, but will note that short trailing arms produce thrust roll, when the car is in a rolled condition, and the effect does increase as the roll angle increases and as the trailing arms get shorter. Also, the effect depends on the respective thrust forces at the two rear tyres, and these vary depending on tyre loadings and are also influenced by the properties of the differential/locker/spool and by the properties of the road surface that the two tyres are on at a particular moment.

The 911 and 914 both use semi-trailing arm suspension. The pivot axis is angled in plan view to give some camber change in ride, some camber recovery in roll, and a roll centre a bit above ground level. This differs from a pure trailing arm system, where the pivot axis goes straight across the car and is horizontal, giving no camber change in ride, and no camber recovery in roll, and a roll centre statically at ground level.

The geometry of the 911 and 914 is pretty similar, but the 914 uses coilovers and has two bushings for the trailing arm, while the 911 uses torsion bars and has one bushing similar to the 914, and uses the bushing for the outer end of the torsion bar as the other bushing. There is a flex plate that works the torsion bar, as in the earlier swing axle designs. Both the 911 and the 914 can use solid bushings.

Roll centre height does not *directly* affect wedge change due to torque roll. The front/rear distribution of elastic roll resistance does affect it, up to the point where the inside front lifts. Beyond that, no change in diagonal percentage is possible, but further roll will adversely affect outside front wheel camber.

To entirely eliminate change to diagonal percentage change due to torque roll, we do not need the front and rear elastic roll resistance to be equal. We need the rear to have all the elastic roll resistance – which of course is not possible, except for a drag car. If we use a lower rear roll centre, we can add rear elastic roll resistance. Therefore, roll centre height does have an influence, *indirectly*.

If we applied a roll moment to the car with a big lever, with no lateral force applied and the tyre contact patches free to float, the car somehow located by some other means, the car would roll independently of the suspension geometry, and the changes in wheel load would be independent of suspension geometry, but the contact patches would displace laterally with respect to the rest of the car in a manner related to geometric roll resistance.

Having two completely separate springing systems for roll and ride, versus conventional springs and an anti-roll bar, offers no advantage as long as everything is linear.

XPB

This month we return to that old favourite: the handling quirks of older Porsches such as the 911 (pictured) and in this particular case the unloved 914 – the mid-engined car suffers from the same power-on push as its rear-engined sister

CONTACT

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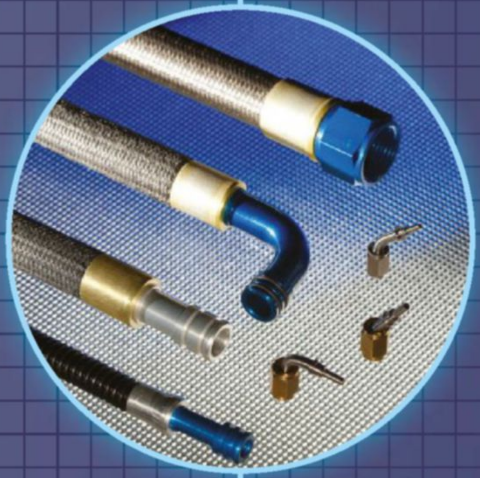

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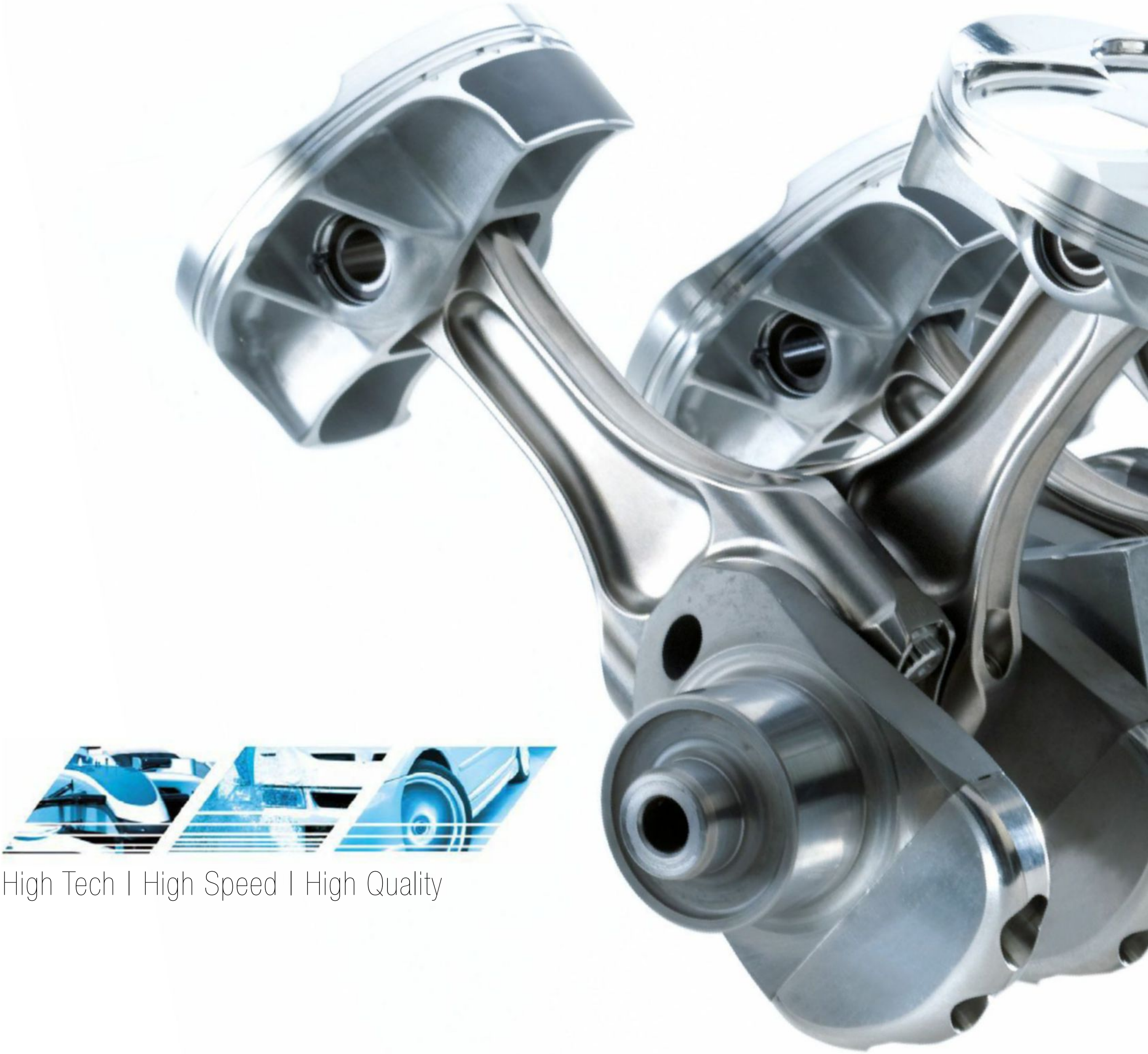

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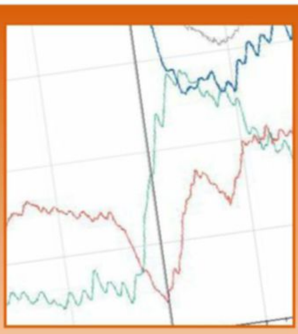

Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Using wheel speed data for car analysis

The speed at which each of the wheels turns on a racecar can tell you a great deal about that vehicle's behaviour out on the race track

This month we are going to be looking at wheel speed data and describing how to view this in the logged data, and what information it can provide about how the racecar is behaving.

Some championships have restrictions on how many wheel speed sensors you are allowed and this can be a combination of only one front and one rear, or only on the undriven wheel speeds. However, in this example we are going to look at an application where all four wheel speeds are available for sensors.

To begin with, we can first give you a reminder of the differences between individual wheel speeds, and the overall vehicle speed. We went through this in a previous article but to summarise, the vehicle speed is often the result of a strategy involving the individual speeds. **Figure 1** (bottom of page) is an example of such a strategy.

- **The front axle is set as fastest wheel. If a single front wheel is locked under braking, the other wheel that is still moving is used.**
- **The rear axle is set as the slowest wheel. If a wheel is spinning, the other non-spinning wheel is used.**
- **The bottom section switches between the front axle strategy and the rear axle strategy dependant upon the brakes being active or not.**

When analysing vehicle performance you may wish to look at all four wheel speeds and vehicle speeds overlaid on a time distance chart. This could be to study a car's wheelspin, locking the brakes, or the effect of the differential after a preload or a ramp angle change.

Firstly, it is often beneficial to set the trace for each corner of the car to a different colour. This makes it easy to distinguish between the different individual wheel speeds when they are overlaid. It is down to personal preference what colours you choose, but here at Cosworth we tend to follow the colours of the Microsoft Windows logo, as it is also often very visible on the screen.

Time and distance

In order to view the data in a representable way, it is crucial that you take note of how the channels are scaled on the time-distance chart. This is particularly important with cars that wheelspin or lock wheels. Series with ABS and traction control systems may not suffer from this quite as much, but it is still highly recommended you study the data in **Figure 2**, which is a representation of a rear-wheel-drive car. At first glance, you may be mistaken in thinking that there is an issue with the front left speed sensor, as it appears

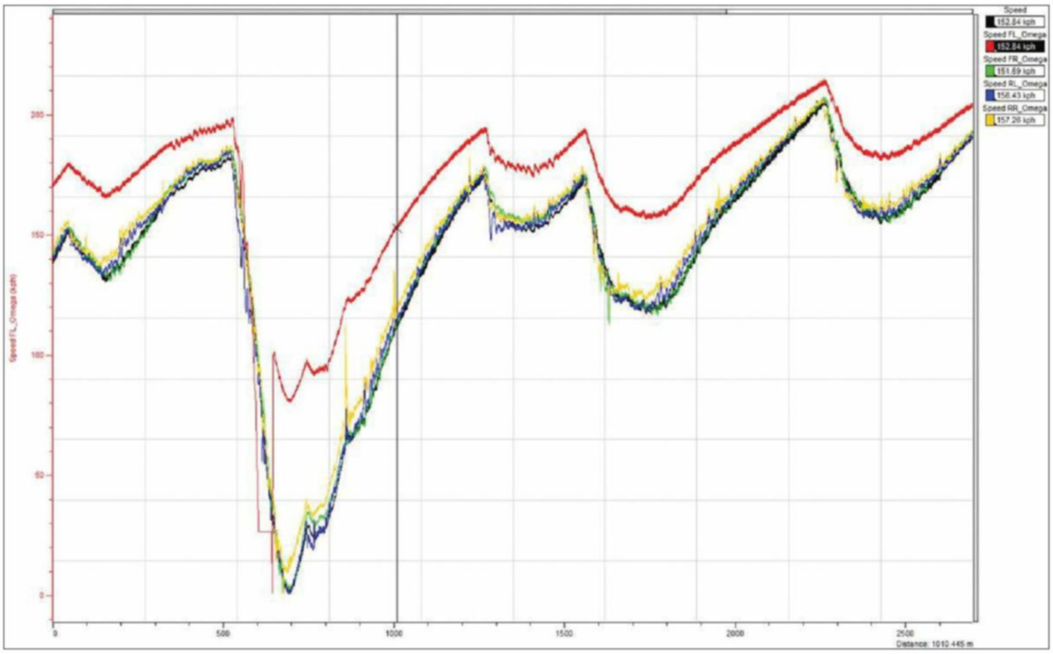

Figure 2: Representation of a rear-wheel-drive racecar. Note that the front left trace appears higher than the others

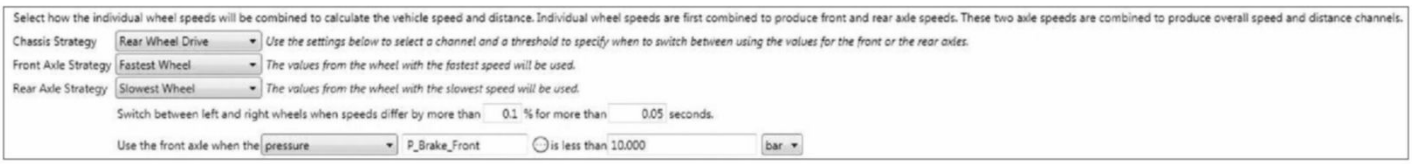

Figure 1: This shows how vehicle speed is often the result of a data collection strategy involving the individual speeds of all four wheels on the racecar

When analysing vehicle performance you may wish to look at all four wheel speeds and car speeds overlaid on a time distance chart

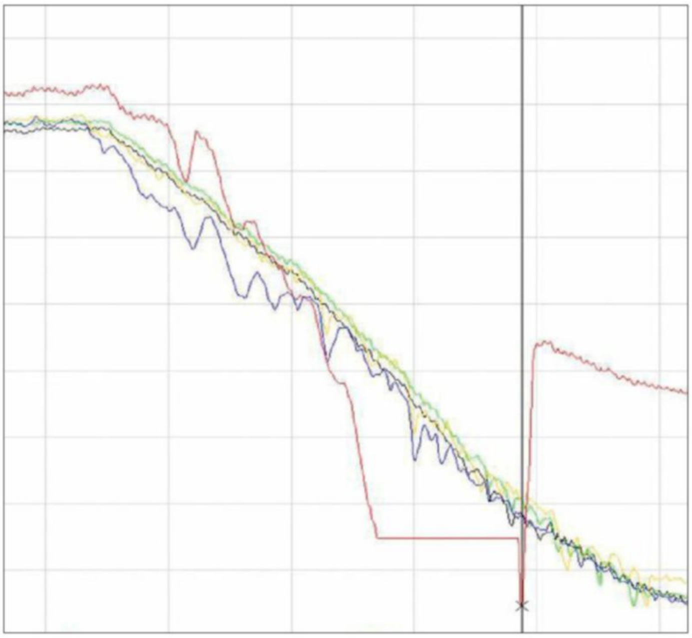

Figure 3: The steep drop in the front left wheel speed indicates a locked wheel

higher than all of the other channels. However, if you look at the actual values displayed in the top right, you will notice that the values of the rear wheel speeds are a few kph faster than the others. It is common that the driven wheel speeds are slightly higher than the undriven wheel speeds. With this being a rear-wheel-drive application, the 4-5kph difference can be expected. However, you will also notice that the front left sensor is actually showing a value comparable to the other channels, even though visually it appears much higher than the others.

The cause of this comes down to the scaling of the channels. You may have noticed the steep drop in the front left wheel speed trace to the left of the image, shown in **Figure 3**. This is an indication that the driver locked this wheel. Because the channels in the time distance chart are set to autoscale, this brake locking alters the scaling used for the front left wheel speed compared to the other three wheels. Therefore it is very important here to always use a fixed scaling when looking at your wheel speed channels.

Figure 4 illustrates the same data shown previously but this time with the fixed scaling applied. Here you can see the trace is visually quite different. You can still clearly see the front left wheel lock up, but because of the fixed scaling it does not offset the channel from the others and they remain consistent thereafter.

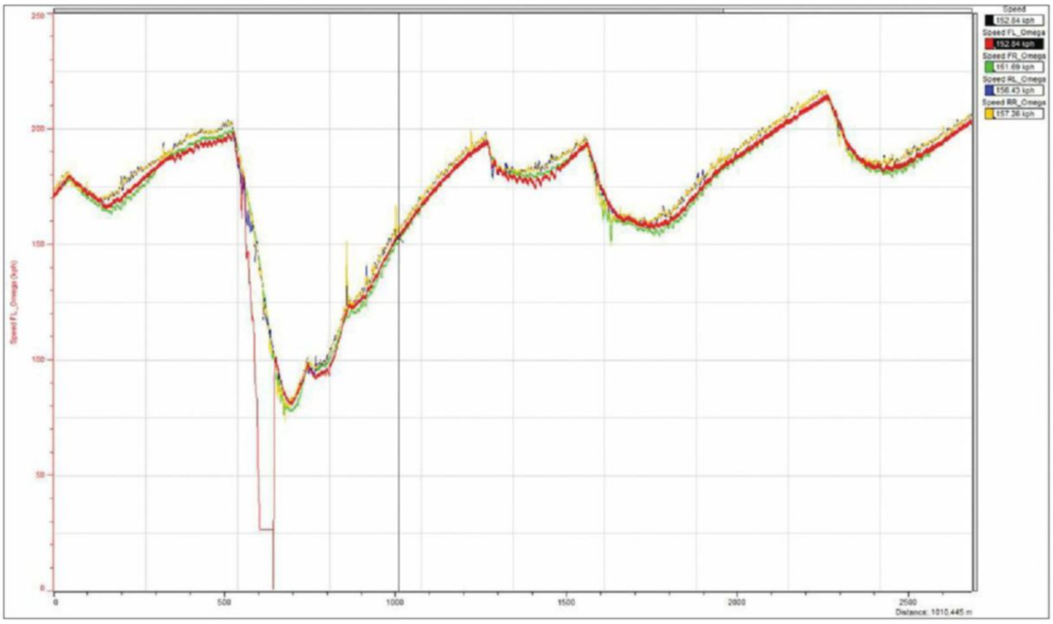

Figure 4: Here is the same information but with fixed scaling applied, which helps give a more representative read-out

Wheel slip percentage

Another channel that can be useful to examine is the wheel slip percentage. This is the proportion of individual wheel speed compared to the vehicle speed, normally displayed as a percentage. This can be calculated as follows: ([Speed FL_Omega] / [Speed]) * 100 - 100

Figure 5 shoes the individual wheel speeds and the wheel slip channels overlaid on top of each other with matching scaling and 50 per cent of the chart assigned to each one of them.

Note that the scaling selected here means that the front left slip trace extends beyond this.

Because the wheels fully lock this means that this channel actually extends to -100 per cent. If we were to select a scaling that extends to this, the other three slip channels would visually be very small. A scaling of -20 per cent is enough to determine that the wheels are fully locked, so anything beyond this is not necessary.

In the next issue we will examine in much more detail what these channels are actually telling us about the performance and the response of the racecar, and how this can be fed back to improve the car set-up and also assist the driver.

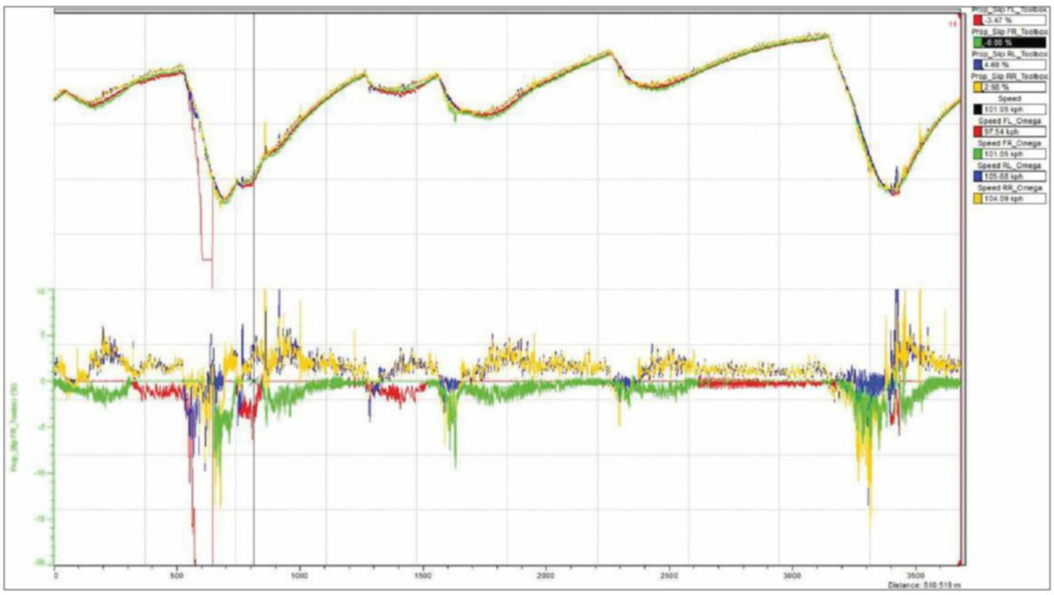

Figure 5: This clearly shows that a scaling of -20 per cent is enough to show us that a wheel is fully locked

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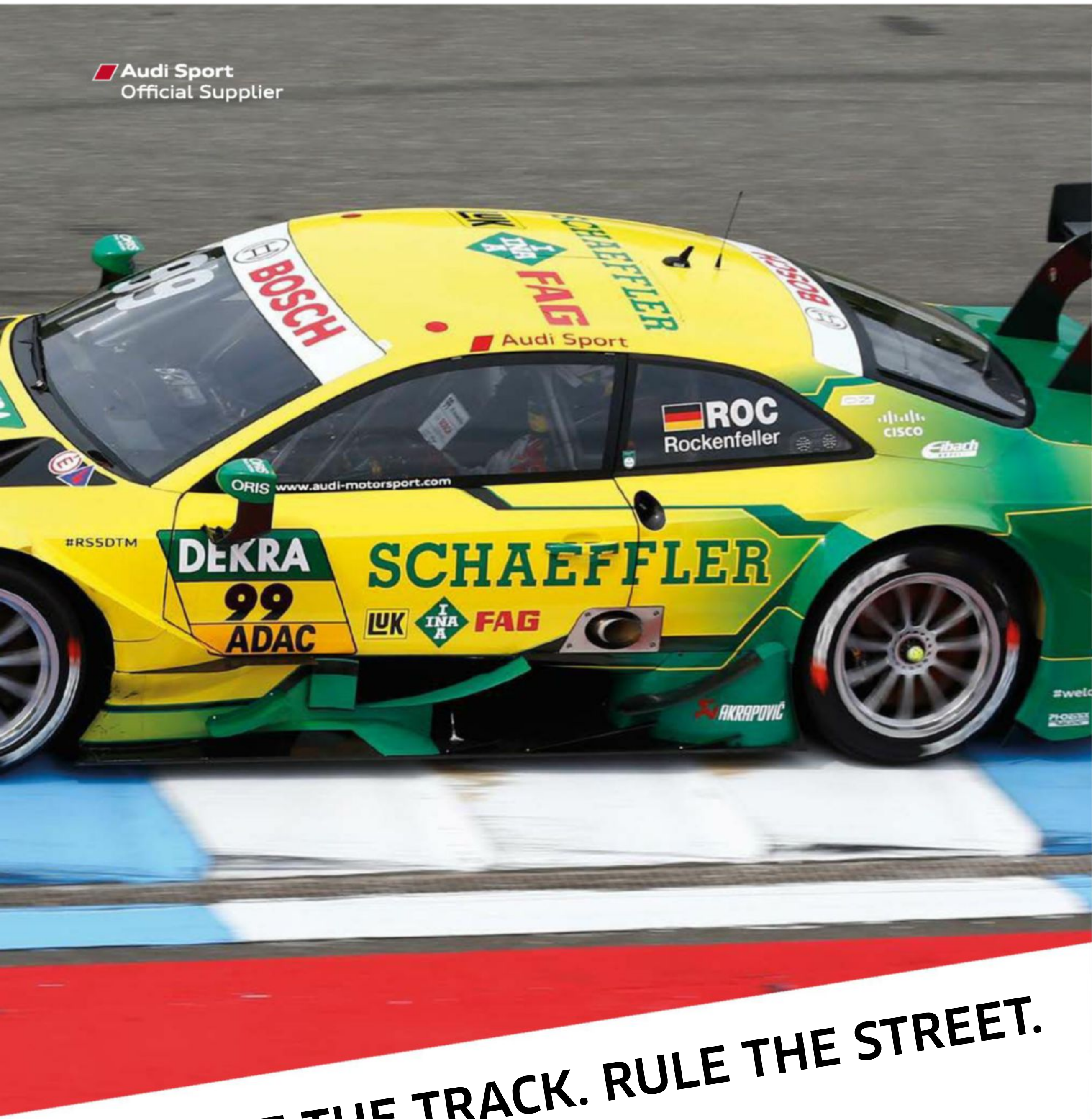

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Subaru Levorg GT: rake it in and wing it

The second instalment in our British Touring Car aero study

This month we continue with our MIRA full-scale wind tunnel session with Team BMR's Subaru Levorg GT, the BTCC's newest entrant. We documented the intense construction schedule of this project – designing and building four cars in just 87 days – in our July issue (V26N7). The compressed time-frame gave no opportunity for aerodynamic development before the car's track debut, and the aerodynamic package that the team started the season with was based on chief designer Carl Faux's previous experience (with RML and Triple Eight Racing prior to joining Team BMR). The car came to our wind tunnel session in mid-June in this guise, fresh from scoring its first win at Oulton Park in round three of the 2016 BTCC, and just ahead of its second win at Croft the following weekend.

Our first run, in the car's baseline configuration with the maximum permitted rear wing angle (one degree nose up), fully open radiators and no chassis rake angle, showed the car to have a modest rear bias to its downforce (the downforce split was 42 per cent front, 58 per cent rear, compared to a 52 per cent front, 48 per cent rear static weight split), which backed up the drivers' assertion of aerodynamic understeer. But drag and downforce seemed to be not dissimilar to the baseline set-ups of previous BTCC cars we've tested. As we were not permitted to quote actual coefficients or loads on those previous cars we cannot be any more exact than that. But we can give the starting coefficients on the BMR Subaru, albeit approximate ones based on a notional but unstated frontal area; see **Table 1**. These at least give us a basis by which to judge the relative magnitude of changes.

In last month's issue we reported on the apparently modest changes to the aerodynamic numbers from smoothing out the undercuts on the front bumper, which reduced the CD by 0.007 (or seven counts) and the -CL by three counts (all from the front). However, Faux's lap time delta calculator spreadsheet showed that there was a valuable theoretical lap time gain from this modest change of the order of 'half a tenth of a second around an average lap', despite the slight loss of downforce. And Faux made the assertion that drag was far and away the most important parameter when it comes to (aerodynamically) gaining lap time on a BTCC car. He also remarked that when looking for downforce, a change would not be installed on the car unless it produced better than a 3.5:1 downforce to drag ratio. So the next set of runs involving a chassis rake sweep was going to be fascinating.

Rake sweep

Chassis rake was adjusted on the suspension push rods in a series of 4mm increases in rear ride height relative to front ride height. Both the front and rear push rods were adjusted in order to maintain a constant 80mm ground clearance at the front splitter leading edge. The rake changes produced a virtually linear response to each of the aerodynamic parameters so **Table 2** summarises the effects of the overall increase in rake of +24mm, with changes to each parameter stated in counts, except for the change to '%front', that is, which is given in absolute terms.

Thus there was a substantial percentage (42.6 per cent) increase in total downforce, most of which was at the front, with what

The shift in balance took the downforce to approximately 50 per cent front, at which it would work well in steady state cornering

Table 1 – Baseline aerodynamic coefficients of the BTCC Subaru Levorg

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.441	0.200	0.084	0.116	42.0	0.454

Table 2 – The effects of increasing chassis rake

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
+24mm rake	+19	+84	+60	+24	+9.1%	+166

Team BMR's Subaru Levorg. The racecar's designer says drag is the most important aerodynamic parameter in the BTCC

Ride adjusted via push rods (top centre) with nuts pre-slackened for rapid adjustments

Rear wing adjustments changed the balance but had little effect on predicted lap time

The British Touring Car Championship rear wings are fitted in specified locations designed to put a limit on the maximum downforce working on the rear axle. Rwd cars, like the Levorg, received a slight benefit in this area in the middle of 2013

The rear wing was an effective means of shifting the aerodynamic balance forwards

Table 3 – The effects of wing angle change

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
5deg reduction	-20	-63	+15	-78	+19.4%	-115

would ordinarily be interpreted by your writer as a modest increase in drag (4.4 per cent); in fact the efficiency of the overall rake increase was 4.42:1, seemingly quite good. The shift in balance took the car's downforce to approximately 50 per cent front, at which it would feel well balanced in steady state cornering. Simplistically then, this 24mm change in rake, which was apparently not beyond the bounds of possibility or practicality, would seem to have made a very worthwhile change to the car's aerodynamic performance.

But what did Faux's lap time delta calculator predict? That, overall, there would be a lap time benefit but that it would only be of a similar order to the lap time gain from the drag-reducing airdam smoothing exercise mentioned earlier, that is, around half a tenth per lap. Put another way, each 4mm increase in chassis rake produced on average less than a 100th of a second lap time gain per lap, this in spite of significant influence on downforce. And this bore out Faux's earlier assertion that gains in downforce would only be worthwhile if their efficiency exceeded 3.5:1; in this case the overall change did exceed that level but even so the calculated lap time gain was relatively modest. However, overall the good news was that the airdam and rake changes had already found a tenth of a second per lap, well worth having in the ultra competitive BTCC.

Wing sweep

In light of the above findings, how would the car – and the predicted lap time delta – react to a wing angle sweep? The wing was swept from (an illegal) +1 degree on baseline to -4 degrees on baseline; the aerodynamic numbers once more changed more or less linearly at each increment so again just the overall delta values are reported in **Table 3**. The data all changed in the expected directions with a 63 count downforce reduction for a 20 count drag reduction (3.15:1), and a marked balance shift to the front. The lap time deltas, however, were almost negligible, with perhaps a few thousandths of a second per lap to be gained from the drag and downforce levels of lowest wing angle. However, it might be that the balance shift, which saw front downforce now in excess of 66 per cent of the total, would militate against the tiny drag versus downforce benefit. In essence, the rear wing was an effective means of shifting the aerodynamic balance forwards, but appeared to have little influence on lap time.

Next month we'll round off with an Aerobytes favourite: gaining performance with race tape.

Racecar's thanks to Silverline Subaru BMR Racing for its help with this feature.

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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The powertrain suppliers had to change emphasis from ultimate power to efficiency, and the need for close collaboration with fuel partners became ever more important

Pump action

When fuel flow was limited in Formula 1's new-for-2014 regulations those companies that supplied its racing juice had to meet a whole new set of challenges head on. Here's how they went about it

Between the start of the 1989 season and the end of 2013 turbocharged engines were banned in F1, and the technical regulations evolved predominantly to govern and reduce displacement and maximum revolutions. But in 2014 all of that changed with the introduction of the current power unit regulations, which saw the reappearance of turbocharging and had fuel flow limitation at their core.

Limiting the fuel flow created a very different challenge for the fuel suppliers; namely Mobil 1, Shell, Petronas and Total. Under the flow restrictions the route to performance became all about considering the maximum fuel efficiency by mass. The change from high-revving, normally aspirated, indirect injection engines, with a non-regulated fuel load, to low(er)-revving, turbocharged, direct injection engines with a maximum fuel load per race and a fuel flow rate limit as well, caused the fuel suppliers to radically change tack, yet still within the FIA's fuel specification regulations.

The powertrain suppliers had to change emphasis from ultimate power to efficiency, and the need for close collaboration with fuel partners became ever more important. In simple terms, the regulation shifted from an air-limited engine to a fuel-limited one.

Tank battle

Four major racing classes adopted fuel flow limitations as the core of their technical regulations from 2014 onwards, but only one, Formula 1, did not also place harsh restrictions on fuel development. The other three all used single specification fuels. In LMP1 all cars would use identical petrol (or diesel) from the same supply, while in GT500 and Super Formula the cars had to run on whatever was sold from the circuit's own pumps in the paddock. This has meant that Formula 1 has become the leading racing category in the world in terms of fuels development and, according to some, it also leads the way in road fuel innovation, and even that components found in conventional road fuels are developed in Formula 1 race fuels.

Unsurprisingly, there is not complete freedom in the rules for fuels in Formula 1 and while it is a myth that F1 cars run on pump fuel – in other words a product which you can buy on a forecourt – the fuel used does have to meet a specification broadly similar to the EU regulations on commercially available fuel. 'All the fuels we are using in motorsport you could run in your road car,' Wolfgang Warnecke of Shell claims. 'The aim is to have the science in the fuel make its way to the road. For example, in the Le Mans diesel fuel we use a very high amount of GTL and that's the same as we sell on the road. But the fuels need to be different to that which you get at the pump, because today's road cars simply cannot meet the efficiency levels that you see in Formula 1 these days. They are close to 50 per cent efficiency. In the past that was only possible with very large marine or energy generating engines.'

Petrol head

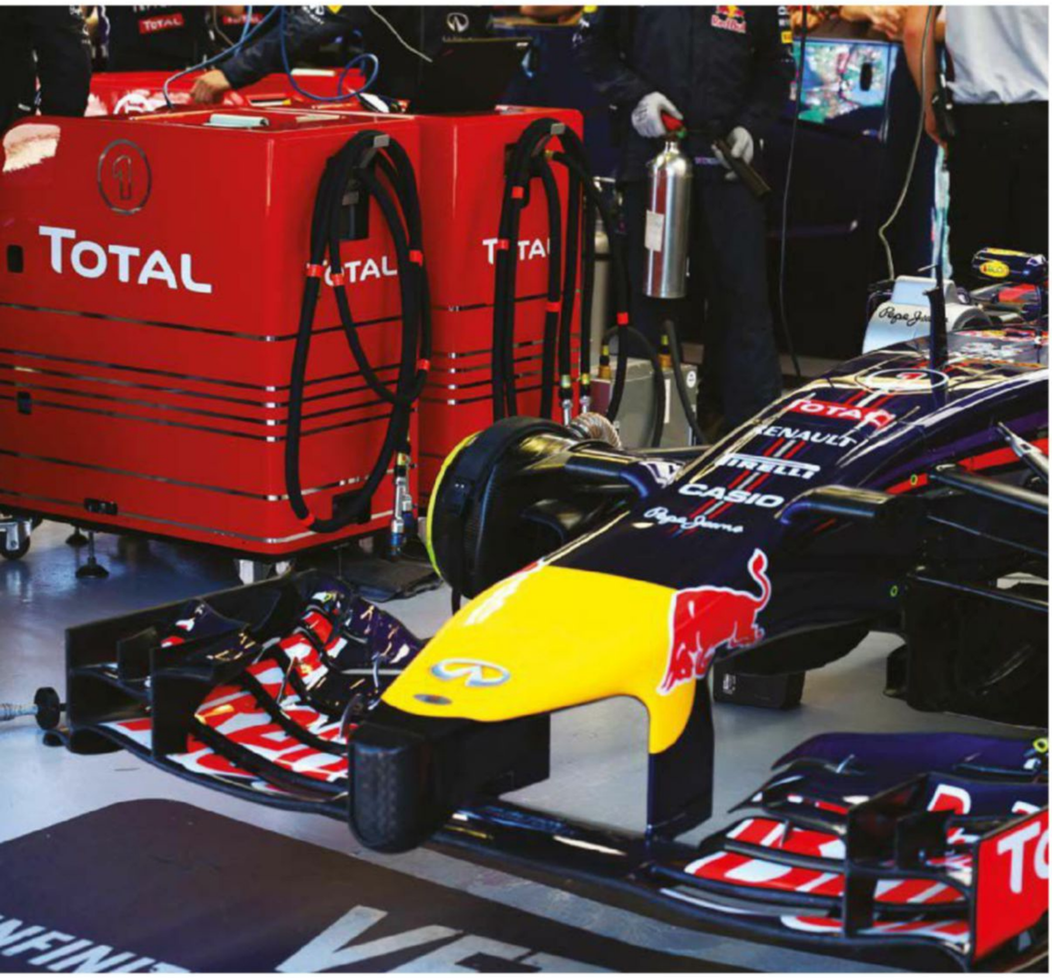
The regulations for Formula 1 fuels (which can be found in Article 19 of the 2016 technical regulations) are divided into two parts; firstly the physical properties of the fuel itself – these limitations on the standard fuel properties are inspired by the European Standard for gasoline: EN228. The second section of the rules relates to the chemical composition and it essentially forces F1 fuel to contain 99 per cent of the same types of compounds as fuels for the road.

High Octane

Racing fuels, based on road car specifications, are a trade-off between octane number and flame speed, and energy density. The first requires high RON aromatics, and oxygenates, the latter high heating value/kilogram paraffins, olefins and naphthenes. These two properties are in opposition to each other and the range of molecules the fuel developers are permitted to work with is tightly restricted. Pre-2014, octane number was king; post-2014, energy

Formula 1's introduction of direct injection engines and fuel flow limits changed the fuel requirements. Now it's all about optimising a fuel-limited engine

Shell is a technical partner to Ferrari. Formula 1 is an adventure playground for racing fuel developers with fewer restrictions than other categories, but F1 gas still has to be similar to road car fuel



Since the banning of refuelling in Formula 1 the fuel rigs are not so prominent but they are still at the very heart of the action

The Formula 1 regulations were recently amended to permit the use of other bio-components alongside bio-alcohol and today they play a crucial role and must make up a minimum of 5.75 per cent of the fuel blend

In terms of engine design all the parameters have been refocused from optimal configuration for an air limited engine to optimal for a fuel limited engine

density rules. Exactly where the trade-offs lie are determined in the simulation computer and proven in combustion research engines in laboratories. Hundreds of formulations are evaluated, and just a few are FIA homologated and find their way into an F1 fuel tank.

According to Total, its Formula 1 fuel is made up of about 200 different substances from the gasoline refining process. These components are selected like a kit of parts to build the perfect fuel for each iteration of the Renault 1.6-litre V6 turbochraged combustion engine. Or, in other words, the regulations force the Formula 1 fuels to be made using the same set of ingredients, but to a very different recipe.

RON speak

Today Formula 1 fuels have no upper limit to the RON and MON values, though previously this was the case. A change was introduced in 2010 in preparation for the return of turbocharged engines, to permit optimised fuel formulations to be explored within the road relevant framework of the regulations. Following this common objective that Formula 1 fuel development should embrace new technologies and their transfer to road fuels, the regulations were further amended to permit the use of other bio-components alongside bio-alcohol, and today they play a crucial role and must make up a minimum of 5.75 per cent of the fuel blend.

Of course, even putting the rules to one side the switch from absolute power for performance to efficiency based performance had a considerable impact on fuel formulation. Under the previous regulations, fuel predominantly influenced the performance of a Formula 1 car in two aspects, firstly absolute engine power output, with an obvious positive impact on lap time and also fuel mass consumption, with an obvious negative impact on lap time due to the decreased car dynamic when carrying more fuel weight.

Absolute power

Weighted in relative numbers, the sum of the two factors was clearly in the advantage of the absolute power number, meaning that the engine power was more important than fuel consumption for competitiveness. The ratio was dependent on the race track and some low speed tracks could have been in favour of a slightly lower consumption fuel when other high speed tracks needed the fuel formulation with the maximum absolute power. So at times the fuel suppliers created track specific blends, a heavier fuel which gave more power at Spa and Monza, and a lighter fuel with a lower power output at Monaco, for example.

Today, as the fuel mass flow rate (100kg/h) and the maximum fuel payload (100kg) is limited, the key factor in ranking fuel performance is the power output of the power unit from this limited quantity of fuel.

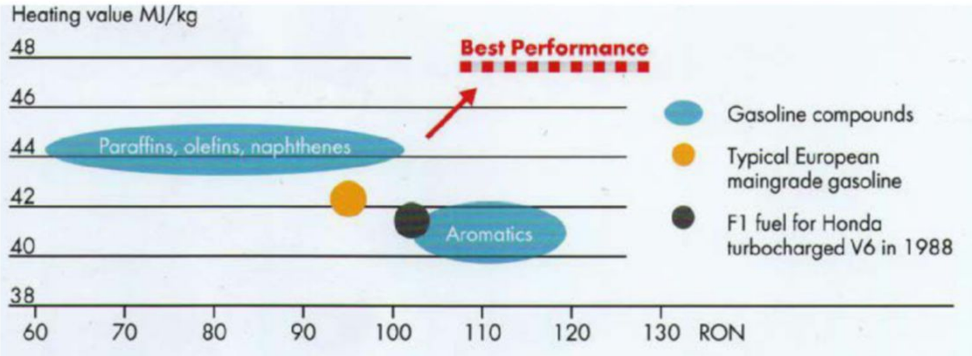


Figure 1: This shows the heating value against RON for a range of gasoline molecules. It can be seen that the racing fuel formulator faces a quite substantial challenge as these two properties are antagonist for RON values above 100

Category	WEC Diesel 	WEC Gasoline	Moto GP 	Formula 1 
Engine	Free	Free	Max. 4 cylinders	V6
Capacity	Hybrids: Unlimited No hybrids: max. 5500cc	Hybrids: Unlimited No hybrids: max. 5500cc	1000cc	1600cc
Air intake	NA or Turbocharged	NA or Turbocharged	NA	Turbocharged
Air flow restriction	No, Turbos boost pressure limited to 4.0 bars	No, Turbo boost pressure limited to 4.0 bars	No	No Unlimited boost pressure
Fuel flow restriction	Yes, max fuel flow between 68,6 and 86,4 kg/h depending on hybrid class	Yes, max fuel flow between 80,6 and 101,4 kg/h depending on hybrid class	No	Yes, max fuel flow: ■ between 0 and 10500rpm : Q (kg/h) = 0.009 N(rpm) + 5.5 ■ between 10500 and 15000 rpm : Q (kg/h) = 100
Refuelling	Yes	Yes	No	No
Fuel tank restrictions	Max between 49,9 and 53,7 l depending on hybrid class	Max between 62,5 and 67,4 l depending on hybrid class	Max 21 l (2015)	Max 100 kg
Race distance	> 5000 km for Le Mans	> 5000 km for Le Mans	95 - 130 km	ca. 305 km except Monaco GP (260 km)
RON/ MON/CN values	CN TBR	RON <105	RON 95 - 102 MON 85 - 90	(RON+MON)/2 > 87
Target for engine performance	Max. engine efficiency (%)	Max. engine efficiency (%)	Max. Power (kW) Lowest vol. BSFC (l/kWh)	Lowest BSFC (g/kWh)
Fuel formulation targets	■ Combustion efficiency ■ Auto-ignition properties	■ Combustion efficiency ■ Knock resistance	■ Combustion efficiency ■ Energy content per volume ■ Knock resistance	■ Knock resistance ■ Energy content per mass ■ Combustion efficiency

Different forms of motorsport have different requirements. It's interesting to see how fuel philosophy differs between series

It is known that a large number of varying fuel specifications were being introduced by each supplier throughout the 2015 and 2016 seasons

In terms of engine design, it means that all the parameters have been refocused from optimal configuration for an air limited engine (naturally aspirated, limited displacement and revolutions), to optimal for a fuel limited engine. The goal is now to achieve the best power from the given 100kg/h fuel flow rate (ie the best efficiency), thus the lowest Brake Specific Fuel Consumption (BSFC, in g/kWh).

This has seen compression ratios rise rapidly as the engine designers seek performance through efficiency and the leanest burn possible. To make this possible the challenge for the chemists in the fuel development laboratories is substantial. There are three main areas of fuel formulation that are now the focus.

Anti-knock

Firstly, the anti-knock properties of the formulation are crucial. High octane value is a known positive property for spark-iginition engine efficiency. Thanks to the better anti-knock properties of high octane fuels, the spark advance can be increased, leading to a better combustion phasing and hence engine efficiency. Secondly, the fuel energy content by mass. As the mass flow is fixed to 100kg/h, it is possible to select compounds with higher energy per mass, i.e. providing more energy with the same given flow. Thirdly, combustion speed. The speed and completeness of combustion through higher flame speed formulations is a constant target as these items are having a direct impact on the thermodynamic efficiency of the ICE.

So to formulate the best possible fuel, these three factors and the relationships between them must be considered. Based on the table (**Figure 1**) of heating value against RON for a range of gasoline molecules, it can be seen that the fuel formulator faces a challenge as these two properties are antagonist for RON values above 100; the use of high RON aromatics will always lead to a decreased energy content of the final formulation.

So the fuel formulator must find the optimum balance between the three parameters for a given engine specification, and the 2016 regulations allow five different specifications a year not including test engines. In the same graph, two typical fuel formulations have also been positioned: a typical European maingrade gasoline, located centrally, showing that the formulation is a balance of all components, paraffins, olefins, naphthenes and aromatics, and a Formula 1 fuel for the turbocharged F1 engine of the 1980s.

Honda's accord

In a paper on the 1.5-litre V6 Honda F1 engine, released some years ago by the Japanese company, the fuel formulation used in 1988 was revealed. The formulation was a mixture of 84 vol% of toluene and 16 vol% of n-heptane. This fuel is obviously positioned close to the

European Union regulations will see bio-content increase in production car fuel so that is likely to be replicated in any new regulation on fuel

aromatics family in terms of RON and energy content. At that time the RON was limited to 102, but the anti-knock properties were key for the engine performance and hence this fuel included a substantial amount of toluene with n-heptane used to trim the RON of the final formulation to exactly 102. This fuel cannot be considered as road relevant because of the very high aromatic content, which falls outside the current levels specified within EN228 and thus falls outside the current F1 fuel regulations.

In the same paper, the BSFC of the 1988 Honda F1 engine is revealed to be 272g/kWh. By comparison, the BSFC of the current breed of downsized and turbocharged Formula 1 power units is below 200g/kWh. Therefore, to achieve the same duty, the fuel consumption has been reduced by over 25 per cent and within the context of road relevant regulations.

New limits

None of the fuel companies will disclose exact details of their current fuel formulations for obvious reasons, but it is known that a large number of varying fuels specifications were being introduced by each supplier throughout the 2015 and 2016 seasons. That practice is being restricted for 2017, however, as a temporary limit on the number of specifications introduced by each manufacturer has been brought in in an effort to even up the power unit performance somewhat.

Fuel speed ahead

Thoughts about the fuels used in Formula 1 are now starting to turn to the future. European Union regulations will see bio-content increase in production car fuel so that is likely to be replicated in any new regulation on fuel. A bigger factor in production car legislation is the EU maximum fleet average CO_2 emissions of 95g/km and this has seen motorsport begin to consider the impact of emissions for the first time (See *RCE* V26N8). This is sure to impact the fuels used, too.

CO_2 is one of the parameters used to evaluate sustainability, and looking to the sustainability of cars it can be seen that there is a reduction already directly due to the increased efficiency of LMP1 and Formula 1 cars since 2014. According to Shell, which supplies the fuel for the Le Mans 24 hours, the CO_2 emissions through fuels have reduced from 436 tonnes in 2012 to 320 tonnes in 2015.

Although a major contribution on CO_2 is based on the production and combustion of the fuels used for the race event, other energy intense sources such as tyre manufacturing will also need be considered.

Ensuring that developments within motorsport ultimately make their way to road car fuel applications is a core mindset within the fuels industry and continuing this will – according to many working in this industry – be essential in nurturing and motivating the fuel industry for the future.

Fuel's paradise

Allowing multiple fuel development cycles per season, and being open to new types of fuels in some race series, is clearly a motivation for the fuel companies, and is also an attractive proposition for those involved to continue to push the technical boundaries. Next month we will look at what the racing fuel of the future might be like, and also the fuels of the past.

Shell presented a paper to the 37th International Vienna Motor Symposium, titled 'Innovation from Track to Road: The Role Fuels can Play in Motorsport'. In it, the history and technical challenges presented by motorsport are described in detail, this article is largely but not entirely based on it. It also draws on interviews conducted by Peter Wright and Sam Collins.

The fuel industry is keen to sell the green credentials of the fuel it uses in motorsport. CO_2 limits could be the next challenge

Cool and the gang

PWR supplies Formula 1 teams, all the NASCAR Sprint Cup field, and many others with its cooling solutions – *Racecar* took a trip down-under to find out the secrets of this uber-cool company's success

By SIMON McBEATH

PWR's impressive purpose-built facility in Ormeau, Queensland, an hour south of Brisbane, was completed in 2009

Unless you happen to work in one of motorsport's higher echelon categories, it's possible that the discreet success of PWR Performance Products makes it one of the most famous motorsport suppliers you've never heard of. As a manufacturer of cooling products – radiators, oil coolers, intercoolers, heat exchangers, cold plates and associated products – PWR started supplying motorsport less than 20 years ago.

PWR's portfolio of categories where it has taken significant market share now includes F1, NASCAR, DTM, IndyCar, LMP1, 2 and 3, V8 Supercars and WRC, to name but a few. Naturally the company won't discuss individual clients in detail but it is well-known that they have supplied cooling solutions to several F1 Constructors' and Drivers' championship-winning teams. Stewart Haas Racing and Penske Racing have won NASCAR Sprint Cup Series using PWR products and its products have also recorded a 1-2-3 finish on the Dakar Rally.

Being selected for these, and many more successful campaigns in highly demanding applications, is down to a combination of factors that have made this Queensland, Australia-based business the supplier of choice for race teams and, in some cases, race categories (as a control supplier) around the world.

Business building

Arriving at PWR's modern corporate headquarters buildings just off the Pacific Highway in Ormeau, an hour south of Brisbane, certainly impresses. But it's what's behind the concrete, steel and glass frontage that explains why this engineering enterprise has become so successful. From its flexible and entirely in-house manufacturing processes to its unique design and development facility (a 30m bespoke wind tunnel) and, perhaps most important, the professionalism and 'can do' culture imbued by co-founder and CEO Kees Weel (see sidebar), PWR seems to have aligned all its resources in just the right way to dovetail with the demanding requirements of professional motorsport.

To understand how the company brought itself into this position it helps to go through a brief history. General manager, engineering, Matthew Bryson recounted the tale: 'It all started as a small family enterprise when Kees Weel founded K&J Thermal Products [in 1987] making aftermarket road and performance car radiators and related products. In the mid-90s Kees' son Paul joined the company and the pair saw that the trend for radiator construction was moving towards aluminium. So they took the brave step to install an aluminium CAB (controlled atmosphere brazing) furnace in 1996. Two years later they established Paul Weel Radiators (PWR), with Paul in charge, to manufacture radiators for custom road and Australian motorsport markets. [Kees and Paul also became involved in racing themselves, running Paul Weel Racing and competing in V8 Supercars for 10 years]. During 1998, the Holden Racing Team notched up the first high level success for PWR-manufactured radiators by winning the Bathurst 1000 that year, something that did no harm to PWR's credibility.'

Bryson joined the company in 2000. 'So PWR had become two

Matthew Bryson, PWR general manager

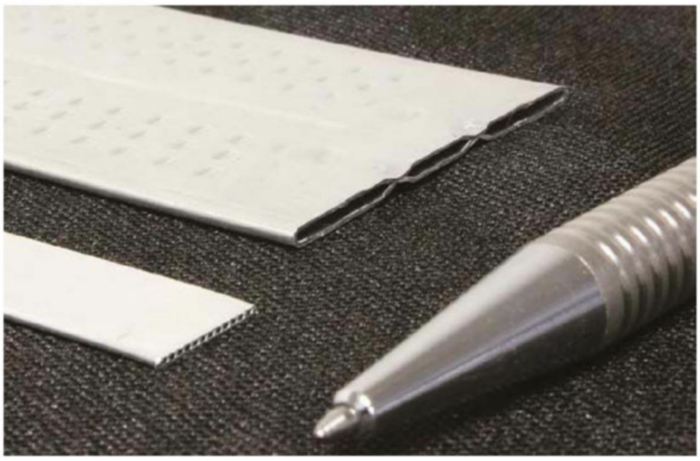
Paul Weel is the co-founder of PWR

Entry into F1 market meant development of new methods to make complex core shapes

PWR now supplies complete billet-tanked assemblies to its high end customers

A cutaway example of a surface plate cooler for an electric car application

Radiators are made for all sorts of competition cars. This one is for a Subaru



Examples of extruded tubing showing part of the range of sizes handled. The larger tube features simple stamped turbulators. These are the only bought-in components at PWR

people and was looking to expand. By 2001 opportunities in the USA were appearing and so PWR USA was set up in California to provide performance products, though not really race products at this stage. Then in 2003 K&J was sold, which was good timing because the replacement radiator business seemed to be on the decline. But Kees and Paul retained PWR and started to hatch grand plans. The bold idea was to build a new factory to "go after the world", the aim being to provide its cooling products to Formula 1, WEC, and all the top motorsport categories around the globe. So they embarked on the construction of the new facility, which not only had to have capable facilities but to also look the part. It took about 18 months to be fully operational,' Bryson says. Meanwhile, PWR Europe was incorporated in 2007, based at Tamworth in the UK.

The company was confident that the products emerging from the new manufacturing facility at Ormeau were good, but decided that they needed to understand them better and also be able to provide real performance data. So in early 2008 a small wind tunnel was constructed that was able to test 300mmx300mm core samples. Bryson says: 'By the middle of 2008 Kees was meeting with NASCAR teams and showing them data and samples, and it became obvious that what we could offer was different to what they were used to, which was stock OE cores being cut down to suit. We had data and flexible designs – our philosophy has always been to produce custom units even if it's a one-off – and it was now possible to adjust the cooling and the associated aerodynamic parameters. NASCAR had not previously had quite the flexibility of choice for core construction up to that stage, and in a short time, around two years, we were supplying half the field.'

Formula 1 work

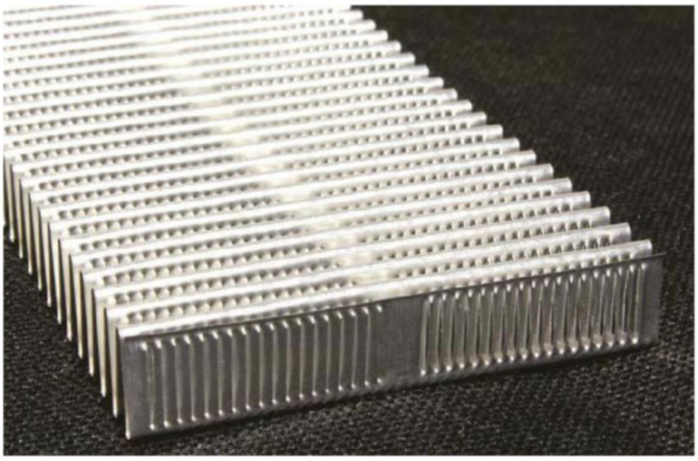
At this stage PWR had not chased any F1 opportunities but the aim had always been there. Then, in late 2008: 'We had a booth at PMW Cologne and an F1 technical director stopped by to have a look at us,' Bryson says. 'We told him what we could do and shared all of our production and component options. Early in 2009 we had received initial drawings and, by May 2009, we had built our first profiled cooler – up until then everything had been rectangular! We had to teach ourselves how to do that. But we had always thrived on a "can do" approach and motorsport has loved that, being able to provide what they want, when they want it. The business has always been built on both quality of product and quality of service, and our customers know that we are a reliable partner, and that they can trust we will deliver on both aspects.'

Initially, as PWR established a presence in F1, it was just supplying cores and the customer then fabricated the assembly with tanks, connections and other parts themselves, but PWR is now supplying complete billet-tanked assemblies for many of its customers.

Meanwhile, progress was ongoing in other categories, too. PWR USA was re-located to Mooresville, NC, in 2009, in the heart of NASCAR country, where: 'A focused effort was made to support and service the category to the level it deserved,' Bryson says. The company is now supplying 100 per cent of the field with every car having at least some PWR coolers. When first dealing with NASCAR and entering the US market, PWR found itself competing with the well-established company, C&R Racing, as Bryson explains: 'C&R supplied radiators and oil coolers

Aluminium strip is converted to concertinaed fin strips on this piece of machinery

Two examples from the very wide variety of different fin strip sizes and configurations



Louvre size and angle can also be varied on the fins to meet with customer demands

Stacking of fins, tubes and side plates to build up oil cooler cores prior to brazing

Loading the 'controlled atmosphere brazing' or CAB furnace with clamped core stacks

Brazing is a multi-stage process in the CAB. Cores are cleaned and flux-coated first

and although their fabrication was good they didn't manufacture cores in-house or have the same flexibility for core development as PWR. So we competed fiercely with them initially, but not too long into our involvement in US racing we figured that as a core manufacturer it would be good if we were able to work with C&R so we approached them to buy cores from us. Naturally, they greeted us very cautiously at first, but they visited us at PWR in Australia to see our manufacturing and testing facilities and decided they had to make it work. To their credit that was a real leap of faith on their part at the time, but they became our largest single customer in the US and the relationship between both companies immediately worked well. Then in April 2015 PWR acquired C&R, which now operates as C&R Racing, and we are continuing to grow into the aftermarket in the US.'

In 2012, and in partnership with Dallara, PWR became a control supplier to IndyCar supplying water radiators and oil coolers, and in other categories PWR works with WEC teams, is control supplier to DTM, Super GT and Super Formula in Japan, and has a big involvement in GT3 and Australian Supercars. It also supplies the control intercooler to the BTCC. Niche OEM cars are also on PWR's customer list, too, including the Porsche 918 Spyder. Bryson says: 'Providing an efficient and robust cooling solution for Porsches running at the Daytona 24 Hours led to supplying GT Cup cars, which in turn led to a wider awareness of PWR and an involvement in the 918 project. Motorsport drives you technically and this has helped us establish credibility with niche OEM projects too.'

Electric fans

The company has also started work on cooling systems for the electric car market, although as Bryson says: 'We weren't sure at first if electric cars were a threat or an opportunity. It turns out they represent a big opportunity.'

The company is now producing a range of surface plate cooling and

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Here's a generic sample of PWR cooler cores showing the tubes and the fins

Tank with its integral connections is welded to a core to become the finished product

The company's new multi-pallet 5-axis machining centres have increased capacity

Pressure testing of a welded cooler in the water bath to make sure it's perfectly sealed

Quality assurance makes use of mechanical and laser coordinate measuring machines

High end aerodynamics demand non-rectangular cores (above left). Intercooler (above)

battery cooling solutions for these emerging technologies.

In 2012 the new, larger wind tunnel was completed (see separate feature on page 58 of this issue) and the company believes this has given it a real competitive edge in the motorsport market place.

'Our small wind tunnel could only do 300mm square sample water and oil radiators and, useful though that was, as our F1 work expanded we wanted a facility to develop solutions for complete installations,' Bryson says. 'So we built the new wind tunnel to replicate the two main applications, Formula 1 and NASCAR.'

Race team mindset

Senior engineer Andi Scott, who moved from working with race teams in the UK to work for PWR, says: 'PWR operates very much like a race team, and is able to provide rapid responses to customers' needs.'

This point was taken up by Bryson: 'We try to make dealing with us as easy as possible. We're driven by passion, and we're in the fortunate position of being able to see how our products help our customers. We can get swept along by that!'

Helping to ensure PWR's agile responsiveness in a demanding market sector like motorsport is that every key aspect of manufacture is carried out in house. So all the relevant components, including radiator cores, side plates, tanks and fittings are made by PWR. This involves a range of specific machinery, plus conventional presses, multi-axis machining centres and welding operations. The only raw material that is bought in 'part-manufactured' at PWR is a range of extruded flat aluminium tubing.

One method specific to radiator manufacture at the front end of the process uses purpose-made tools to carry out the pressing, folding and cutting operations that turn thin aluminium strip into concertinaed sections of the 'micro-louvred' fins that form the large surface area within a radiator core from which heat is transported. A wide range of tooling for these machines enables fin height, pitch and louvre design and angle to be modified to suit different demands.


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Header tank: just one of the many products produced by PWR

The Weel deal

Dutch-born Australian Kees Weel started his working life as an apprentice mechanic on Holden Cars back in the early 1970s before a spell mining in Papua New Guinea. He moved to Queensland's Gold Coast in 1987 and then established his first radiator manufacturing operation – the rest is recounted in our main piece. When interviewed by the local media following the successful stock flotation of the company in 2015, he responded pithily to the question on how it felt to become an overnight success by saying: 'It's taken three decades to be an overnight success.'

And this seems to typify the no-nonsense directness of PWR's CEO, managing director and business development manager. He recounted anecdotes that also demonstrated his equally forthright approach with prospective customers. 'In 2008 I met with Jack Roush and various other NASCAR folk, and I had with me samples of tubes, cores and so forth. I told him: "I will be more expensive than your current supplier." Jack Roush stood up, shook my hand and said: "You're the partner we want; we don't want the cheapest who can't supply what we want, when we want it." And I say that everywhere we go, but also that when you buy from us you get a part of us.'

Weel expands on this last point on the PWR website, saying 'We like to point out when entering into a business relationship, that we don't want to just sell the customer a radiator, we want to sell them a business relationship that means they can use our engineering department to purpose-build exactly what they want.' This was clearly the motive that catalysed the building of the new factory and the bespoke wind tunnel. In Kees Weel's words: 'We decided to build a facility to take on the world.'

But how does the CEO see the company expanding without losing its trademark responsiveness? 'It's important that we don't lose who we are as we expand,' said Weel.' But we can double in size.'

There's a tangible drive that runs throughout the workforce at PWR, and there's no doubting where it comes from: 'I'm passionate about what we do; I eat, sleep and shit radiators, mate,' Weel says.

Weeler dealer: PWR Co-founder, CEO and managing director, Kees Weel

Further machines roll the edges of the fin material into double thickness to increase robustness.

'Core stacks' of alternating tube and fin sections together with side plates are assembled on easels and then held in clamps prior to passing through the controlled atmosphere brazing (CAB) furnace. Those components that are to be brazed have been pre-coated in what is referred to as 'clad'. This is a thin aluminium alloy coating that has a lower melting point than the parent metal beneath, and is what then melts and bonds the adjacent surfaces together in the CAB furnace.

The brazing process is a multi-stage one in which the assembled cores are cleaned, dried and coated in flux before passing into the oxygen-free nitrogen atmosphere within the main furnace at around 600degC. The cores then cool prior to being pressure tested, after which the tanks with integral connections are welded in place to become a finished radiator, or oil cooler, or intercooler.

Billet built

Manufacture of the tanks has conventionally involved pressed aluminium sheet parts, in one or more pieces that are welded to the ends or sides of the cores, as appropriate. However, for more demanding applications PWR also CNC machines the tanks from billet; this not only gives greater control over thickness, but can also enable internal rib structures and local thickening to be incorporated to provide improved strength and stiffness. 5-axis machining centres are employed for these processes and new machines were being installed during our visit, to increase capacity.

One aspect of high end applications is that core density does not have to be uniform; a single cooler may encompass more than one section, one perhaps for air/water, another maybe for oil/water with baffles in between, which may require different core densities for best heat transfer. Or optimisation of a core may dictate that the core density is varied across the face in order to provide an even thermal gradient. That PWR manufactures all its own cores gives it the ability to assemble different core densities in a single cooler and then enables it to meet this requirement when it is needed.

Aero demands

A particular feature of high end applications such as Formula 1 is that external aerodynamics has dictated sculpted sidepods into which rectangular coolers would no longer fit. Hence, back in 2009/10 when PWR first became involved in F1, it had to develop new skills to create non-rectangular cores. Precise details of the process are secret but cores can be made the desired shape and are then meticulously final-trimmed and finished by hand. CNC-machined tanks and side plates are then painstakingly matched, fitted and welded to the cores to produce the finished item. Needless to say the whole process of producing a product like this is highly labour-intensive, which helps to explain the price tag of this type of cooler. It has to be said though that the workmanship is exquisite, not to mention (necessarily) dimensionally highly accurate

It seems to be working, too. At the time of *Racecar's* visit the company's prospectus showed turnover approaching AU$50m (£29m), with in excess of 185 employees on the books worldwide. Illustrating that its location in Australia is no barrier to its activities, in 2015 59 per cent of sales were to the UK and Europe, 25 per cent to the USA, 15 per cent to Australia and one per cent in Japan. And a successful stock flotation in 2015 valued the company at over AU$300m (£178m); well-placed to invest in future expansion plans.

It has achieved its success so far by focussing on elite motorsport

Radiating growth

PWR has achieved its success so far by focussing on what it calls elite motorsport. It sees future growth by expanding uptake in that same sector but also into the huge global motorsport market and emerging technologies. This will require a fine balancing act between expanding while retaining the responsiveness that has been crucial to its success so far. But you can be sure that the PWR name will become much more widespread at all levels.


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How to be cool

Ever wondered how a cooler is designed to meet specific motorsport requirements? We did too, so *Racecar* visited renowned expert PWR Performance Products in Australia for a cooling master-class

By SIMON McBEATH

Boundary conditions to model cooling requirements might include vehicle speed and duct expansion ratio. British Touring Car Championship cars use PWR intercoolers – this is the Subaru Levorg's radiator and intercooler inlet duct installation

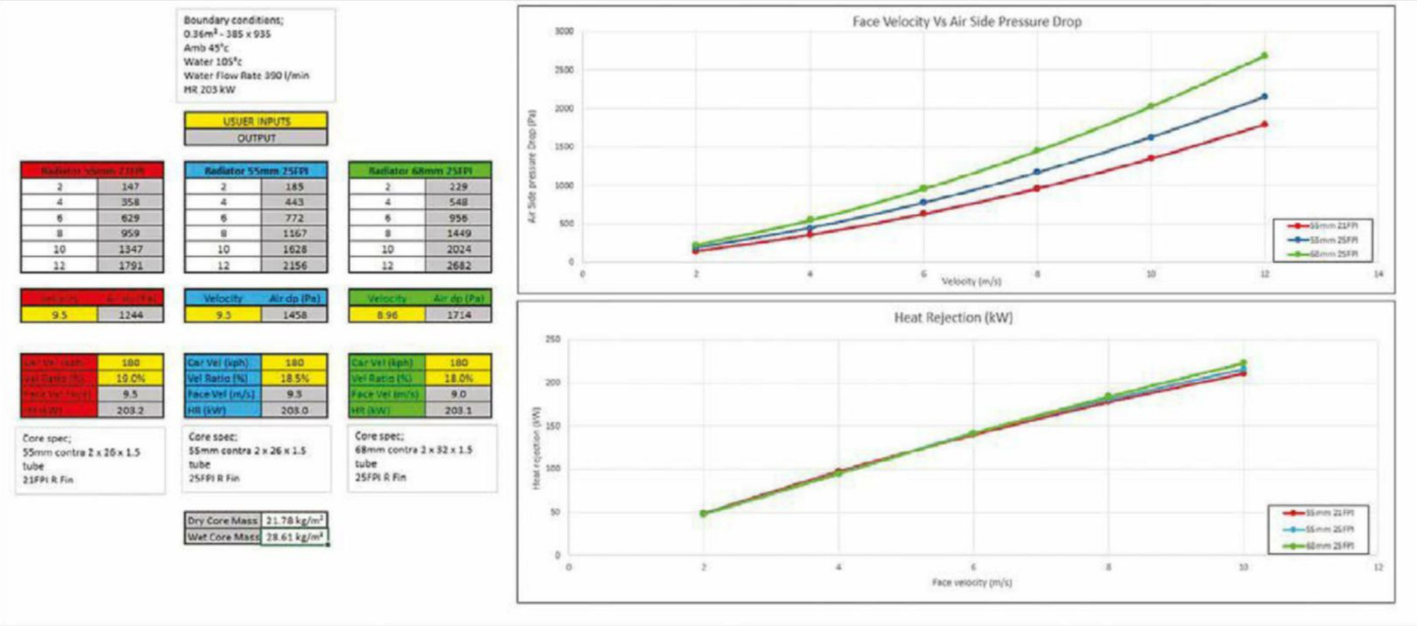
A small part of PWR's library of samples for all cooler types. This contains hundreds of different cooler core configurations

In recent years top level motorsport engineers have chased ever smaller performance gains, and one area that has now come in for much closer attention is cooling system design. Whereas this might once have simply focussed on the aerodynamics and efficiency of the ducting leading to and from a stock radiator, increasingly it is the radiator itself (or whatever type of cooler) that is being purpose-designed to achieve improved performance. An operation that is at the forefront of this endeavour is Queensland, Australia-based PWR Performance Products. *Racecar* has been to see this company at work.

Time was when a radiator was universally a simple rectangular matrix and a racecar designer's choices for meeting cooling needs were limited to face area, core thickness and possibly some decision over fin size and density, and tube size and design. More to the point, the ability to select which of those parameters to use was probably based on past experience, following a path trodden by others, or just good old fashioned guesswork. Now, with the additional demands of overall aerodynamic performance going hand-in-hand with effective cooling, a data-driven approach is demanded. As we saw in the previous feature, this is what's given PWR a substantial market share in most of the world's top motorsport categories within a small number of years, following the decision by co-founders Kees Weel and his son Paul to build a bespoke wind tunnel cooler test facility in their purpose-built factory near Brisbane.

Design process

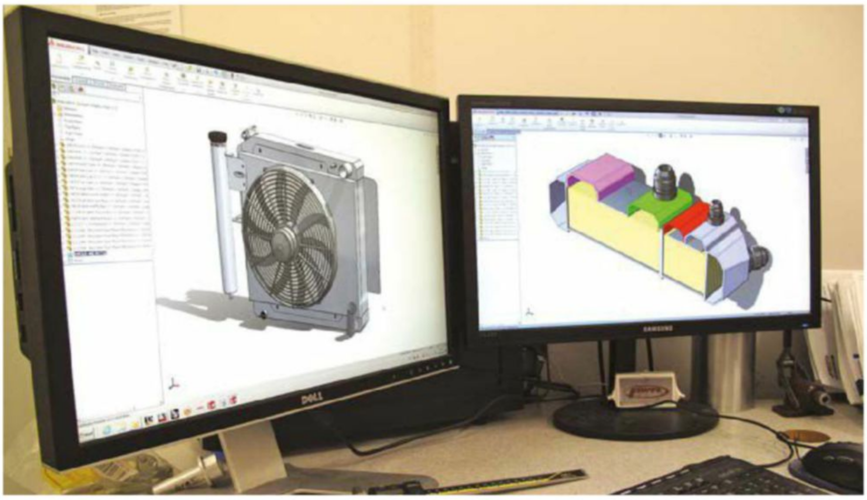
So how is this data-driven approach used to design a more efficient cooling system? PWR design engineer Andi Scott, formerly a race and design engineer with top level teams based in the UK, who emigrated to work at PWR, explained. 'Firstly we need the boundary conditions for the core. This will be either the maximum face area or the complete core dimensions including the size of tube and the stack height. For a non-rectangular shape we would use an average tube length and face area with which to begin our modelling. Then we ask



PWR's modelling enables heat rejection and air side pressure drop predictions to help narrow down the core specification. This data is also useful for a customer's CFD simulations

Further design validation may also involve testing a new core sample in the wind tunnel

Designs pass on to the drawing office for the practicalities; this is an F1-style installation



PWR uses SolidWorks CAD in its design office. After this step a first-off cooler core is made and validated

for the ambient operating temperature, plus either the car speed and the duct expansion ratio or a mass flow figure for the 'air side', and the coolant (e.g. water) and its temperature for the 'water side'. We may also be supplied with a target outlet temperature or perhaps a heat rejection requirement, for an array of input conditions. Additionally, we will ask for a pressure drop versus velocity curve that the customer would like to stay below. The water pump specification may dictate a pressure drop requirement on the water side.

'From this we can either provide a single point prediction for a specific core design or a matrix of target points,' Scott adds. 'A single point prediction would involve a specific condition, like the lap average inputs for face velocity, inlet temperatures and flow rates of both fluids to meet an average heat rejection target, whereas a matrix output will allow the team to generate the performance curves of the cooler for more detailed analysis of varying conditions. Usually we will have received an outline model of the core shape or an average tube length from which we can work out the stack height to design a core to meet the customers' requirements.

What is different at PWR is that predictions are based on physical samples tested in the wind tunnel. 'We will have an applicable heat rejection curve for a 300x300mm sample and we can run a range of tests to bracket the extremes of the desired performance range, and then interpolate for the specific application,' Scott says. 'We have a library of hundreds of samples for all cooler types (with different core configurations, for example; thickness, fin height and pitch, tube size and type, and so on) which can provide several solutions from which

Fan end of the on-site wind tunnel, which plays a pivotal role in design and development

The test end of the wind tunnel. This equipment is at the core of the PWR operation

Julian Conlan (JC) completing the installation of a charge cooler which is to be tested

JC driving the test from the control room. The part tested is for a high-end race team

to choose for a given application. We can then go on to refine these choices to tailor for the desired air side or water side pressure drop.

'We then take the wind tunnel data and feed it into our model to re-process and provide the pressure drop curves for both fluids, be they air/water or other, along with the heat rejection figures in kilowatts, and send them to the customer so they can look at the necessary velocity ratios or mass flow needs,' Scott adds. 'For example, if we get a request for a specific heat rejection value we can pick a range of configurations at different velocity ratios with similar pressure drops. This data will obviously also be useful for the team's CFD simulations too. And we will also have temperature readings from the rear of the cores from the thermal imaging cameras in the wind tunnel.

'Then, once a configuration has been selected, we can, if required, build a core sample to that configuration to test in the wind tunnel to further validate the predictions. This might be a 300x300mm sample again, or we might test the customer's specified face area or a different aspect ratio (of tube length to stack height) to evaluate potentially more efficient solutions.

'The recommended configuration is then passed to the drawing office to look at the manufacturing practicalities, for example whether fabricated or billet machined tanks are required, whether internal ribbing will be needed in the tanks to handle pressures, and so on. There are plenty of options but our experience helps to narrow the choice. We then make a first-off core and possibly validate that again in the wind tunnel in the configuration it would be run in in the racecar.'

The process described above was for a single core in isolation. It is also possible to have complex core assemblies, combining perhaps engine oil, gearbox oil and energy recovery system cooling in one matrix, with baffles between sections and separate inlets and outlets on each section. It's also possible to piggy back systems, too, in one cooler, so there might be a water radiator sitting behind an intercooler. As long as there is a temperature delta, heat can be rejected; making the most efficient use of the available temp delta ensures an optimised package is designed. It is also possible to thermally isolate separate panels with an air gap or an insulating layer; by doing this, efficiency can be improved to help achieve tough targets, and although this approach adds complexity and cost it is all part of providing solutions in challenging applications.

Scott says: 'With plenty of information available we can see where improvements can be made on cooling, pressure drops and weight of a component. We also work hard to minimise package weight for a specific task and provide predictions of weight before making a final assembly. There are lots of components, and estimates are made for everything from the core and tanks, through to the weld allowance.'

Physical testing

The on-site wind tunnel built by PWR to replace its earlier, smaller facility clearly plays a pivotal role in the design and development process. As well as adding to the company's library of sample core test data that the original smaller wind tunnel was conceived for, it facilitates the testing and validation of proposed designs as outlined in the foregoing section and, in some instances, the ongoing optimisation of those designs. *Racecar* was privileged to sit in on one such test session involving the charge cooler of a high end team. This therefore was a completed product rather than a test sample and as such it encompassed the full size and complex shape together with the tanks and connections, as would be found on the racecar itself.

Wind tunnel operator Julian Conlan (JC) was finalising the installation of the test component on our arrival, connecting the multiple lines and cables to supply charge air to the test

'We also work hard to minimise the package weight for a specific task'

The thermal gradients across the sections of the core had changed

part and gather the necessary data. There were two temperature probes on the inlet side of the cooler face and thermocouples monitored core temperatures along the centreline, as well as temperature sensors in the charge air inlet and outlet pipes. Pressure sensors sat upwind and downwind to provide 'air side' pressure drop characteristics. Charge pressures were also measured on the upstream and downstream sides of the cooler too. A pair of thermal imaging cameras, one within the tunnel looking at the upstream face of the cooler, and one outside monitoring the downstream face provided real time imaging of temperature distributions; static thermal images are taken at the same time as data points are being logged and are provided with the client's report. The control and data logging software, all developed in-house, provide automatic control of test functions and enable manual override should circumstances require. Test protocols, or 'recipes' as they are known in-house, drive each test program through its pre-planned sequence.

This time the map involved a range of air side inlet velocities (determined by mass flow, air density and face area) versus a range of charge air mass flow rates, all at representative charge air pressures in excess of 2bar. Ambient (inlet) air temperature is also controllable up to 45degC and tests were carried out at 40degC in this case.

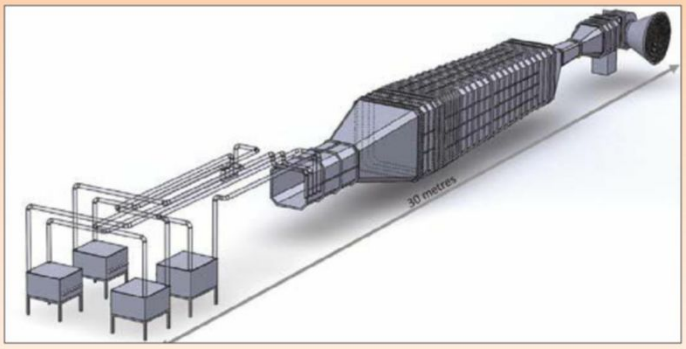
Charge air

The choice of inlet velocities and charge air mass flow rates broadly bracketed the expected on-track values. JC explained that ramping up the temperature and pressure of the charge air system takes roughly half an hour for safety and stability reasons, so after systems were checked at ambient conditions the charge air was heated and pressurised to head for the first data point and the test was underway.

This particular non-rectangular core featured a variable core density across the matrix stack to compensate for the differing tube lengths across the core. It was this aspect that was being refined in order to try and achieve as even a temperature gradient across the matrix as possible. Comparison between the thermal imaging pictures taken during testing of the previous core iteration with the latest one enabled an immediate view to be formed on progress made. It was evident that the thermal gradients across the various sections of the core had changed and that the temperature distribution across this

The PWR wind tunnel

The current PWR wind tunnel took a year to build and was commissioned in 2012 following a design process that was assisted by some of the leading race teams around the world. The schematic graphic (below) shows the overall blown open-jet design of the 30m long by 2m wide (maximum) wind tunnel. Atmospheric air is drawn in by the centrifugal fan and passes through a diffuser before entering a flow conditioning contraction section which contains flow-straightening screens. The flow is then diffused into a settling chamber, the purpose of which is to achieve uniformity in the flow, and in this case a large heater matrix is also incorporated in this chamber to heat the air to 40-45degC to simulate high ambient temperature conditions. The flow then enters the contraction zone where its velocity increases, thus further reducing flow turbulence and non-uniformity before passing into the test section, where another mesh screen further conditions the flow quality. At the end of the test section coolers under test are bolted to large adaptor plates which in turn are bolted on to the periphery of the test section outer walls.



The 30 metre long and two metre wide PWR wind tunnel is a blown open-jet design. The coolers which are under test are attached to the downwind end of the test section

Temperature and pressure probes upwind and downwind of the test cooler provide cooling efficiency and pressure drop data. Further temperature and pressure probes also monitor all coolant and, where appropriate, charge air inlet and outlet conditions, and temperature probes are also inserted into the cooler(s) under test to provide a centreline temperature profile. Thermal imaging cameras monitor the upwind and downwind faces of the test cooler(s).

Test recipes

Control software uses 'recipes' to run through a test sequence, which might be a matrix of inlet air speeds versus charge air mass flow rates, as in the test run *Racecar* witnessed, but obviously conditions appropriate to the type of cooler under test would be used. Water radiators, engine oil coolers, transmission oil coolers and charge air intercoolers can all be evaluated. Air velocity, temperature and pressure, oil temperatures and coolant flow rates can all be controlled, and heat transfer,

Charge cooler connected to the charge air feed. Temp and pressure sensors monitor conditions; thermal imaging cameras monitor upwind and downwind faces of cooler

Two heated water circuits plus two heated oil circuits and a single heated charge air circuit are available. It is also possible to test multiple cooling components together

latest iteration had been improved, but equally that further refinement might be achievable. For example, parts of the centre of the core on the downwind side did not seem, from the thermal images, to be as hot as others, meaning they were not rejecting as much heat as they might. JC suggested that perhaps the local core density could be reduced further to aid performance.

It was evident from watching this test session that the measured and visualised performance of a finished cooler is another step on from testing and analysing the 300x300mm sample cores that provide the initial configuration. Testing the finished cooler under repeatable laboratory conditions highlighted the areas where efficiency had been improved but also where further improvements could be made. An example of where this has proved valuable in the past is where a PWR-specified core went to the customer who then fabricated his own tanks. The finished product fell well short of expectations but when the full assembly was wind tunnel tested it became clear that the tank design was not effectively distributing charge air across the core. So, while defining a core specification is a key part of the process it is just one part of the design and development process. PWR works with its clients on tank design to aid flow distribution and ensure the full face area is used in the most efficient way possible

Coming back to *our* test session, the programme continued through intermediate face velocities to the lowest face velocities used in the session and it was apparent that the charge air outlet temperatures had climbed considerably on the values obtained at the medium and high velocities. And the thermal images also showed higher temperatures on the downwind face of the cooler.

Needless to say the lower velocities used here were intended to replicate the extreme low end of range likely to be seen perhaps only briefly on the race track.

Customers and teams regularly visit the PWR test facility to evaluate the performance of their coolers, benchmarking them against earlier or alternative designs. If a cooler does not perform as well as hoped, with all component parts and manufacturing processes being available on site, a new test item can be manufactured for re-test in a matter of hours.

Iterative process

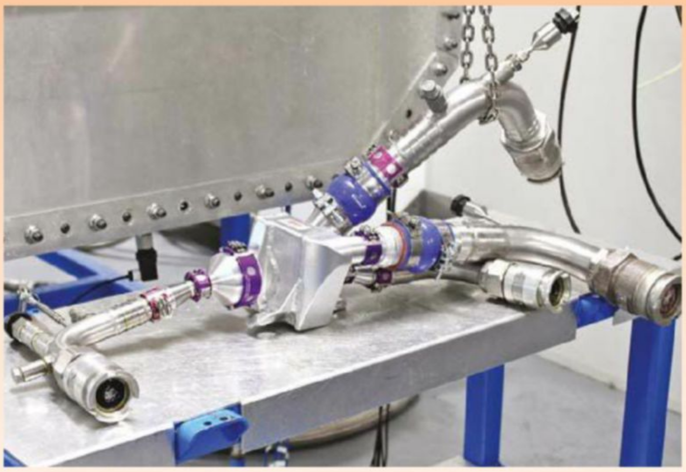
So PWR's engineers not only generate cooler designs using wind tunnel-tested reference samples and data but, in some instances, those designs are evaluated further using the wind tunnel to validate or refine the design. These abilities, coupled with the possibility of making quick physical changes to cooler designs for rapid re-test, quite clearly give PWR's customers a competitive advantage.

coolant pressure drop and air-side pressure drop can all be simulated and monitored. Two heated water circuits, two heated oil circuits, and a single heated charge air circuit are available for system testing, and it is also possible to test multiple cooling components, such as a charge air cooler in front of a radiator, to replicate configurations that are found out in the real world.

The installation and optimisation of the wind tunnel stems from the desire of CEO Kees Weel and engineering manager Matthew Bryson to provide ever more accurate data and predictions for high-end customers. The tunnel is a key tool for PWR and often accommodates customer visits from various categories when, for example, they wish to have further input in the benchmarking of several cores. If required, PWR can modify or build an entire new assembly for test in just a few hours to help with a company's product development.

A wide variety of coolers can be tested, too. After the test on the high end race team charge cooler described in the main article, a large water radiator from a commercial bus was next up, followed by a rally car oil/water heat exchanger, which was not directly connected to the wind tunnel itself – a water radiator matrix that conditioned the water feed to the heat exchanger was cooled by the wind tunnel. So flexibility is the name of the game in this interesting test facility.

PWR can modify or build an entire new assembly for test in just a few hours to help a team's component development



The oil/water heat exchanger being connected to oil and water supplies prior to its test

Oil/water heat exchangers (above) can also be tested here. This one is from a rally car

JC (left) and senior engineer Andi Scott confer on the heat exchanger test; note that the water radiator is connected to the wind tunnel outlet to control the water temperature

Connectivity

Prodrive's quarter of a century in business has encapsulated huge changes in the way computers are used in motorsport. But one thing has remained constant – its strong bond with tech wizard DTE

By DR CHARLES CLARKE

There has been much change and evolution in the computing world, with significant shifts in technology and innovation every five years or so

The Prodrive and Desktop Engineering (DTE) relationship has spanned almost the whole lifetime of both companies, and also a turbulent development period in CAD, CAM and CAE disciplines, in terms of both hardware and software.

Twenty-five years ago we were emerging from the UNIX era when the cost of hardware and hardware support reduced by at least a factor of four. Many lament the passing of the UNIX age, as 'mean time between failure' also went down by a factor of 10 (at least) and the Windows BSOD (Blue Screen Of Death) crept into common technical parlance.

There has then been much change and evolution in the computing world, with significant shifts in technology and innovation every five years or so. DTE, which is based in Witney in the UK, in the heart of the British motorsport business community, has ridden these changes, retooling and training its staff to accommodate evolving trends.

'I founded the business in 1986, with the aim of providing engineering software on personal computers', says DTE managing director, Geoffrey Haines. 'The IBM PC was becoming available at the time and software was being written in the US for this platform.

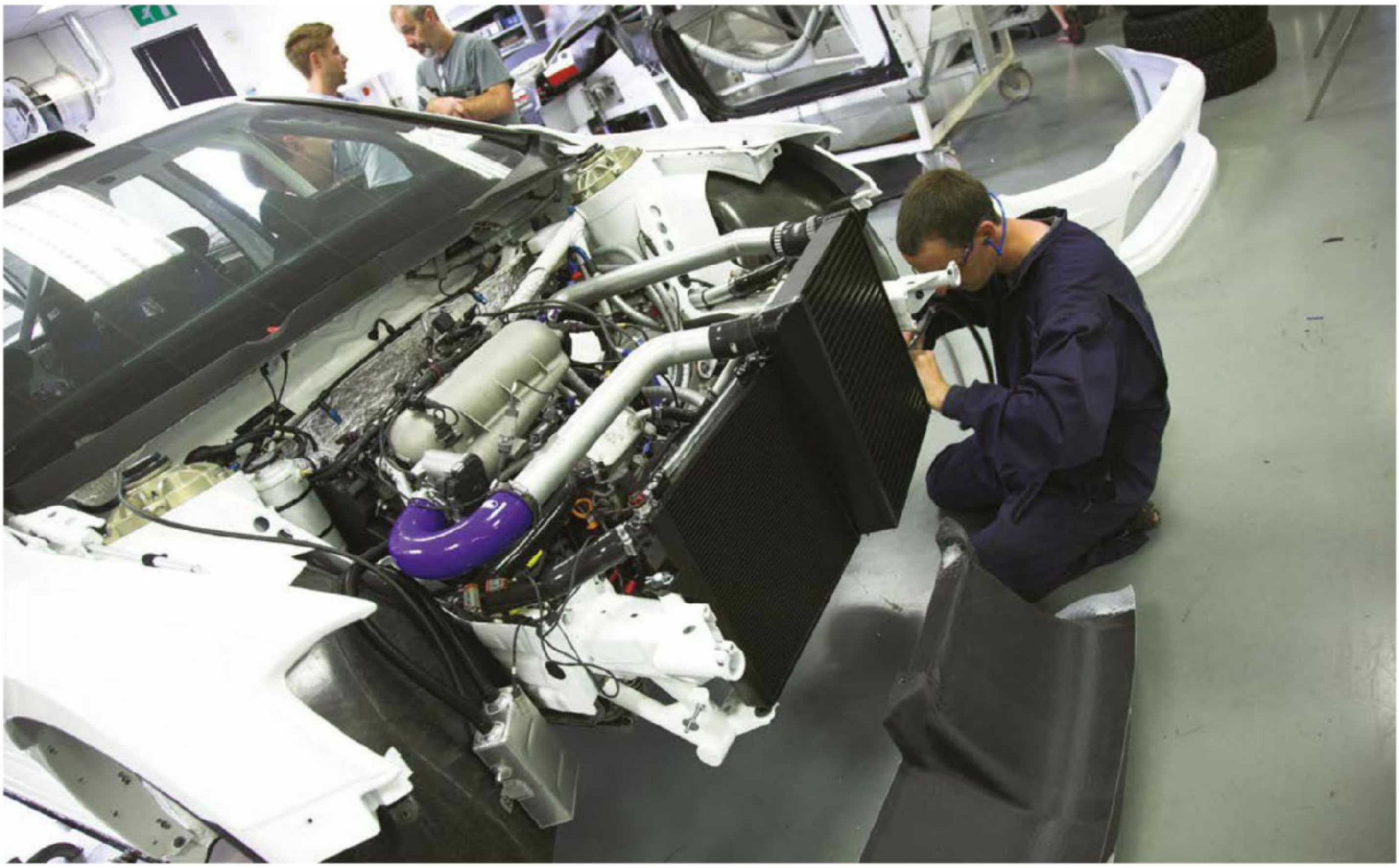
'We started out securing distribution rights to these applications here in the UK and we began with just two of us selling and supporting them. We had started at the early adopter phase of this new market, and quickly grew to be a dozen or so engineers.'

DTE was first approached by Prodrive in 1988, which then became a customer of its 3D surface modelling application, called Personal Designer – which proved to be ahead of the market at that time. 'We've always had a soft spot for Prodrive because they were one of our early customers,' says Haines. '

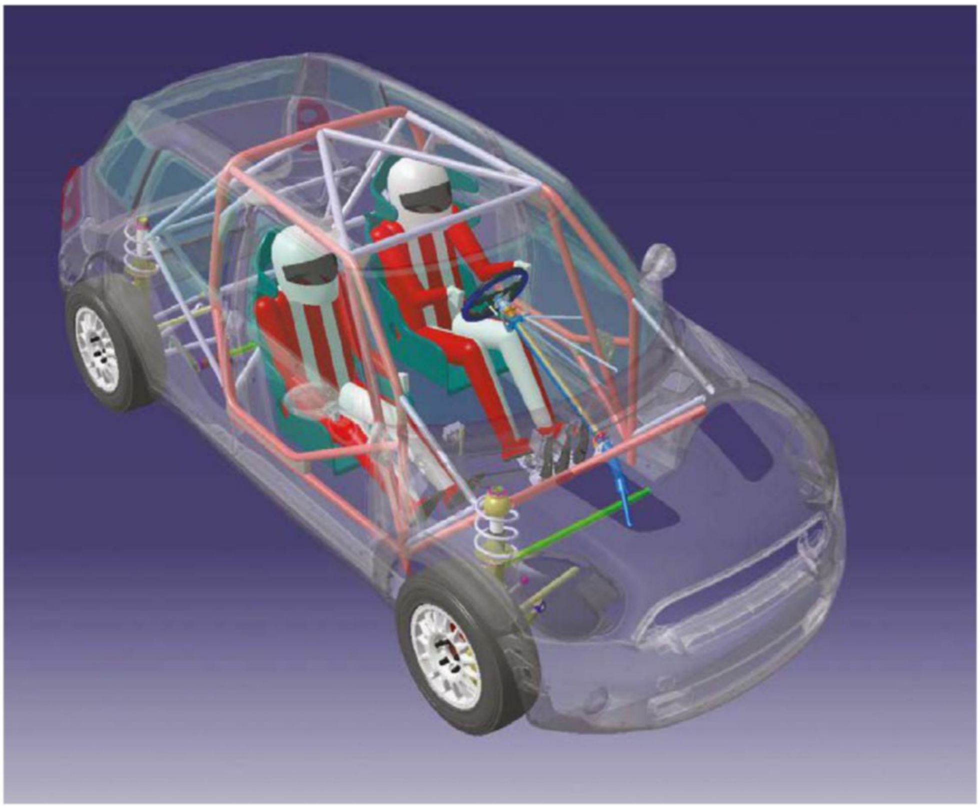
Rapid evolution

The early days of the PC CAD market were very dynamic. With the rapid developments in software technology, new products arrived and existing ones faced challenges almost on a monthly basis. Major upgrades every six months

DTE has been on hand to help Prodrive with a number of its motorsport projects, including its Volkswagen Golf rally car



Tasks begun on 64-bit Windows 7-based workstations are completed in a more hands-on way on the shop floor at Prodrive. CAD now plays a vital part in all of the company's work



CAD rendition of the complex roll cage installation in the Prodrive-built Mini WRC car. Prodrive uses release 19 of CATIA

The design of the wiring harnesses needs the sophisticated spatial manipulation capabilities of modern 3D CAD software

were not unusual. DTE had to keep abreast of these changes ensuring it always had the best, most suitable solutions for its customers.

In software the partnership has witnessed CFD come of age as a meaningful design application. CAD has gone from 2D to 3D, through parametric solid modelling, history based modelling, dynamic modelling, direct modelling and now, The Cloud.

Personal Designer was the first application purchased by Prodrive. It was a 3D surface modelling and drafting package, developed by Computervision as the 'little brother' to its high end CADDS software, used by most of the automotive industry at the time. Although it ran on PCs, it enabled designers to truly visualise their designs. It was this that influenced Prodrive's decision to use it.

Subaru influence

The next evolution came in 1991 with workstations, led at first by Sun Microsystems. This brought the cost of hardware down considerably and also provided improved performance. Prodrive followed this evolution and purchased CADDS5, the latest high-end application from Computervision. DTE had by now evolved its business to offer this high end, high performance technology, which offered 3D parametric design – a key enabler for improved design productivity at the time.

The purchase of CADDS5 was actually heavily influenced by Subaru – Prodrive was then running the Subaru WRC team, one of its

Prodrive is developing into a world-beating general engineering services consultancy serving the wider automotive industry

Having access to 3D geometric data of the roll cage, accurate to fractions of a millimetre, is essential to the build process

more famous motorsport collaborations of the 1990s, and in to the 2000s.

The technology drivers shifted in the late 1990s to CATIA from Dassault Systemes – an integrated software platform marketed worldwide by IBM, delivering design, analysis and drafting in one package. At about this time, the high-end engineering software market was consolidating into two or three main players – CATIA among them.

'Prodrive uses release 19 of CATIA,' says Enrique Goddard, Prodrive's CAD and PLM (product lifecycle management) specialist. 'CATIA is quite good at translating from other CAD systems, but like-for-like [native] data is always quicker. There is lots of manufacturing on site, so the links from CAD to manufacturing are of prime importance. Suppliers and subcontractors also manufacture from DXF files generated by the ProDrive CATIA system

'A lot of people also use a CATIA add-on that is called Q-Checker, which is a methodology based tool which makes sure you are sending the right information to the right people,' Goddard adds. It sounds very useful.

Hard drive

All the CAD work is done on 64-bit Windows 7-based Dell workstations with nVidia Graphics cards and Prodrive has a multi-node LINUX cluster for the CAE and simulation work. 'The support from Dell is really good,' says Goddard. 'We are currently on four-hour support, but they routinely turn up much quicker than that.'

Prodrive uses HyperMill from Open Mind for all its CNC work as well as Vericut from CGTech for simulating and checking tool paths.

HyperMesh and HyperWorks from Altair are used for CAE as well as Abaqus, a non-linear product from Simulia, another Dassault Systemes software platform. It also uses Simpack, which is a general purpose Multi-Body Simulation (MBS) tool used for the dynamic analysis of mechanical or mechatronic systems, again from Dassault.

'We don't really have any issues with the software products,' Goddard says. 'The help files are good and we've always got DTE as backup when we can't figure things out. They are very local and are very reactive when we have problems. It's a well balanced partnership. We have very capable CAD engineers here, but the systems are so complex they sometimes get to a point where they need outside help or just another pair of eyes.'

Paper view

Prodrive still produces drawings, although quite a lot of the OEMs are using 3D documentation on the CAD models and phasing out paper

Prodrive case study: Subaru WRX STI TT Attack

Prodrive is certainly not averse to taking on unusual motorsport projects. 'As well as our World Rally and sportscar groups, we occasionally do one off-cars,' says Enrique Goddard. 'Most recently we built the Subaru WRX STI TT Attack car which is a very special Time Attack type vehicle which recently secured the Isle of Man TT course lap record.' The car was sponsored by Subaru USA, which tasked Prodrive with building the ultimate WRX. It was based on the running gear from a Prodrive 2008 World Rally Car, but with a bigger turbo producing 600bhp and 800Nm of torque, it also ran on Dunlop slicks. Three-time British Rally champion Mark Higgins smashed his own Manx TT course record with a 17m25.139s – an average speed of 128.730mph – in the Prodrive-built super Subaru.


Factory R&D

‘Drawings are still used on the manufacturing floor and in the inspection departments’

XPB

Prodrive-run Subaru Impreza WRC in 2003. It purchased CADDS5 on the recommendation of the Japanese manufacturer

drawings. ‘Drawings are still used on the manufacturing floor and in the inspection departments,’ says Goddard. ‘With the best will in the world it is very difficult to replace drawings in a manufacturing context. Sometimes you just have to get a very big drawing and spread it out on the bonnet. Drawings are also a fundamental part of the wiring harness lay-up process.’

Beyond motorsport, Prodrive is now also developing into a world-beating general engineering services consultancy serving the wider automotive industry, so having industry standard software is vital. DTE identified the need to change, to move to a relationship with Dassault and support this software that was fast becoming standard in automotive and aerospace markets. It was inevitable that Prodrive then looked to DTE to help them with this new platform.

Prodrive prep

Although probably best known for its relationship with Subaru and WRC, Prodrive achieved prodigious success as a motorsport constructor and developer. The list of its achievements would fill pages, but suffice to say there aren’t many years over the last 27 that did not include wins and championships in WRC, BTCC, Sportscars and Endurance Racing in Europe, the USA, Australia and China.

In developing a World Rally Car, to use just one example of its work, the Prodrive process is to take a standard production car bodyshell from the factory, strip it back to bare metal in an acid bath and reinforce it to take World Rally punishment. This involves modifying and strengthening the suspension turrets to take the specialist spring and damper assemblies that help the car grip the road and respond to the impacts that the rally stages impose on the car at speed. It also involves bracing the turrets and incorporating them into the custom roll cage that provides more overall stiffness and torsional rigidity to the rally car.

Having access to 3D geometric data, accurate to fractions of a millimetre, is essential to this modification process, and having access to ‘native’ 3D data from the original car manufacturer is a vital component in streamlining the process to produce design modifications as fast as possible with zero defects – watchwords in the motorsport industry. Industry standard software is the only way Prodrive is able to do this.

Custom build

Alongside the stiffening of the body and the suspension turrets, there is extensive customisation required to turn a road car into a rally car. Custom location for the steering column and pedal box; custom pick-up points for the sequential transmission levers and handbrake; custom fuel tank location; provision of optimum location for the Mil-spec wiring

Prodrive case study: VW Golf SCRC

In 2014 Prodrive developed a new rally car based on the Volkswagen Golf – the Prodrive VW Golf SCRC – specifically for the Chinese Rally Championship. This was designed to compete in championships that run open class type regulations for 2-litre turbocharged cars with four-wheel-drive. The car now competes for the FAW VW Team in this series with Prodrive support.

The car is based on the VW Golf Mk VII five-door bodyshell and has been built to the spirit of the World Rally Car regulations. It includes many of the proven systems and concepts from previous Prodive Rally Cars, such as Xtrac gearbox and differentials and AP Racing brakes, as well as a roll cage and safety features that encompass the latest FIA standards.

Many of the standard Volkswagen steel body panels were retained with flexible composite front and rear bumpers and wings. A Prodrive designed carbon composite rear wing completes the aero package.

As said, initially it was built to the Chinese Rally Championship regulations, but it can readily be modified to suit almost any open class type championship in the world. Its engine is also already used successfully in rallycross and the car could be re-engineered to FIA World Rallycross regulations and for the GRC (Global Rally Cross), as was the case with the Prodrive Mini RX.

Major software upgrades every six months were not unusual

harness, brake lines and fuel lines. All these processes rely heavily on accurate 3D data and fast and effective software.

The design of the wiring harnesses needs the sophisticated spatial manipulation capabilities of modern 3D CAD software – there's no point trying to get a bundle of 30 wires into a space too small to accommodate it – and feedback on bend radii, as harnesses, hydraulic and fuel lines are threaded through the virtual body structure, is vital.

Engines, transmissions, suspensions and brakes tend to be outsourced, but to Prodrive's design. Again having access to native CAD data that virtually all its suppliers and subcontractors use and generate is essential to meet the insanely short time-scales in motorsport.

XPB

Prodrive's motorsport business includes running the works Aston Martins in GTE while it also supplies GT racecars to customers

Considered change

In motorsport, the last thing you need is for everything to keep changing constantly. As CAD/CAM and CAE are only tools, motorsport engineers need the fastest and most effective of each, but they don't want them continuously upgraded or changed unless that upgrade shaves time off the process or improves accuracy. This is where DTE comes in. One of its most important roles is to supply the best solution in an appropriate manner for the team to do what it does most effectively. It's DTE's job to evaluate new trends and manage their introduction where and when appropriate. 'Over the years we have had to make key decisions on which software developer to partner with,' says Haines. 'Always considering our existing customers and the relevance of the new software changes to their businesses.

'It is significant that all this time Prodrive has listened and moved in the direction we headed. Their loyalty and belief in our choices is an endorsement to their commitment to their suppliers – treating them as partners rather than just mere suppliers. During this period, we have moved through three major changes in technology – all of which Prodrive endorsed and implemented,' Haines says.

Prodrive, during the same period, has gone from a one-make rally car builder to a global general automotive consultancy and sportscar builder with Formula 1 interests.

'We always look to our software suppliers as key to our advancement,' Goddard says. 'In this period of our company's growth we have all faced many changes and challenges, and DTE's leadership and support has always been second to none and hence our long relationship is a testament to these values.'

Power house

Prodrive has recently moved from its original premises adjacent to the M40 to a new purpose-built site nearby. Although not quite as conspicuous as its old building the new headquarters can still be seen from the M40.

The new HQ is home to both its Motorsport business, which runs the Aston Martin Racing team as well as the VW Golf in rallying, and its Advanced Technology division, which works with businesses in the automotive, aerospace, defence and marine sectors. In the new facility, race and rally cars are built alongside advanced active aero systems for supercars, centre console modules for luxury cars, and the latest control systems for electric vehicles.

'This is the beginning of a new era for the company,' Prodrive chairman David Richards said when the facility was opened. 'For the first time all of our motorsport, advanced technology and manufacturing operations will be under one roof in a modern purpose-built facility. This will enable us to operate far more efficiently and to increase the collaboration and technology transfer between our businesses.'

Prodrive's Advanced Technology business employs around 300 staff and develops new technologies and systems for clients, which include Jaguar Land Rover, McLaren Automotive, Bentley, and Airbus Defence and Space.

The company also has a carbon composites manufacturing facility in Milton Keynes, UK, making lightweight components for premium vehicle manufacturers and the aerospace industry. Advanced Technology represents about 50 per cent of the Prodrive Group turnover.

Prodrive is also working with the Land Rover BAR team to help develop its America's Cup challenger. It is an Official Technical Supplier and, amongst other areas, has developed the control systems for the foils, which help the boat to 'fly' out of the water.

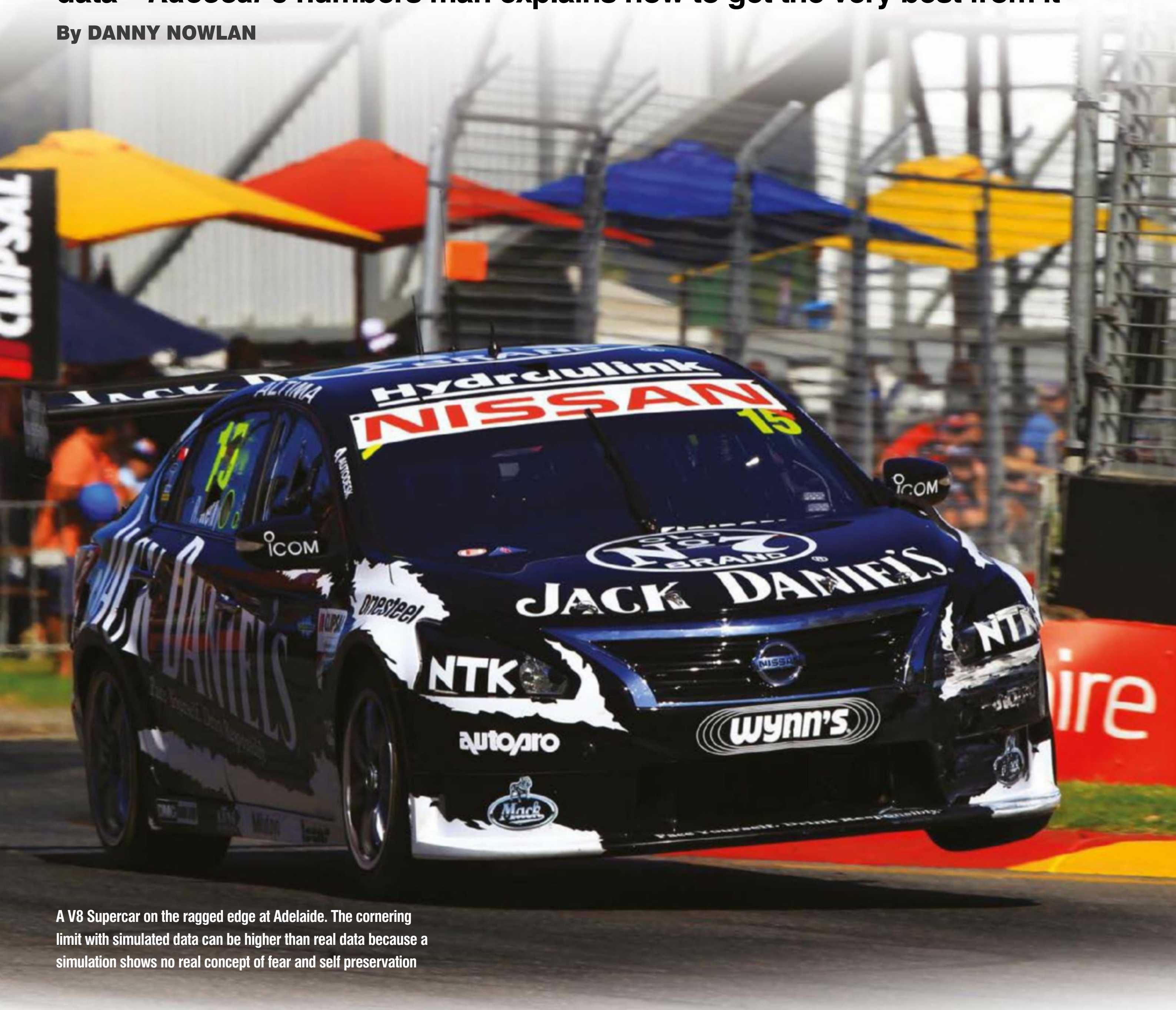
Other examples of Prodrive's work include the design and manufacture of the active aero system and the composite bodywork and interior trim for the McLaren P1 supercar; the development of a highly efficient DC-DC converter for electric and hybrid cars, and the manufacture of the centre consoles for the Range Rover Autobiography Black.

The white house: Prodrive moved in to this new facility last year. It houses the motorsport programmes and the Advanced Technology group

The data day

There's a real skill to reading, digesting and understanding simulated data – *Racecar's* numbers man explains how to get the very best from it

By DANNY NOWLAN



A V8 Supercar on the ragged edge at Adelaide. The cornering limit with simulated data can be higher than real data because a simulation shows no real concept of fear and self preservation

One of the biggest misconceptions with racecar simulation is how you look at the data it returns. In particular, the context it needs to be taken in. This was best summarised by ChassisSim's Australian Dealer, Pat Cahill, who said the real trick to using simulated data is that you have to look at it with a slightly different lens than actual data. It was a profound observation, because this is one of the biggest sticking points that I have seen when people employ simulation to engineer their cars. So, how to look at simulated data and what to focus on will be the focus of this article.

Let me also state that what we are about to discuss is not theory. The lessons I'm about to present to you here have been hard won through many years of practice in the ChassisSim community, looking at what counted, but more importantly what didn't.

The first thing to understand about using simulated versus actual data is that the changes with the former will be much smaller than actual data. This is for two primary reasons:

- **Your simulator always knows just where the grip is.**
- **The simulator has no concept of its own mortality.**

These are the key reasons actual data will always show more variation than its lap time simulated counterpart. One of the corollaries of this is that simulated changes will show up primarily as corner speed variations. To

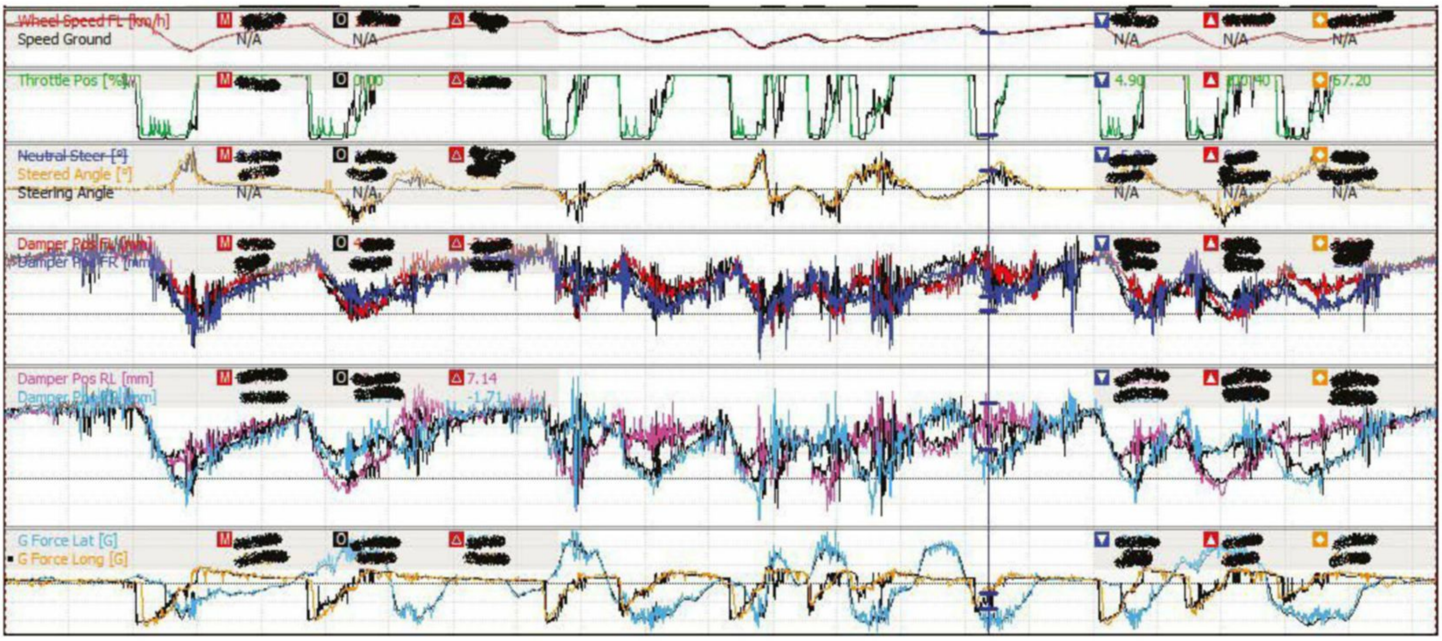


Figure 1: Customer correlation using 2D tyre model. This was from a high downforce racecar with a speed range spread of 80 to 300km/h. The grip is represented well everywhere

understand this we need to have an informed discussion about what we get from a tyre model. To start we'll use a simple second order Traction Circle (TC) radius *vs* Load curve, so we can get some very good correlation right across the speed range of the car. The correlation in **Figure 1** is a very good case in point.

As always, actual is coloured and simulated is black. This was from a high downforce car with a speed range spread from 80 to 300 km/h. As can be seen in the speed trace the tyre model has represented the grip very well everywhere. This means we have done a very good job of representing what the car was doing at that particular set-up condition. This is also represented in **Equation 1.** At this point in the game most people would pat themselves on the back and say 'job done.'

DeV8ted data

However, there is a flip side to this and to flesh this out let's illustrate it using some typical live axle V8 Supercar numbers. Some typical set-up values are shown in **Table 1**, while a representative two-dimensional tyre model for a V8 supercar is shown in **Table 2**.

Now that we have this information to hand, let's explore some set-up sensitivity parameters. One big change in a live axle V8 Supercar is with the rear roll centre. Typically, a 10mm change will produce a measurable difference. To keep things simple let's apply a lateral acceleration of 1.4*g* and use this to estimate tyre loads and the corresponding cornering force. The results are shown in **Table 3.**

What has been presented in **Table 3** is a very simplified analysis. We are simply taking a static weight and applying a load transfer to it for a typical low speed corner. However, what is really revealing in **Table 3** is that while the speeds are representative the magnitude of the change is very small. With the 10mm rear roll centre change, the tyre loads have changed by a mere 3kg, and the speed has changed by 0.2km/h. Yet, in practice, on the racecar you will typically see a change of 0.4 to 1km/h. In reality the truth is somewhere in the middle, but this does illustrate that just because you get good correlation it doesn't necessarily mean you will have huge set-up sensitivity.

True grip

What this example shows very clearly is that in terms of absolute grip, which is where simulators live, you don't get huge variations with set-up changes. In fairness, a 2D traction circle radius *vs* load model doesn't represent the subtle temperature changes in the tyre that will increase this sensitivity. However, if we factor this in with the case above it might go from 0.2km/h to 0.4km/h. This is why, with a simulation, you will primarily be looking at corner speed variations.

To understand the difference between actual and simulated data, it is best to illustrate it with an example of two simulated set-up changes. This is shown in **Figure 2**. The baseline is coloured, the simulated change is black. Note the illustrated cursor point where the difference is 138.9 km/h *vs* 141.3 km/h. Also note the subtle changes in throttle and steer applications as well. Now some of you might react and say a real car would never do this. In response to this, look at the correlation we

EQUATIONS

EQUATION 1

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

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

Where:

F_y = Maximum possible force (N)

k_a = initial coefficient of friction

k_b = drop off of coefficient with load (1/N)

F_z = load on the tyre (N)

L_p = Load at which maximum grip is generated

Table 1 – Typical V8 Supercar set-up

Parameter	Value
Front roll centre	100 mm
Rear roll centre	240 mm
Front Wheel rate	60 N/mm
Rear Wheel rate	60 N/mm
Front bar wheel rate	40 N/mm
Rear bar wheel rate	10 N/mm
Front track/Rear track	1.6m/1.6m
Front tyre spring rate	305 N/mm
Rear tyre spring rate	305 N/mm
c.g height	0.45m

Table 2 – Representative two-dimensional tyre model for a V8 Supercar

Parameter	Value
Initial co-efficient of friction	2.2
Peak Load	850kg

The real trick to using the simulated data is that you have to look at it with a slightly different lens than when you're looking at actual data

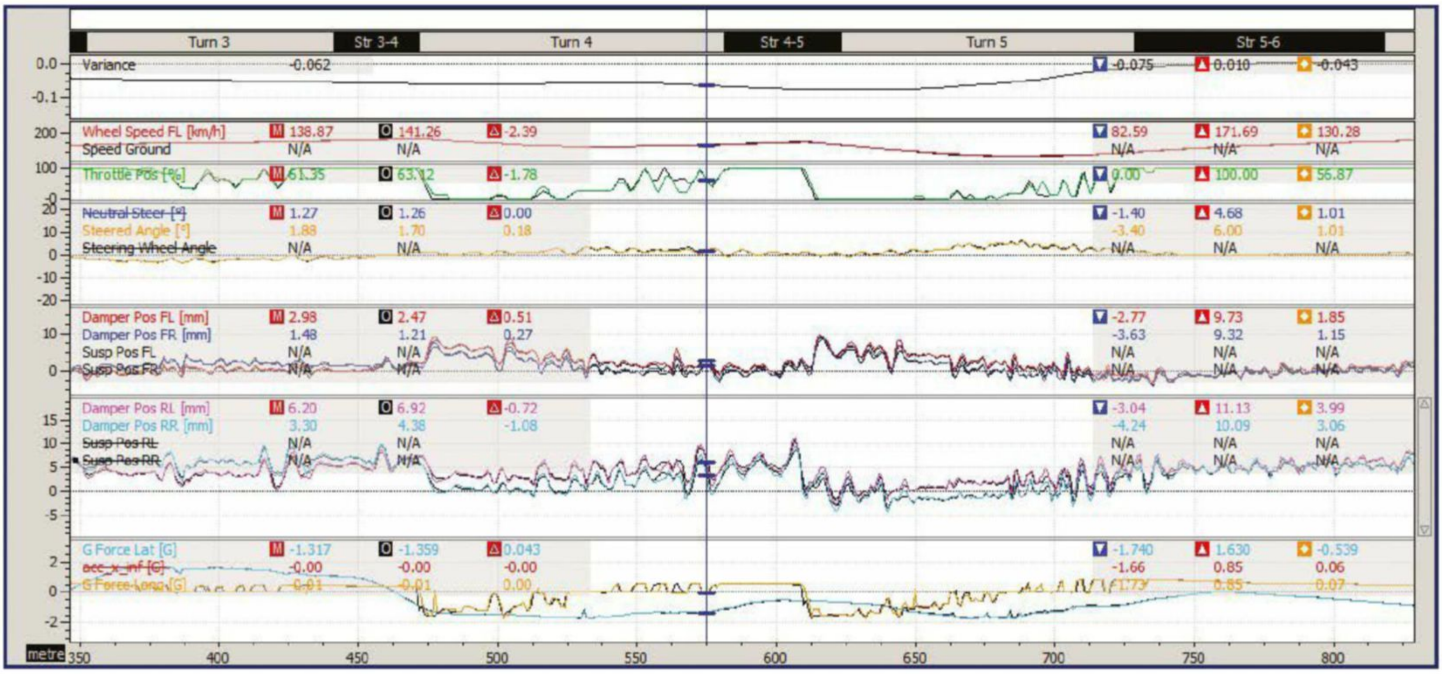


Figure 2: The differences between two simulated set-up changes. Note the subtle changes in throttle and steering applications. But would a real racecar ever behave in this way?

Table 3 – Predictive numbers for a rear roll centre change

Set-up	Load FL	Load FR	Load RL	Load RR	FyR	V_pred
RRC 240	674.96	133.82	694.58	54.47	9993.5	81.47
RRC 250	671.61	137.16	697.93	51.1	9938	81.27

All Loads are shown in kg, the lateral forces are shown in N and V_pred is in km/h.

Table 4 – Magnitude of speed changes to the severity of the set-up change

Change Delta	Severity
0.1 - 0.2 km/h	Mild
0.2 - 0.6 km/h	Moderate
0.6 km/h +	Severe

EQUATIONS

EQUATION 2

$$m_t \cdot a_y = m_t \cdot V_x^2 \cdot iR$$

Where,
m_t = Total vehicle mass (kg)
a_y = Lateral acceleration (m/s2)
V_x = Mid corner speed (m/s)
iR = Curvature (1/m)

The key questions to ask here are, what sort of magnitudes are you looking at, and what trends should you be seeing?

achieved in **Figure 1.** This was throughout the speed range. Then, if we take a look at a small change you'll see mathematically the tyre simply does not have the sensitivity to pull off a grip change in the order of 3 to 4 km/h. If you can comprehend this you are well on your way to understanding how to use simulated data.

So the key questions to ask are what sort of magnitudes are you looking at and what trends should you be seeing? To help guide you through this **Table 4** is an example of some simulated trends I've seen over the years.

Cross referencing back to our V8 Supercar example, you'll see this is entirely consistent with the example we presented. You can also illustrate this in a mathematical way. So, at the mid corner condition, we have **Equation 2**.

Take this example, at 100km/h and an acceleration of 1.4g for the V8 Supercar above, figure out how much the tyre forces need to change to produce a 1m/s speed differential. The answer will be most revealing.

Consistent changes

The other trick to looking at simulated data is that you are looking for small and consistent changes. This is illustrated in **Figure 3.**

The key here is to look at your 'compare time' plot. What you are after here is small and consistent changes. If you get a big spike, chances are the simulator has tripped over itself and that should be an instant red flag. If you have small and consistent changes you put this set-up change on the car. This also illustrates another key point, that you must always log and critically review your simulated data.

The other thing I need to touch on here is what sort of effort you need to make in correlating the simulator to data. This is actually a really important topic, because I have seen race and performance engineers waste months and months on this. **Table 5** shows some rough rules of thumb that have worked well within the ChassisSim community.

Perfect correlation

Remember, a lap time simulator is a closed loop solution. Consequently, in order to get perfect correlation your tyre model and driver has to be spot on. If you don't recognise this then you will waste a truck-load of time. Let me tell you a true story to illustrate this point.

About six years ago I did some modelling work for a race team. I performed all the ChassisSim modelling and while the trends were great they were consistently 1 to 2 km/h quicker than the actual driver. I then made a critical mistake. I trusted the racecar driver. Anyway, they got to their first race meeting and got blown away. In a move of exasperation or desperation I was given the data of the frontrunner and it matched the original tyre model perfectly. The moral of the tale is don't get carried away with perfect correlation.

The exception that proves this rule is ovals. On an oval, because the car is loaded for a fair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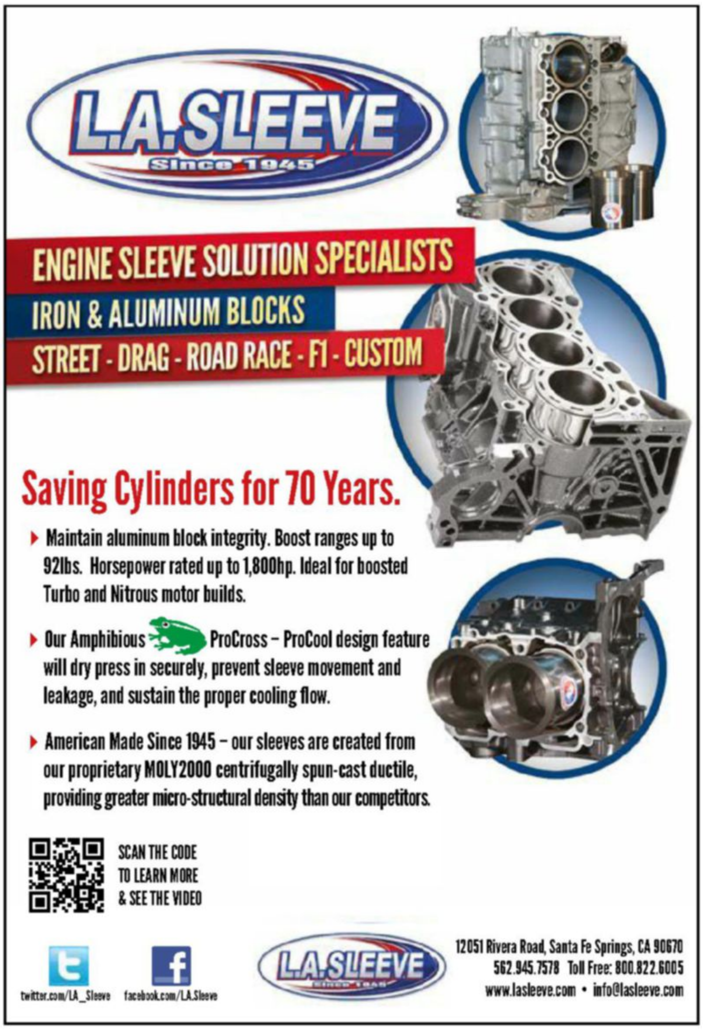
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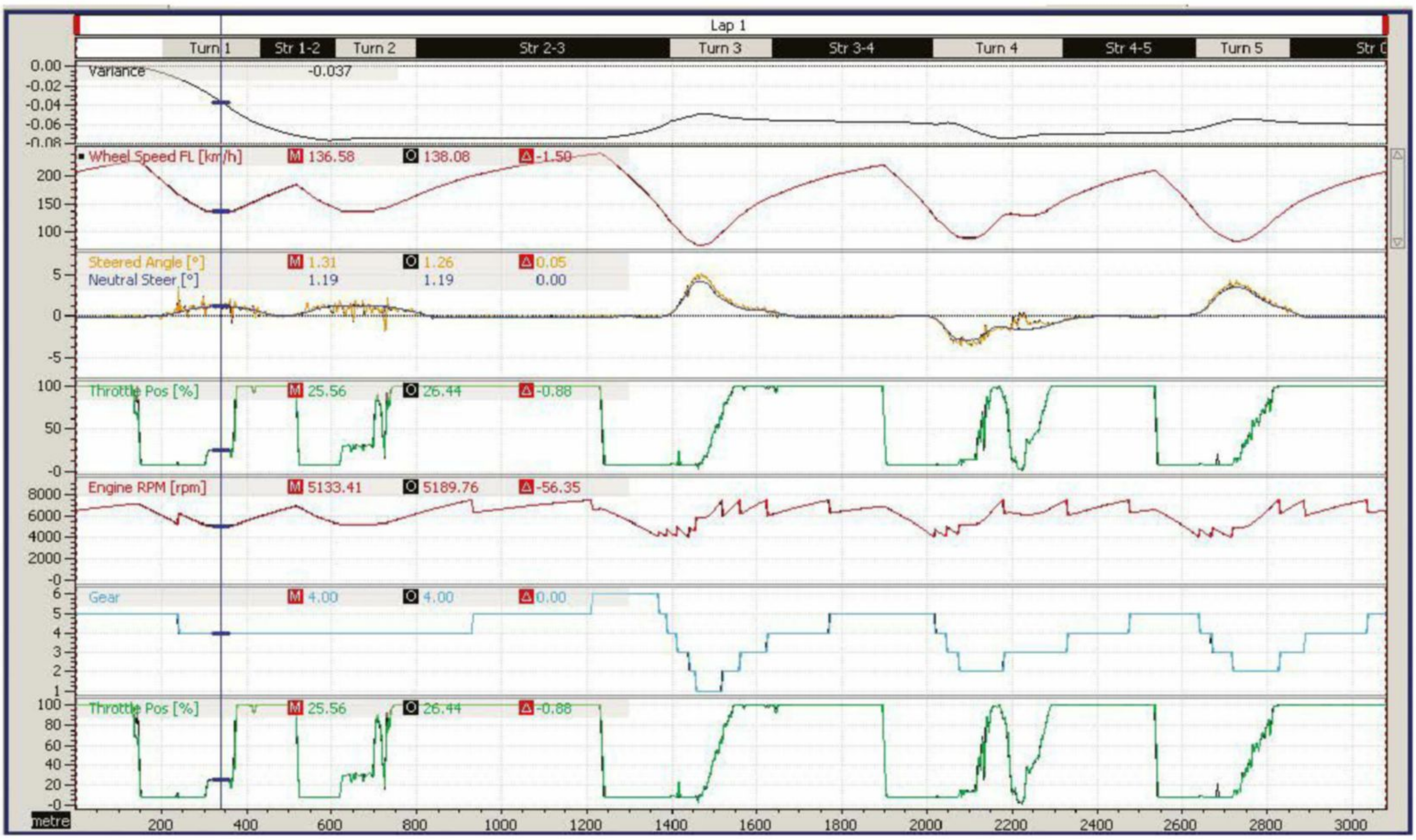

Figure 3: This is an example of a good simulated change – when evaluating the simulated data it is important that you are looking for quite small and also consistent changes

Table 5 – Rough rules of thumb for lap time simulation correlation

Corner speed	Delta
80-120 km/h	1 – 2 km/h
120-160 km/h	2 – 3 km/h
160 km/h +	3 – 4 km/h

Table 6 – Results of Lateral load transfer *vs* the stability index

Lateral Load transfer	Total lateral force (N)	Projected front slip angle (deg)	Stability index
0.1	21952.64	4.24	0.162
0.2	22264.4	4.42	0.13
0.3	22479.4	4.6	0.09
0.4	22597.6	4.80	0.05
0.5	22619.05	5.01	-0.00291
0.6	22543	5.24	-0.072
0.7	22371	5.51	-0.166
0.8	22102.6	5.8	-0.303
0.9	21736.9	6.14	-0.524

percentage of the corner, matching the tyre loads takes priority. Consequently you need to get the corner speeds within 1 to 2km/h at least. This is particularly pertinent for tracks such as the Indianapolis Motor Speedway, or superspeedways like Daytona and Talladega, which are all high speed circuits.

Trial and error

The other thing I'll say about correlation is that it is a consequence and not the end goal. When I teach novice ChassisSim users tyre modelling and in particular how to use the ChassisSim tyre force modelling toolbox, I always tell them it takes three to four iterations to get the tyre model right. This is because different circuits subject the tyres to different loads and you need to model this first. If you do this job right, the correlation that ChassisSim is well known for comes as a consequence. So don't chase your tail here. I can't speak for other simulation packages, but for ChassisSim if you do your modelling work properly the correlation comes as a consequence, so don't waste months on it.

To wrap up this discussion it would be worth touching upon one of the things I mentioned in my previous article on the magic number (*RE* V26N9). Take a look at **Table 6** to see just how the total lateral force varies as a function of lateral load transfer and also how the stability index varies.

Note that the lateral force varies by 1000N or four per cent, but there is a huge spread in the stability index. This illustrates the point that the simulator gets you into the ballpark, but you will always have to do some more tuning at the race track to dial it in for what the driver needs. Always keep this in mind.

A data remember

In closing, the key to using simulated data effectively is knowing how to look at it and interpret it. Remember, the changes will be a lot subtler and will show themselves up as corner speed. Also, bear in mind that you are looking for small and consistent changes. If you can understand this, and understand that correlation is a consequence and not the end goal, then you are well on your way to using simulation as a powerful tool to get the very best out of your racecar.

In order to get perfect correlation your tyre model and driver has to be spot on. If you don't recognise this you will waste a truck-load of time


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Bath's time

Team Bath Racing has made British Formula Student history by chalking up an outright win outside the UK with its TBR16. We reveal the secrets of this very neat little racecar's success

By JOSH KRUSE and SAM COLLINS

In the Czech Republic recently the University of Bath's Formula Student team achieved something no other British team had ever done – it won an FSAE competition overall. Team Bath Racing, as the students have branded the outfit, has been a very strong outfit in recent years, missing out on the podium at Formula Student UK by just a single point for two years running, but an overall victory had proven elusive. And while Formula Student Czech is a relatively new second tier competition, it is still a major achievement to take the overall victory.

The 2016 Bath car, the TBR16, made its official competition debut a few weeks earlier at Silverstone, and while clearly a well funded and well engineered project it bucked the trend towards electrification of the powertrain. 'Our approach was to think about the resources we had available to us in terms of personal and experience and the first decision making process was: do we go for an electric car or a combustion car', team leader Noel Moorhouse says. 'Obviously coming to the UK event that's a massive decision because you're competing directly against the other powertrains so you really need to consider your options. We made concepts for both electric and combustion and the question we asked ourselves was what could we feasibly build? And what could we build that would put us in the best place to allow us to go for the win at Silverstone. In the end we went for a combustion car, just based on the people that we had available to us and the infrastructure of the university.'

ICE Bath

Opting to take the combustion engine route the Bath students selected the 510cc KTM EXC engine, something more commonly found in offroad motorcycle competition. 'We've gone for a single cylinder engine which is inherently reliable, it's from an enduro bike so it's used to being ragged about on the limit; we had a lot of trouble with reliability before so that was a big push for going for that. It's also a lighter weight than the engine we were using before, so with that engine, using a custom turbocharger, using E85, we get about 75bhp', Moorhouse says.

Getting the most out of an engine for a FSAE competition requires that the students do some major development work on it, and that is exactly what the Bath team has done, and they have opted to utilise everything they can, including the natural characteristics of the fuel. 'We've got a system called pre-compressor injection functioning,' Moorhouse says. 'Basically it utilises the high latent heat vaporisation of ethanol fuel to cool the intake charge before it enters the combustion chamber, and that gives you effectively the benefit of an intercooler but without using an intercooler. So we don't have the same mass drag increased intake length that that would give you. We've managed

After missing out on a podium at the Silverstone FS competition (pictured) by just one point for two years running the Bath University team's success in the Czech Republic event was well-deserved

The TBR16 bucked the recent Formula Student trend towards electrification of the powertrain

The Bath car has been designed to run with either unsprung aero or sprung aero; the latter shown here at Silverstone. Major aero elements are the big wings fore and aft plus a neat rear diffuser. There's a tube chassis at the rear, a tub at the front

to get rid of all those negatives but still have the positives of increased charged entity and higher volumetric efficiency.

'We've done lots of dyno testing, we have the pre-compressor and across the operating range it gives us about a five per cent torque increase which is a decent amount, especially in this Formula Student event where low end grunt is quite important, especially coming out of corners,' Moorhouse adds. 'That was one of the big reasons for going turbo in the first place, the KTM in standard trim has got a very peaky power curve, so the driver feedback was that our turbo version was far more driveable at the low end so it gave them confidence. Peak torque is about 62Nm at 8500rpm and we would get 80 per cent of peak torque from about 45000 up to 9000, so a really nice, flat driveable curve. We've got the drive-by-wire throttle functioning as well quite nicely, so you can map the pedal position so actually it doesn't give the exact linear response to the throttle, but it gives a torque linear response, so the driver gets exactly what he's expecting from the pedal. We haven't implemented it, but would have liked to have done auto-blipping on downshift and increase the driveability from that. On the skid pad event we're able to limit the throttle travel so the pedal can go full travel but only gives you 20 per cent throttle, and it gives you much higher resolution in the pedal, so you can control the car far easier and keep it on the limit. The driver feedback from that was really positive.'

Bath tub

The KTM engine is mounted to the rear chassis of the car, a tubular steel construction, while the front chassis is a carbon fibre monocoque. The whole car tips the scales at 180kg. The suspension on the car appears at first glance to be fairly conventional, especially compared to some of the exotic solutions used by a number of other teams in 2016 (see *RE* V26N9). It is double wishbone all round with pullrod actuated front spring/damper units and pushrod actuated at the rear.

Soap and glory

Moorhouse says: 'We looked at all of the options available, right back down to going to MacPherson strut or other concepts, but in the end we chose to go with a double wishbone. Double wishbone gives you good camber control in bump and rebound, without the complexity multi-link suspension would give you, so it's kind of a good in-the-middle place to be. We have a pullrod layout at the front and that gives us a good centre of gravity, the dampers are quite heavy components and we managed to drop them right down underneath the chassis. It also means we can do things with motion ratios with the bell crank, so we can get progressively higher damper rates as

‘The centre of pressure is pretty much where the centre of gravity is’

suspension travel grows. We can also package the anti-roll bar quite nicely underneath the chassis, it’s quite a tidy way of doing it.

‘We went for a pushrod layout at the rear,’ Moorhouse continues. ‘The reason we couldn’t go pullrod was mainly down to the packaging, finding the room to house the damper itself underneath the car when you’ve got the whole engine compartment, and being able to get the motion ratios we wanted meant that we needed some giant bell cranks, and it just wouldn’t have fitted. So pushrod was simply the best option, despite the slightly higher centre of gravity,’ Moorhouse explains.

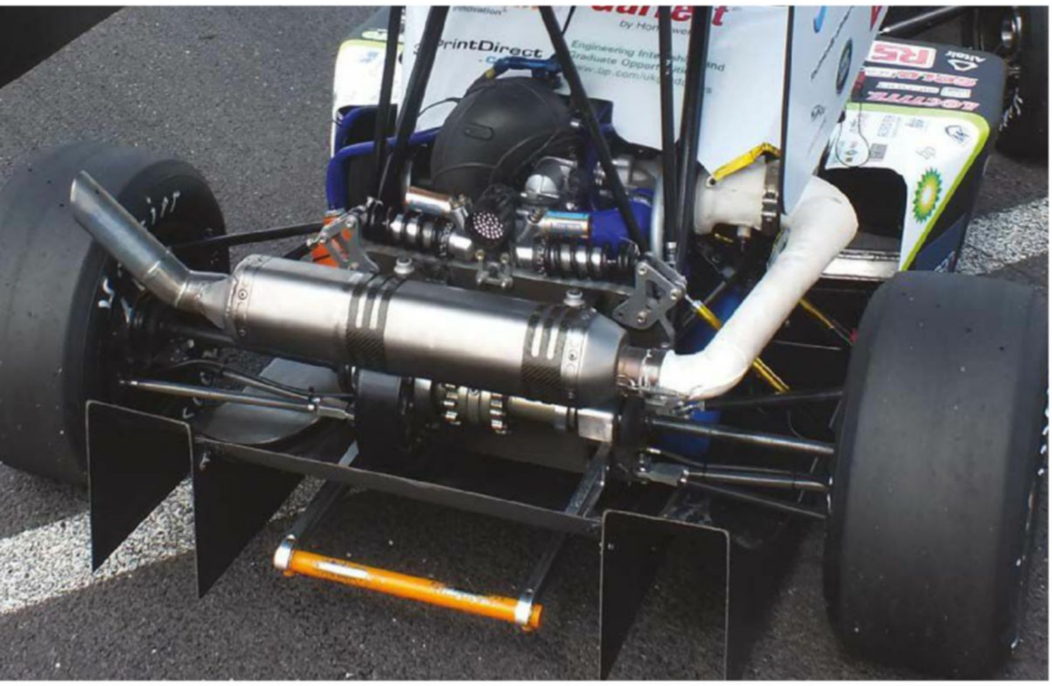
Aero wash

One major aim for Team Bath was to get the car ready early to leave plenty of time for testing. As Moorhouse reveals, it is lucky they did. ‘The car was running mid-May for the first time, and that was chassis and powertrain but no aero. We got a decent amount of testing, then mid-June we had a wishbone failure. It broke completely. We did a proper analysis, saw what went wrong, and made sure we fixed the root causes of the issue. It took a couple of weeks. It was a full front suspension redesign and a front suspension manufacture, so that ate quite a lot into our plans for testing, but we fixed it and came back out again, and the car has held together.’

A recent trend in FSAE globally has been towards optimising the aerodynamic package of the car and Team Bath has benefited from full scale wind tunnel work at MIRA. The result is a car which features big front and rear mid wings. ‘We completely revisited the aerodynamic design for this year,’ Moorhouse says. ‘We started from scratch and reviewed the options that were available. As this class allows it, we had a big drive to explore unsprung aero, so mounting the aero devices straight to the wheels rather than via the chassis allowed us to use softer springs and get better mechanical grip without having to allow for downforce and the effect it has at high speeds.’

But Moorhouse also admits that not everything went to plan: ‘We had the contingency in place to run with sprung aero, which is what we used at Silverstone. So our aero has been designed for almost both factors, which is a compromise, but it’s what we had to do to allow us to be [at Silverstone]. It’s a case of front and rear wing, and balancing the two with the diffuser, so we have the centre of pressure pretty much where the centre of gravity is, and you get a nice balanced car from that.’

The team opted for a conservative approach to the suspension, reasoning that a double wishbone layout gives good camber control in bump and rebound without the complexity of multi-link suspension. It’s pullrod up front and pushrod at the rear



Bath chose a turbocharged internal combustion power unit over electric. The engine is a single-cylinder 510cc KTM EXC, more commonly found propelling an enduro race bike, and it was chosen because of its light weight and proven reliability

Cold Bath

Keeping the KTM 510cc engine cool was also a factor to consider, especially considering that during the 2016 event the track temperature at Silverstone exceeded 40degC. ‘We spent a lot of time looking at that, with CFD mainly, looking at different shapes and positions of things, making sure we get enough cooling into our radiators while not disrupting too much flow,’ Moorhouse says. ‘The radiators are in the two sidepods, they’re kind of tall and skinny and tight to the monocoque. It’s actually quite a well-sized system. In testing we ran an endurance simulation without any fans, so even though we’ve stopped and soaked for three minutes, we’ve been able to go back out again without any fans with the temperatures being pretty consistent. Unfortunately we were going to some hot events late in the year, so we thought we might need the fans just in case.’

In the Czech competition Bath took victory by being relatively strong in all aspects of the competition. The team only won in two elements of the event overall, cost and fuel efficiency, but the points scored over its less consistent rivals, especially in the latter event, were enough to give the team overall victory. Next year it has already set its sights on one objective: to win its home event overall.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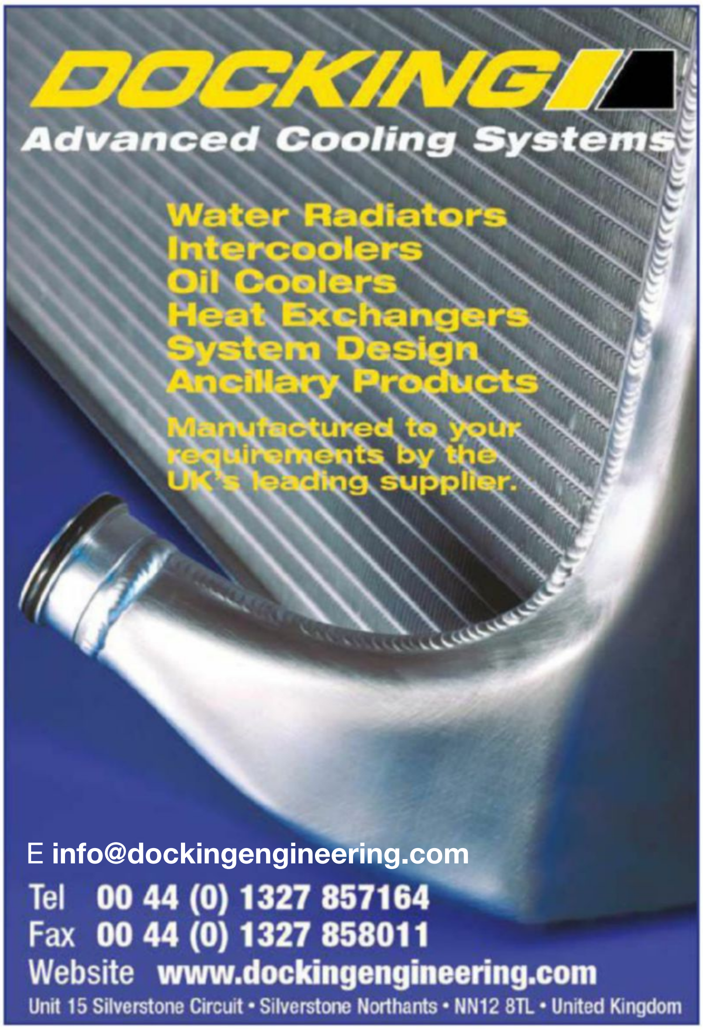
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Formula 1 tech heads call for swift start to 2021 engine regulation talks

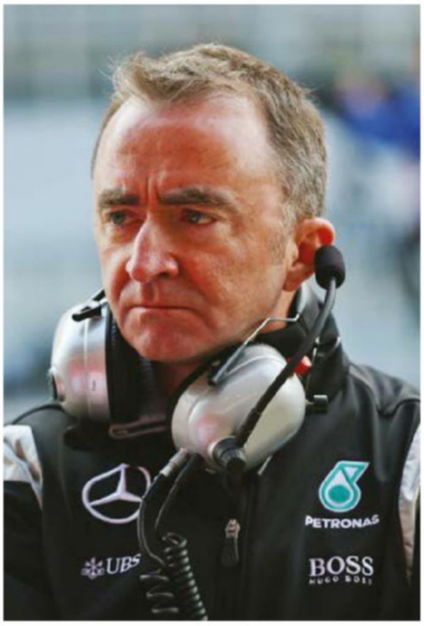
Formula 1 technical chiefs have said they believe the sport should start the process of deciding on the next engine regulations, set to come in in 2021, as soon as possible.

The current power unit regulations have four years left to run, but took five years to formulate, and have proved costly for teams. With this and other factors, such as road car relevance, in mind, F1 tech bosses believe talks need to start now.

Paddy Lowe, executive director (technical) at Mercedes, said: 'I think it is about time we started to talk about the engine beyond this [current] one, really. And it does raise a number of very big considerations: how do we define an engine or power unit that is correct for the sport but also relevant to the kind of power units that we will see in the future in road cars? Do we make them remain in some way related to that technology which is increasingly electrical or, do we go our own way?

'I think road cars of the future, at some point not that far off, will be completely silent if they are all electrical, so will we want noise, will we associate noise with performance or not? There are some very interesting debates there and I think we need to start that process,' Lowe added.

XPB



Mercedes tech boss Paddy Lowe believes F1 should already be thinking about its 2021 engine regulations

Jock Clear, senior performance engineer at Ferrari, said: 'It needs to be thought about. I think what we have learned from this cycle and this era of hybrid engines is that the power units now are very, very complicated and it needs a lot of planning…The sooner we start, the sooner we'll be aware and the sooner we can come to a solution that will be the best for the sport.'

Matt Morris, engineering director at McLaren, said an early decision might also entice new manufacturers in to F1: 'I think it is good to start the talks now because it's important for the engine manufacturers that are already in to see what is happening in the future, because they need reassurance that what we are going to do in the future is still relevant to their business and I think also having visibility of the future could potentially attract more engine manufacturers into our formula. So I think for our side the sooner we start discussing this, then the better.'

Lotus Formula 1 team built up losses of hundreds of millions

The Lotus Formula 1 team's losses during the six years of its operation add up to a staggering £238.2m, new and previously published accounts have confirmed.

Lotus, which was bought by Renault from private equity group Genii in December for just £1 and now races under the French car manufacturer's name, recently published its accounts for 2015, which show a loss of £57m.

This loss represents a significant increase on 2014, for which it had recorded a loss of £5.8m. The accounts are dated for December 31, which was a matter of days after the purchase of 90 per cent of the team by Renault. The £238.2m figure noted above is cumulative losses over the six year period of Genii's ownership, during which time the team also raced under the Renault name and as as Lotus-Renault.

The newly issued accounts show turnover decreased by £36.3m in the 2015 period, but that this was related predominantly to a reduction in sponsorship earnings for the year.

Meanwhile, operating expenses for the Lotus Formula 1team increased by £6.7m, while financing costs rose by £1.7m to £22m.

The accounts state: 'The increase in financial loss relates to a number of points, some of which are considered not to be ongoing transactions and therefore a better result is expected in 2016.'

Lotus's accounts also show that the amount of people working at the team rose modestly from 464 in 2014 to 475 in 2015.

Meanwhile, it's been reported that Renault has received substantial additional investment from its parent company and is now speeding up its development programme after a troubled return to Formula 1 as a works operation – at the time of writing it is 10th in the constructors' standings with just six points.

Renault is also said to be in talks with two major Spanish sponsors for 2017, mobile phone company Movistar and BBVA, a global bank. Both of these companies have blue corporate liveries, which could mean an end for Renault's current, historically evocative, yellow colour scheme.

The sun goes down on Lotus in F1 at the end of the 2015 season – the team made substantial losses during its time as a Formula 1 operation

LMP1 privateer team scales back World Endurance assault

WEC team Rebellion Racing is to run just one car for the rest of the season as it diverts resources to developing its sports prototype for the new LMP1 privateer regulations, set to come in to force next year.

The Anglo-Swiss squad aims to focus on optimising its AER-engined Rebellion R-One for the 2017 changes – which are for non-works, non-hybrid cars only, and have been brought in in an effort to narrow the gap between the privateer and the manufacturer teams in LMP1.

Next year's changes include a lower minimum weight of 830kg, the allowance of larger dive planes at the front of the car, and an increase in the width and chord of the rear wing. The engine regulations will also change while there is some talk of the adoption of a DRS system for 2018.

Bart Hayden, Rebellion Racing's team manager, said: 'The level of competition in LMP1 is being taken to ever greater heights by the manufacturer entrants, so to improve our own competitiveness in the category, we feel the need to invest more time and resources into updating the Rebellion R-One cars ready for the 2017 season.

'As a small private team with limited resources, we have decided to focus on racing one car rather than two in the remaining FIA WEC events and this will allow us to put more effort into updating the cars for 2017. Hayden added: 'Splitting our focus between running one car in the remaining races and on updating the cars for next season will mean that we can continue to be a part of the World Endurance Championship whilst at the same time making sure that we are as competitive as possible next year,' he said.

At the time of writing there were five rounds of the 2016 WEC remaining: Mexico City; Austin; Fuji; Shanghai and Bahrain.

XPB

The No.13 Rebellion will race on alone for the rest of 2016 as the team concentrates on new 2017 LMP1 rules development

Silverstone boss put on leave amid track sale talks

The protracted negotiations to sell Silverstone to the Jaguar Land Rover Group (JLR) have taken another turn with the news that the British Grand Prix venue's managing director, Patrick Allen, has been placed on a leave of absence, due to his relationship with another party also interested in buying the circuit.

The British Racing Drivers' Club (BRDC), which owns both the track and the Silverstone Circuit Ltd company that operates it, has been in talks aimed at selling a lease on the facility to JLR for some time now.

Back in the spring club members voted 54 per cent in favour of accepting the JLR deal that was then on the table. However, Ginetta owner and BRDC member Lawrence Tomlinson had made a counter offer just before the vote and the club decided to wait before making a final decision – largely because it had signed an exclusivity clause with JLR which stated that it could not talk to other parties.

The time limit on this exclusivity clause has now passed and a number of other deals, including Tomlinson's *Racecar* understands, are set to be considered.

Because of this, Allen, who has worked with Tomlinson in the past and came to the circuit on his recommendation, has been placed on a leave of absence. Allen has never hidden his close links with the Ginetta boss, telling this magazine last year: 'Lawrence is a good friend of mine, I've done a little bit with him at Ginetta.'

BRDC chairman John Grant said: 'Patrick is taking a leave of absence because we are in discussion with Lawrence, alongside continuing discussions with JLR and exploring a number of other expressions of interest.'

The BRDC's annual general meeting will take place at the end of September, and the club's board is expected to use this occasion to update its members on the progress of these negotiations.

Silverstone Circuits Ltd MD Patrick Allen has been placed on leave of absence for the duration of the British Grand Prix venue's sales negotiations

SEEN: Formula E season three update

Formula E has revealed the new front wing assembly that will adorn its electric-powered racecars from its third season, set to start in the autumn of this year and finish in 2017. The nose job is aesthetic rather than aerodynamic, FE tells us; its CEO, Alejandro Agag, saying: 'Formula E aims to be different, and this new front wing creates a look that's different to every other car out there. I think this is a great addition to our car and further emphasises the fact that this is a modern, forward-thinking championship that is taking a completely different approach to all the other racing series.'

Other changes for FE's season three include new, lighter Michelin tyres and a brand new steering wheel. There had been talk of a new button-operated brake-bias adjustment system, but this seems to have been shelved. In season five (2018-2019) the current chassis, the Spark-Renault SRT_01E, will be replaced, but the FIA has yet to announce which company has won the tender to produce the new for 2018 Formula E spec racecar.

IN BRIEF

CVC set to sell F1 stake?

According to respected business news agency Bloomberg, CVC Capital Partners is poised to sell off its majority stake in Formula 1. In a report in August Bloomberg said that CVC was looking to unload its multi-billion dollar stake in the sport 'possibly in a matter of weeks'. It also claimed that well-known US multi-national banking firm Goldman Sachs had been brought onboard to help find a buyer and that CVC had set a price tag for its share in F1 of close to $10bn.

Formula V8 3.5 to join the WEC bill

Single seater series Formula V8 3.5 is to support a number of World Endurance Championship events in 2017.

FV8 3.5 was formerly known as Formula Renault 3.5 (and World Series by Renault) but the French manufacturer pulled out of its long-term sponsorship deal at the end of last year, leaving the series to go it alone under its new title in 2016.

Gerard Neveu says Formula V8 3.5's inclusion in the WEC's weekends will create 'festivals of motorsport'

The series, which is run by Jaime Alguersuari Sr, will now join the WEC for six of its nine races in 2017. These will include long-haul events such as Mexico, Bahrain and Fuji, plus three European counters – at Spa, the Nurburgring and also at Silverstone.

The transport costs for the teams are to be met by media and marketing giant Densu Aegis Network, the company that bought Alguersuari's RPM company – which promotes the series – last year.

Alguersuari said of the deal: 'The new series, linked to the WEC, is a historic challenge because a single-seater championship of this level has never before offered such a wide international calendar at an affordable budget.

'Racing in the same major events where official manufacturer teams from renowned automotive brands such as Toyota, Audi, Porsche as well as Ferrari, Aston Martin, Ford and Corvette are competing in the world's leading endurance championship, will allow our talented drivers to show off their skills in front of a prestigious and knowledgeable audience,' Alguersuari added.

Gerard Neveu, the WEC's CEO said: 'It is very good news that the Formula V8 3.5 series will join the WEC race meetings from 2017. This single-seater championship has demonstrated for many years now how very appealing and exciting it can be, while at the same time providing many great champions.'

Neveu added: 'This combination of Formula V8 3.5 single seater cars and sports prototype and GT cars, in the same place at the same time, will provide great racing over the same weekend, a real festival of motorsport.'

Iconic Indycar sponsor to end its involvement with Chip Ganassi

US supermarket giant Target is to cease sponsoring the Chip Ganassi Racing IndyCar operation at the end of this season.

Target has been involved with CGR since 1990, the year after the team was formed, and CGR cars have won four Indy 500s and 11 championships bearing the famous red and white livery.

Recent changes within Target's management structure are believed to be behind the decision to quit IndyCar – though the company will still be involved with CGR's NASCAR Sprint Cup operation, remaining in place as the primary sponsor on Kyle Larson's Chevrolet in 2017.

Team owner Chip Ganassi said he understood Target's decision. 'It's the greatest sponsor in racing, ever,' he said in a quote issued by the team. 'They've been nothing but good to me. They developed me personally and professionally. I understand things change and people have different marketing efforts, and the way they want to stamp their name on things.

'But it's one of the longest running sponsors in racing and they delivered for me and the team, and the team delivered for them,' Ganassi added.

IndyCar CEO Mark Miles said: 'IndyCar would like to thank Target for its exceptional commitment to open-wheel racing and Chip Ganassi Racing for its stewardship of the partnership for the past 27 years.

'The Target brand will always be an integral part of our sport's history, as the number of race victories, championships and Indianapolis 500 wins that occurred in the iconic red livery of Target were unprecedented.'

The Target and Ganassi partnership has been an integral part of the IndyCar scene since the early 1990s and it is one of the longest running sponsorship tie-ups in motor racing history. Target will still back CGR in NASCAR

Engine development specialist opens new UK technical centre

Engine development and consultancy company Mahle Powertrain has opened a new half a million pound Vehicle Engineering Centre (VEC) in Northampton, UK, in the heart of Motorsport Valley.

The VEC houses a new, fully-equipped workshop with six vehicle build stations, and two new project offices capable of accommodating up to 50 members of staff.

The state-of-the-art facility will see Mahle Powertrain further its work on various projects such as 48V supercharging, advanced engine downsizing, EV range extenders and developing parallel hybrid technologies.

It will be used for a variety of services, including the development of prototype vehicles, installation of alternate powertrains and developing thermal management systems. It will also serve as a base for Mahle Powertrain's real driving emissions (RDE) testing, with two sets of PEMS (Portable Emissions Measurement System) equipment available.

Simon Reader, Mahle Powertrain's engineering director, said: 'We are delighted to be able to open our new VEC, which allows us to expand our operations and technical capability here in Northampton.

'Mahle Powertrain has a long-term commitment of investing in its facilities and driving forward the automotive industry, not just in the UK, but across Europe and further afield. This is highlighted by our work with some of the industry's biggest automotive brands,' Reader added.

IN BRIEF

Williams and Thales tech tie-up

Williams has announced a new technical partnership with Thales, a leader in critical information systems, cyber security and data protection. As part of the agreement Thales will deliver state-of-the-art cyber security solutions for real-time global telemetry transmission to both the race team and Williams Advanced Engineering, the engineering services and technology division of the Williams group. Claire Williams, deputy team principal of the Williams Formula 1 operation, said: 'With the help of Thales, we will be introducing cyber security systems that keep our data secure from wherever we are in the world.'

ISC improves on first quarter results

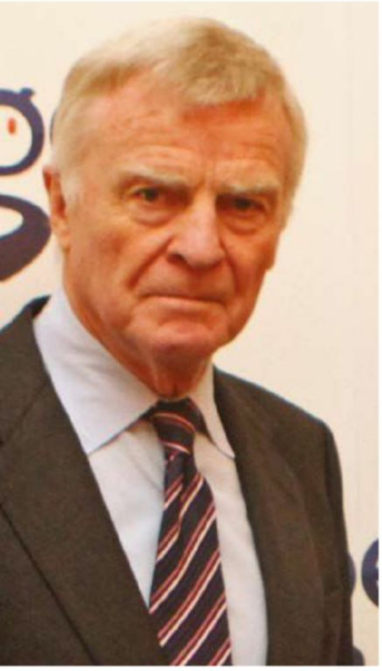
International Speedway Corporation (ISC), the publicly-owned NASCAR company that owns and operates many of the tracks on which the premier US race series competes, has reported improved financial results for the second quarter of 2016. Total revenues for the second quarter were approximately $167.6m, compared to revenues of approximately $164m in the second quarter of 2015. Operating income was approximately $23.7m during the period, compared to an operating income of approximately $19.2m in the second quarter of 2015. Lesa France Kennedy, ISC chief executive officer, said: 'Revenues increased year-over-year driven by contracted broadcast rights increases and strong corporate partnerships. We remain confident that our consumer marketing initiatives are working.'

INTERVIEW – Max Mosley

Max talk

The former FIA president speaks candidly about his own impact on F1, cost control, and the man who succeeded him as the head of world motorsport

Interview by ANDREW COTTON



XPB

'I never stopped being amazed by the ingenuity of the teams working in Formula 1'

Max Mosley has done it all: lawyer, racing driver, racecar manufacturer – he was even a part time paratrooper for a spell in the 1960s. But, in motorsport at least, it is for his time as president of the FIA, which ran from 1993 until 2009, for which he will be remembered, covering as it did the safety advances in the wake of the Ayrton Senna tragedy, the emergence of cost control as the hottest of hot topics, and the introduction of energy recovery into the sport.

The last of these, with hybrid power units, is now a major part of both Formula 1 and LMP1, but how this all came about in the first place tells you much about the man and his modus operandi. 'With me, quite a lot of these things I can lay claim to have had the original idea, but executing it was all done by engineers,' says Mosley. 'We had a joke at March [the racecar manufacturer he part-founded in 1969] called *just* jobs – could you *just* fit that V8 into that chassis. I tend to be a just job person. I am fascinated by the ideas, then you have the concept, then you talk to someone good technically like Peter [Wright], and this was the start of hybrid systems in Formula 1. He did all the serious work on that and kept me informed, and then I had to debate with the teams, as they didn't want to do it. I got them to do it in 2009.'

This was largely achieved by selling the PR value of hybrids, Mosley says. 'They realised that even if they didn't understand, the sponsors did. To me it was so obvious that once you understood the concept everyone would see the point, talk about it, the public would think that it was a good idea to use the petrol two or three or four times. There was great resistance from some of the teams, some for the sake of it, some because it was expensive, but then the penny dropped. Eventually.'

The Max factor

But it's one thing having a great idea, formulating those ideas as rules is where it all gets a bit more complicated. 'Thinking of those things and being fascinated by them is completely different to the nitty gritty of writing the rules,' Mosley says.

And then there's the day-to-day policing of those regulations to think about, as well. Mosley conceived the idea of informing the FIA of a team's intentions when developing a car in a bid to reduce wasted time and money. 'When we realised in 1993 or 1994 that the teams were massively evolving the cars, we had the idea of saying "tell us in the strictest confidence what you are planning and we will tell you if we think that it is legal or illegal. If we think that it is illegal you can still turn up with it at your own risk, and we can let the stewards decide." I never stopped being amazed by the ingenuity of the teams, but the basic idea of getting the principles sorted before they make it seemed to be logical.'

It's not just about wasting time, though. Spending money has always been a part of Formula 1, and Mosley was the first to introduce the concept of a cost cap, back in 2008. It's an idea that's still very close to his heart. 'You want close and competitive racing. You want as many cars on the grid to be fast or capable of winning a race as possible, and the only way that you will do that is to level up the money,' he says. 'For ages I was pushing the idea of a cost cap. They said that we couldn't enforce that, so we set up a committee in 2008, headed by Tony Purnell [then a technical consultant at the FIA], but also with the CFOs [chief financial officer] of each of the teams, and everyone other than Ferrari agreed.

'They came up with a report of how to do it. It can be done, you can control the costs,' Mosley adds. 'Then it is a question of do you want to? The rich teams don't want to because they have a competitive advantage. If you have three or four teams with a lot of money you have two or three competitors each. If you have teams with the same money, you have potentially 11 other teams competing. Immediately you are in trouble there.'

Cap in hand

You might have assumed that the smaller teams would have been behind such an initiative, but apparently not. 'The strange thing is how the struggling teams didn't back this, but joined in

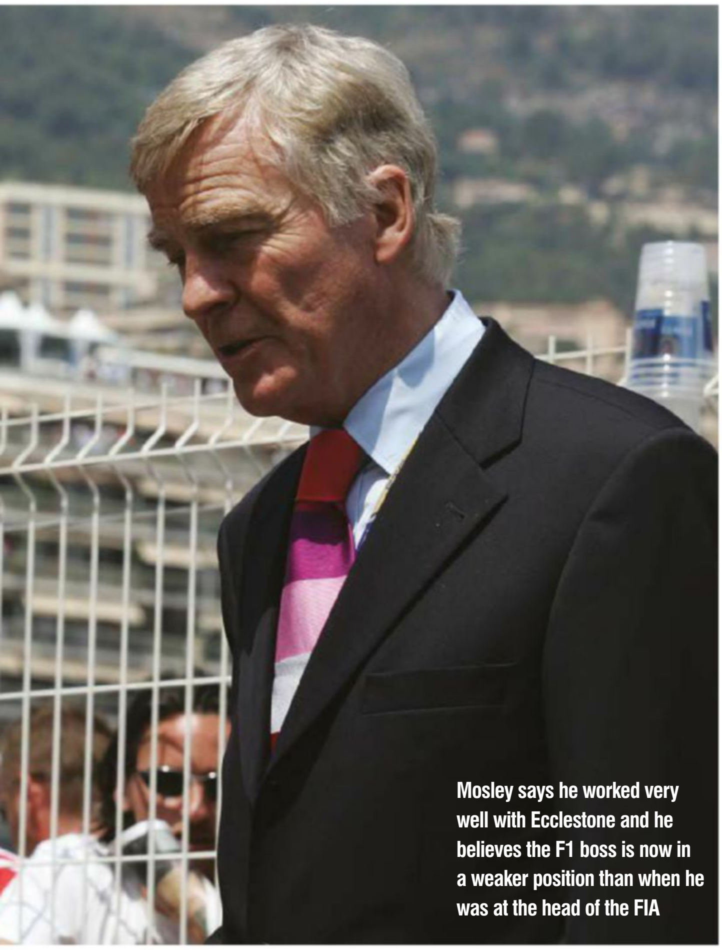
with the FOTA [Formula One Teams' Association]. It was a waste of time. The small teams wanted to stay with the big teams. Luca [Montezemolo, then Ferrari chairman] was very good at patting people on the back, saying "you are my friend", and Luca kept the whole thing going until he got a new special deal with Bernie [Ecclestone] and then he was gone!'

Speaking of Bernie, there was a time when Ecclestone and Max Mosley were almost always mentioned in the same breath, during the FOCA-FISA war of the early 1980s in particular, but they worked closely together for many years after that, too. But how does he think the F1 impresario's position has changed since Mosley's successor, Jean Todt, took the reins at the FIA? 'I think that he is probably [weaker] with Jean as president because they don't have quite the same understanding as Bernie and I did,' Mosley says. 'We could discuss things, and I like to think that I could get Bernie to be more reasonable in ways, and he was good at damping down extreme technical ideas that I might have had. We were a good combination. His strengths were my weaknesses and vice versa.'

Dear Jean

As for Todt's effectiveness in the role of president: 'I think, arguably, he is a little bit too reluctant to have a confrontation with the teams. Confrontation is unavoidable in F1, it is part of the act. I think that the original theory of the strategy group was that Bernie and Jean together controlled the proposals that go to the Formula 1 commission, but in reality Jean does not want to do the more extreme things, and the teams are not going to agree anyway. The teams are under the control of those who supply the engines, and so all in all it is not the ideal management structure.'

While there has been no word on whether Todt is intending to stand for a third term as president –theoretically not allowed; of which, more later – there have been mutterings about Ecclestone stepping down. But Mosley doubts this will happen



Mosley says he worked very well with Ecclestone and he believes the F1 boss is now in a weaker position than when he was at the head of the FIA

XPB

RACE MOVES

XPB

James Allison has stepped down from the post of technical director at Ferrari after three years with the Scuderia. Last year he signed a contract extension that would have seen him at Maranello until 2018, but he has now decided to return to the UK, after the death of his wife earlier this year. **Mattia Binotto** has now stepped up to the role of chief technical officer.

Former IndyCar boss **Tony George** has been appointed chairman of the Indianapolis Motor Speedway board. George was president and CEO of the Indianapolis 500 venue and the IndyCar series until he was ousted in May 2009, and then removed from the board in 2011. He rejoined the board in 2013. In the past George was responsible for bringing the NASCAR Sprint Cup, Formula 1 and MotoGP races to Indianapolis, while he also helped to fund the research and development in to the SAFER barriers.

Dan Gurney has been awarded the Peter Bryant Challenger Award. This accolade is named after the late racecar designer **Peter Bryant**, who designed and engineered many well-known competition cars, among them the cutting-edge Ti22 and UOP Shadow Can-Am racers. Gurney received the award for his achievements in race engineering and racecar construction.

US race driver **Bryan Clauson**, who competed in the Indianapolis 500 on three occasions, has died from injuries sustained in a midget car accident at the Belleville High Banks dirt track in Kansas. Clauson was a big star on the American short-track oval racing scene, having won four USAC national championships.

Tony Parella now has an ownership stake in the Trans Am race series after his company, Parella Motorsports Holdings, acquired a significant share of the famed US touring car championship. Parella is also CEO of the Sportscar Vintage Racing Association, with which Trans Am holds joint weekends throughout the year. Parella, **Jim Derhaag, David Jans** and **Mike Miller** all now hold equal shares in the Trans Am ownership group, while **John Clagett** joins **Simon Gregg** as a minority shareholder.

Jon Tait, the former chief designer at race brakes manufacturer AP Racing, has now taken up the role of chief engineer at 920Engineering (920E), which is part of Liberty Vehicle Technologies and offers products to the motorsport, OEM and aftermarket sectors. Tait joined AP as an apprentice over 30 years ago.

Steve Saunders, a key member of Mazda Motorsport's competition parts team in the US, has retired. Saunders has been with Mazda for 30 years, and the vast majority of this time has been spent working with the motorsport arm of the company.

Mike Allen is also leaving Mazda Motorsport's competition parts team (see above). Allen has been promoted within Mazda and will now work in the technical operations department. Allen played a big part in the development of the current MX-5 one-make racer in the US.

Motorsport journalist **John Blunsden**, who was the managing director of motorsport and motoring book publisher Motor Racing Publications and was widely-known as the motor racing correspondent of *The Times* for 20 years from 1970, has died at the age of 86.

Rodney Childers, crew chief for the Kevin Harvick-driven Stewart-Haas Racing No.4 car in the NASCAR Sprint Cup, was suspended and fined $20,000 after the Chevrolet was found to be running with improperly fastened lug nuts following the Brickyard 400 NASCAR Sprint Cup counter at Indianapolis.

The **Joe Gibbs Racing** NASCAR Sprint Cup operation has changed its pit crew coach, with Mike Lepp now moving in to a new role as senior athletic adviser while Matt Osborn will take his place as the head of pit crew operations.

any time soon. 'He has never seriously suggested stopping. Those who continue into old age tend to be able to be active. [Enzo] Ferrari went on until he was well past Bernie's age. If Bernie wants to go on, he will.

'At the back of everyone's mind is how much longer does he want to go on? At the moment he shows no sign of stopping. He is as switched on as ever, as mischievous as ever, as much fun as ever,' Mosley says.

Yet while Mosley agrees that Ecclestone has done a good job in growing F1 over the years, he admits that Ecclestone does have his blind spots. 'Bernie has always been anti-internet. And for many years his office was not allowed to email. They secretly used to email, but if Bernie had to see it then they would have to fax. They use [email] now, but I have always said that if the founders of Google had pitched to Bernie their business, he would have thrown them out of the office!'

Unsocial media

This perhaps might explain why in recent times F1 has struggled to achieve quite the exposure it might have, while it is certainly seeing increasing competition from other sports that have embraced modern media, and it already had plenty of rivals when it comes to fighting for the attention of the man on the street. 'Football in most countries on a Sunday is a direct rival. Flavio [Briatore] always said that you should have a grand prix at 5pm, when people are coming in from the beach, but he was talking of Italy in summer, and F1 is global,' Mosley says. 'What is difficult to understand is how F1 finished up being the next big global thing alongside the Olympics and the World Cup.'

This, Mosley contends, has happened despite, rather than because of, the huge spend in technology. With manufacturers increasingly looking at alternatives for spending their money, with other dsiciplines in racing or even different sports, such as soccer, yachting and golf, is F1 in trouble? 'You could take away the manufacturers and an awful lot of the money and you wouldn't notice much of a difference. My 40 to 50 million [cost capped] teams, you wouldn't see much difference on the television. The most expensive things are the things that you cannot see, such as the amazing gearboxes.'

Which brings us back to the haves and the have nots, and these days the former tend to be the manufacturers, and they are now having a much bigger say in how the sport is run than ever before. 'The thing that gives the game away is that [Sergio] Marchionne [Ferrari president] turns up at the [race] meetings. That was unheard of. You never got [Gianni] Agnelli [former Fiat/Ferrari boss] at the meetings, or Dieter Zetsche [Mercedes chairman]. The minute you see them in the pits, that is a really bad sign. When you see one of them in the pit lane with a silly jacket, all is lost. When we were young, you would think "I wish I could afford a Hewland FG400 [gearbox], but I don't have the money and I can't borrow it from the bank". Nowadays, the team principal comes in, and Mr Big says: "why didn't we win?" and he replies XY or Z, and Mr Big says: "How much will that cost?" Out comes the chequebook.'

Max senate

With such comments you sense that Mosley is not missing the political maelstrom of Formula 1 right now. But what does he think the future is for motorsport, in political terms? 'I don't know what is happening at the moment. I don't know if Jean wants to stand again. The rules say that you can only stand for two terms, but he can easily get that changed. He might decide that he wants a third term, or he might think that the level of work might not be worth it, plus he has this thing with the UN – but that was the personal gift of Ban Ki-moon [Todt is the UN special envoy for road safety]. Equally he might be interested in going on with the road safety at the FIA. If he decides that he does want a third term, in these big sports federations it is very difficult to get the incumbent out. If Jean decides not to continue I don't know who the candidates [to replace him] are. There are people around the FIA, but it has been seven years since I stopped, so I am well out of touch.'

'If the founders of Google had pitched to Bernie their business idea, he would have thrown them out of the office!'


XPB

Mosley believes that Jean Todt, his successor in the post of FIA president, has been unwilling to confront the F1 teams, and has also not been extreme enough

Of course, one man who is certainly not out of touch is Ecclestone. Could he have a Todt successor, allied to his own causes, waiting in the wings? 'I don't think that Bernie thinks like that. In the old days, people used to think that he put me up for standing. In fact he was quite against it. He might have someone in mind, he might be planning something, but if he has, he hasn't told me!'

Which begs the obvious question: how would Mosley feel about returning to his old role at the top of the sport? 'Most races I don't watch. I am interested in the concept and structure and philosophy of F1, but it is very unwise to go back, and if you are not involved, it is better to not interfere. I have my objectives, and I am working away at those.' These include some very effective, and ironically high profile, campaigning on privacy issues. Just one more role to add to that impressive list we opened with, then.

RACE MOVES

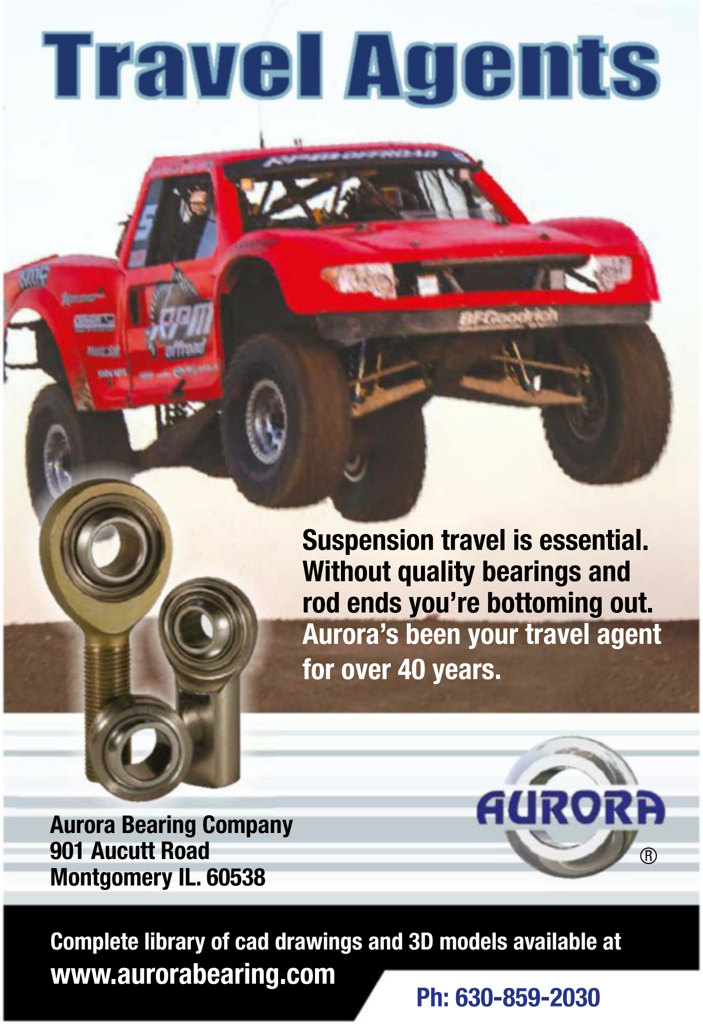
The first British Saloon Car champion, **Jack Sears**, has died at the age of 86. While he will be fondly remembered for his exploits in tin tops he also raced sportscars at the highest level. Sears gained some notoriety for hitting 180mph on the M1 motorway in a factory AC Cobra Coupe while testing for the 1964 Le Mans 24 Hours – a myth subsequently grew out of this episode, to the effect that it was the catalyst for the UK's imposition of a 70mph speed limit.

NASCAR has announced several changes within its executive team. Chief amongst these is **Steve Phelps**' appointment as executive vice president and chief Global Sales and Marketing officer. Phelps will oversee Global Marketing, Partnership and Series Marketing, Business Development, Integrated Marketing Communications, Licensing and Consumer Products, and NASCAR Digital Media.

As part of the NASCAR leadership team reshuffle (see above) **Jill Gregory** has been named senior vice president and chief marketing officer. Gregory joined NASCAR in July 2007 after working in executive roles at Bank of America and Sprint. The business areas that Gregory will now oversee include Brand and Consumer Marketing, Brand Platforms, Entertainment Marketing, Driver Marketing, Team Marketing, Social Media and Analytics and Insights.

Norris Scott has been named vice president, Analytics and Insights, a new position within NASCAR. Scott, who joined NASCAR in 2005 in Partnership Marketing after working at ESPN and the NFL, will now oversee consumer research functions at NASCAR, including Social Analytics, Digital Research, Sponsorship Valuation, and Media and Market Research.

The final move in NASCAR's leadership team reshuffle sees **Lou Garate** promoted to vice president, Partnership Marketing. Garate has been at NASCAR for nearly 10 years, working closely with official partners such as Chevrolet, Ford, Goodyear, MillerCoors and Toyota.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Formula 1 team bosses question congested calendar

F1 bosses are concerned that the sport's tight summer schedule puts too much pressure on team personnel

F1 team chiefs and leading tech figures have queried the wisdom of the shoehorning in of six grands prix in just eight weekends in the run-up to the August break this year.

Between the Canadian Grand Prix on 10 June and the German race on 31 July the sport also visited Azerbaijan, Austria, the UK, and Hungary, and team bosses have said the strain on personnel is now beginning to show.

Jock Clear, senior performance engineer at Ferrari, said: 'We've got a lot of guys out there who, during this five-week period, are really, really up against it to get enough sleep and to find time to look after their families. I don't think it's necessarily not sensible, I don't think we're worried about the safety of it, we're still very comfortable that we can put those cars out there safely, but people are just very, very tired.'

Pat Symonds, chief technical officer at Williams, said it has already looked at ways of countering the problem: 'We're not at 20 races any more, we're at 21, and who knows whether it will go beyond [that], but we've also got tyre testing to take into account next year, so I think we're way past the tipping point and we, as a team, are looking at a completely different structure because we cannot ask our personnel to maintain the level of activity that's being asked of them. And therefore we're going to have to look at rotation. It's an incremental cost, we have to put people in there. I've been in racing now for 40 years and this is the first time when I'm starting to see people say, "well, actually, we don't want to go racing. We love Formula 1, we enjoy working in the factory, but it's actually too much of a drain on family life and quality of life to be on the road all the time".'

Guenther Steiner, team principal at Haas F1, said that this sort of calendar congestion is simply unsustainable: 'Is it sustainable? I don't think so. I think we should try to make it a little bit [better] scheduled.'

OBITUARY - Chris Amon

Former F1 driver and sometime racecar constructor Chris Amon has died at the age of 73 after losing his battle with cancer.

While the New Zealander is widely known as one of the unluckiest F1 drivers in history – he never won a grand prix but came close on a number of occasions – he also tried his hand at fielding a Formula 1 racecar that bore his name, the Amon AF01, though the project was not a success.

Amon started 96 grands prix between 1963 and 1976 and finished on the podium on 11 occasions, driving for Ferrari, March and Matra, amongst others. He retired from racing in 1977 after a spell with Wolf in Can-Am – his seat was taken by Gilles Villeneuve, but Amon then recommended the Canadian driver to Enzo Ferrari.

Chris Amon, probably the best Formula 1 driver never to win a grand prix, has died at the age of 73

Amon was active in the sport after his retirement – though his main work was on his family farm – lending his support to the New Zealand TRS single seater series and also helping to redesign the Taupo race circuit, also in New Zealand.

His family released a statement which read: 'Chris battled cancer in recent years but retained not only a close interest in Formula 1 – and his very wide range of favourite topics – but also his wonderful sense of humour complete with infectious chuckle.'

McLaren chairman Ron Dennis said of Chris Amon: 'I have not met Chris for many years but, even so, I have extremely fond memories of him and I would describe him as one of the most likeable men I have met in my long racing career.'

Chris Amon 1943 – 2016

RACE MOVES

Lisa Noble has resigned from the post of president and CEO of the Sports Car Club of America (SCCA), a role she stepped into in 2013 after serving on the SCCA board for six years. Noble said she now aimed to pursue other challenges, although she conceded that she had 'philosophical differences' with the SCCA board. The SCCA is now searching for a new president and CEO.

Mick Jones, the former competition boss of Ford Motorsport and a legendary rally mechanic, has died at the age of 83. He played a major part in the development of the Capri rallycross car and the Escort Twin Cam rally cars, and led the team that built the first RS200 Group B car. For a time he also ran Ford's motorsport programme in South Africa.

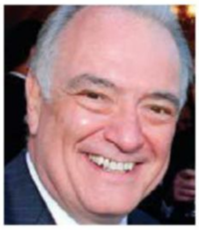
New Zealander **Tony Lentino**, the owner of Australian Supercars Championship team Super Black racing, has died at the age of 42 after losing his battle with cancer. Super Black Racing was formed in 2014 and made its debut in what was then called V8 Supercars at the Bathurst 1000 that same year.

BEN, the not-for-profit organisation dedicated to supporting those working in the automotive industry, has announced the appointment of **Zara Ross** as its new chief executive officer. Ross has taken over from David Main, who has now retired from his CEO duties at the organisation.

Kurt Zeigler, a crew member at IMSA outfit Action Express Racing, was injured while loading equipment in to the team's transporters after the WeatherTech SportsCar Championship counter at Road America. Zeigler suffered leg injuries in the accident and was taken to hospital, but the team says he is expected to make a full recovery.

The Virgin Australia Supercars Championship (VASC), Women of Australian Motor Sport (WAMS) and Women in Motor Sport New Zealand (WiMNZ) organisations have joined forces to launch a new race officials exchange programme to strengthen connections between Australia and New Zealand when it comes to female participation in motorsport. The new initiative is called the VASC Trans-Tasman Female Officials Exchange.

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



A time for action

Why Brexit could provide motorsport businesses with golden opportunities

It's only been a couple of months since the UK decided to leave the EU and create a new government under a new Prime Minister, yet it already seems a long time ago. UK motorsport companies are entering a period of unparalleled change, but with careful management and business planning they can seize many opportunities for growth as they arise, and there will be plenty.

Competitive exchange rates will allow UK companies to grow exports fast but at the same time import prices for vital materials and supplies are rising fast, so management has to work hard to protect their margins. As UK motorsport operates globally, we need little encouragement to chase exports However, new trading conditions will be created, probably increasing the bureaucracy involved in importing and exporting, so costing time and money.

Civil unrest

The UK Civil Service is recovering from a double shock wave – senior ministerial changes with different policies and vision puts it to the test, alongside its new challenge of operating outside the European Union. These call for new skills and talent as the current experience is very limited. I expect this vital area for UK businesses will take a long time to reach acceptable efficiency. The civil servants urgently need clear, strong leadership, and to recruit new people to meet these challenges.

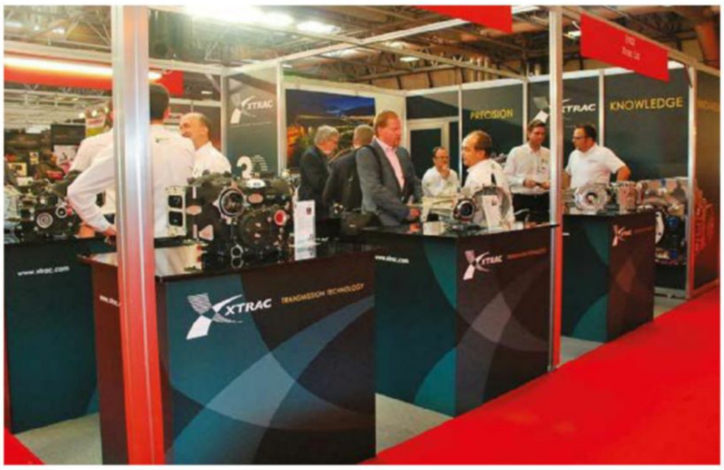
An exciting new business world is ahead, encompassing globalisation, disruptive business models and technology change with rapid innovation. The last few years have seen the arrival of many extremely disruptive concepts, such as Uber and Google. Future economies will have fewer borders as rapid communications become even simpler; UK companies must adapt and be flexible.

In the short term, growth in international trade in high performance engineering and motorsport will be particularly strong in Germany and the USA, the most immediate targets for motorsport exporters. Both India and China will also develop over the next few years, and so export management needs to learn and understand these markets better, to be ready to engage with them.

Sales within the UK will grow as major customers will be forced to switch from importing newly expensive products to UK-based, convenient, top quality suppliers. Now is the right time to knock on the doors of those customers who you know now buy from your overseas competitors. You need to remind them how competitive your service is today at excellent prices; don't wait for them to call you – seize the opportunity.

You must chase exports by exhibiting, or simply visiting, the PMW Show in Cologne between 9th and 11th November, and also PRI in Indianapolis, USA from 8th to 10th December. They give you the chance to meet thousands of buyers, some of which offer new opportunities for you to grow.

Competitive exchange rates will allow UK companies to grow exports



The new trade environment created by Brexit means it's even more important to visit industry shows such as Autosport Engineering (pictured) to search for new business

On top of all this, there is still plenty of money ready to be invested in your business, particularly by increasing your collaboration with the UK automotive industry and defence.

Also, please don't ignore putting in a claim for R&D Tax Credits – this is easy money to secure and will make a huge difference to your bottom line and your future business. Just take free advice and get your claim in – you may be pleasantly surprised.

Get connected

The future of connected and autonomous vehicles is here now, and is full of new business for motorsport companies. So many aspects are relevant to your capabilities and there is over £100m available from government research grants. It includes areas such as rapid prototypes, additive manufacturing, data collection, data use and interpretation, electronics, simulation, testing, visualisation, light-weighting, and so many more. Read all you can – attend meetings and learn how you can get on board – this is a major new world opportunity and the UK plans to go large in leading it.

You've nothing to lose and much to gain from keeping a check on Innovate UK. You may have just missed a funding competition where it pays 70 per cent of project costs between £25,000 and £1m, for any innovative product or service, or even just a feasibility study. Motorsport companies are always planning to deliver an innovative product or service, so why not get the money from the government now? There will be other funds announced, so keep an eye on the Innovate UK website.

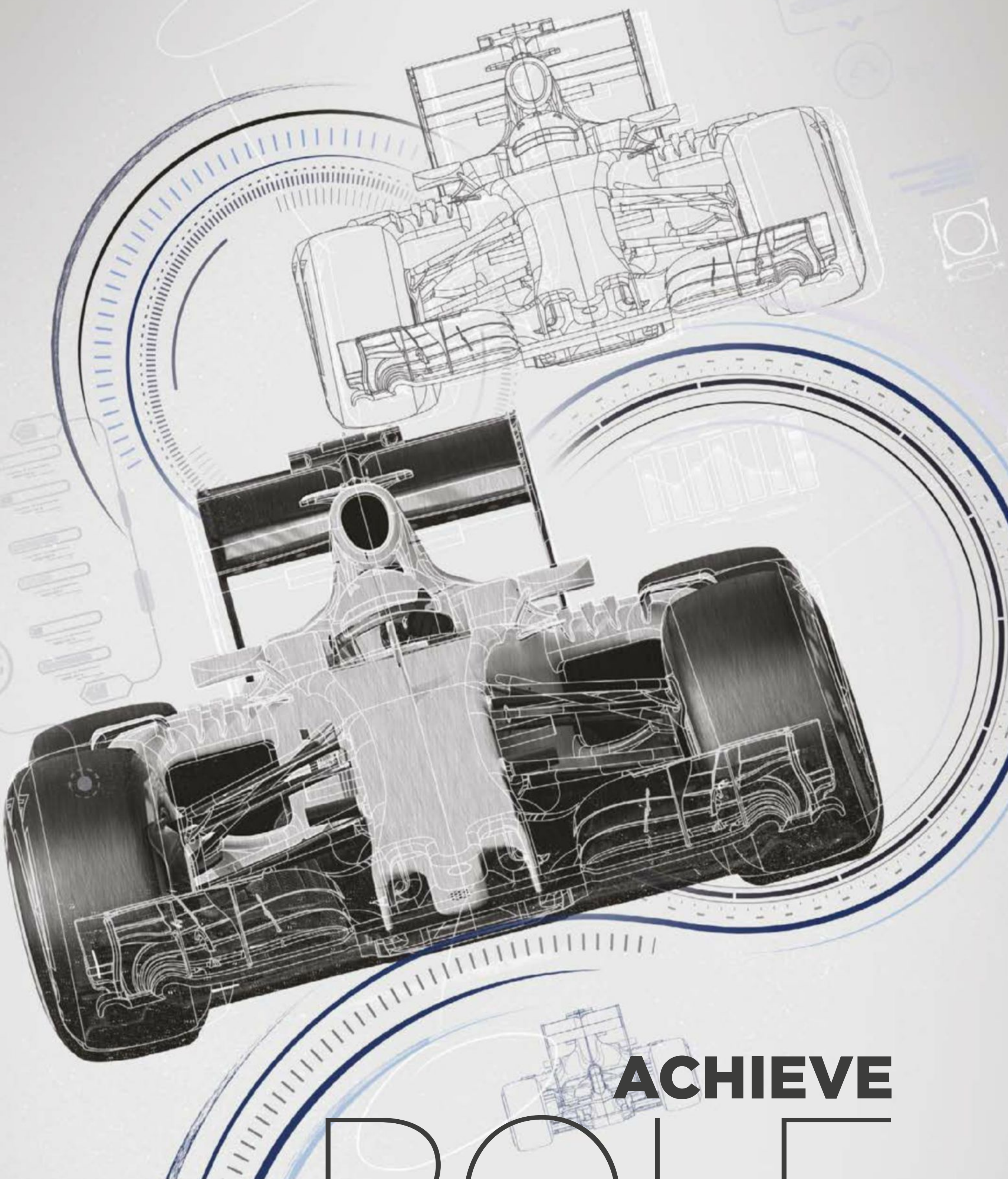
R&D funds

Another Innovate UK scheme has £25m available. Here you have to collaborate with a major automotive OEM and others, but the Advanced Propulsion Centre (APC) helps you to find those partners and you can secure 70 per cent of your project costs. This is called APC 6 and is for R&D into particular disruptive technologies, that 'accelerate low emission propulsion technologies'.

This sort of thing is just what motorsport companies do all the time, usually focusing on internal combustion engines, lightweight vehicles and powertrains.

To encourage collaboration with the defence industry, the Ministry of Defence has just announced £80m each year for the next 10 years, to 'harness innovation, particularly from SMEs', who it says are the secret to success. It plans to increase the amount of defence business given to SMEs to release their talent. More details of this funding was announced at the DVD (Defence Vehicle Dynamics) Show at Millbrook, which was set to take places as *Racecar* went to press. Even if you missed the show it's worth checking this out, and there are still many other opportunities in this sector.

I started this article explaining some difficulties which lay ahead, but also highlighted how many opportunities will arise. I hope you now see how much money is available in the UK to help you to grab those opportunities. We, at the MIA, are being flooded with enquiries from companies who are keen to do just that and we would love to help you to secure growth in complex times. We are always available at www.the-mia.com or info@the-mia.com. Please feel free to contact us to enjoy the benefits and ignore the negatives.



AUTOSPORT INTERNATIONAL ENGINEERING SHOW 2017 IN ASSOCIATION WITH Racecar engineering

ASI's perfect 10

Not sure you'll be going to Autosport International in January? Well here's 10 good reasons why you should

Autosport International has built its reputation over the past 26 years as Europe's premier pre-season motorsport event and is the must-attend show for trade and industry professionals from around the world. But if that's not enough, here's 10 more reasons why you should book your place at ASI 2017:

1. It's the first major event on the calendar
Exhibitors from all four corners of the globe choose to showcase their newest and most sophisticated products within the Trade and Technical area at ASI and at Autosport Engineering ahead of the new season.

2. Where the industry does business
Leading suppliers and buyers of motorsport technology attend ASI to keep up to date on the latest developments in the sector.

3. The world's leading high-performance and precision-engineering companies
The exhibitor list at ASI always boasts the biggest names, such as: Arrow Precision; Brembo; McLaren; Quaife; Race Logic; Variohm-Eurosensor; Xtrac; and Young Calibration.

4. Dedicated two-day trade show
The Engineering show hosts the industry's decision makers and professionals over two trade days. The ideal platform to find new suppliers, new products and explore new opportunities in a B2B-focused environment.

5. Networking and business opportunities
Just over 27,500 local and international business professionals attend Autosport International over the two days, with deals worth an estimated £664m finalised during and after.

6. UK businesses and innovation
The show has played an influential role in driving business in the industry for over 25 years. In 2017 it will host over 600 exhibitors from five different continents and help maintain the UK's place as a global centre of excellence.

7. Cutting-edge technology
Engine sensors, aerodynamics, lightweight structures, precision machining tools, fuels , transmissions, and careers in motorsport are just some of the areas of interest at ASI.

8. Transfer of technology
The motorsport industry is renowned for developing innovative solutions to complex problems in a short space of time, and many of the technological advancements from the sport are applied and adopted in the defence, marine and automotive sectors.

9. Most established exhibition of its kind
For over a quarter of a century, Autosport International has played host to the world's leading buyers and suppliers of motorsport technology.

10. Perfectly situated
Held at the Birmingham NEC, it is conveniently located near to Motorsport Valley, the world's hub of motorsport engineering.

Autosport International is the perfect start to the season and a must-attend event for all in the racing business

AUTOSPORT INTERNATIONAL OPENING TIMES: 12-15 JANUARY 2017
Saturday: 9:00am to 6:00pm
Sunday: 9:00am to 6:00pm

TRADE TICKETS

TRADE	Advance Price	Door Prices
Adult	£28	£30
MSA members	£23	£25
BRSCC members	Free*	*Free
Trade Group Tickets		
1 to 10 people	£28	-
11 to 20 people	-	-
21 to 50 people	-	-
51+ people	-	-

Tickets do not include access to LAA – LAA sold separately at £11 (advance & on-site)
Each ticket includes a Trade Directory (value £10) collectable on the day.
Note: No registration fee and tickets do not include a seat in the Live Action Arena. Live Action Arena Tickets = £11 each

STUDENTS

Ticket type	Trade days (12 & 13 January) Advanced	Public days (14 & 15 January)
Student 1 day entry pass	£28	-
Student 1 day entry pass + LAA	£33	-
Tutor 1 day entry pass *	£28	-
Tutor 1 day entry pass + LAA	£33	-

How to book
Trade Days - To register visit www.autosportinternational.com or call 0844 335 1109
(BRSCC Members should contact the BRSCC directly)

CONSUMER TICKETS

CONSUMER	Adult	Child (6-15yrs)
Standard*	£35pp	£23pp

ASI has played an influential role in driving business in the industry

Cockpit
New release of life

The new B-G Racing Quick Release system allows for quick and easy removal of the steering wheel from the column, making it much easier to get in and out of any racecar.

The product features a 20mm steel splined shaft available in a choice of 5/8in, 3/4in and one-inch diameters, to be welded to the steering column. These are cross compatible.

Its steering wheel mounting plate comes with two sets of holes pre-drilled for two different bolt patterns: 6x70mm – to suit MOMO, OMP and Sparco steering wheels – and 6x74mm, for wheels from Nardi and Personal.

A master spline positioned dead centre allows the steering wheel to be used as a reference point, thus ensuring perfect realignment every time, B-G tells us. Finished in black anodising and bright yellow powder coating, the system is manufactured from aircraft grade aluminium and 4150 grade hardened steel for both performance and durability.

Although intended for competition cars the system is also suitable for kit cars and track day cars, which these days often feature complex roll cages.
www.bg-racing.co.uk

Heat managment
Foiled again

Design Engineering has introduced a new low profile heat screen with adhesive backing. Suitable for racing applications the DEI Heat Screen is made from Mylar foil, laminated to a glass-fibre matting backed with an aggressive pressure sensitive adhesive for easy peel and stick application with high cohesion strength.

The heat screen will protect against excessive direct or radiant heat and will withstand 1200degF (649degC) direct heat, or up to 2000degF (1093degC) radiant. Measuring only .06in in thickness, this versatile, thin profile reflective material adheres quickly and easily to any surface, even or uneven, painted or unpainted, Design Engineering tells us.
designengineering.com/

Electronics
Plug and play Holley day

Holley's new range of EFI distributors are designed to plug and play with the Holley EFI systems increasingly being used in oval track applications.

The design includes dual Hall Effect sensors for the crankshaft and camshaft signals.

They can be used as just a crank speed input, as well as providing a cam sync signal for sequential fuelling operation. They can also be used for crank and cam signals for Coil-On-Plug applications. The precision machined shutter wheel design ensures accurate timing, even at very high engine speeds. They can also be used with other EFI systems that support Hall Effect sensors. The distributors feature a CNC machined billet aluminium housing, Integrated LEDs for easy set-up, a hardened steel distributor gear and a precision machined shutter wheel, which is designed for improved accuracy at extreme engine RPM.

Finally, a blank cap is available for Coil-On-Plug applications.
www.holley.com

Clutch
A bite to beat

Alcon has launched a new design into its already wide range of clutches. Aimed at rallycross, this triple plate carbon clutch is designed to be one of the most competitive clutches on the market.

Built on the success of its predecessor, the new 2016 clutch is approximately 10 per cent lighter and offers 18 per cent reduction in inertia, as well as an impressive 38 per cent reduction in deflection.

The new Alcon rallycross clutch will give the driver the best possible start through increasing the stiffness and reducing the deflection of the clutch, Alcon says. Alcon also claims that the clutch offers extremely low inertia, high temperature resistance and smooth engagement/quick shift response.

The housing has an open design for greater heat dissipation and improved dust removal, while the cover has been made to be very stiff for improved start line control.
Alcon.co.uk

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Time and punishment

France has seemingly led the way in introducing the summer shut down. Before it became an interruption in the normal racing schedule, it was fiercely observed by the French who, *en masse*, headed for the seaside in the month of August. Had anyone decided to invade France, August was generally a pretty good month to do so. Now, the summer shut down has been adopted throughout the European racing community, to the envy of NASCAR's aerodynamicist Eric Jacuzzi who by email considered the practice 'smart!'. Looking through the race schedules, the Spa 24 hours at the end of July precedes the first sprint race on August 28. Formula 1 shuts down for a few weeks, as does TCR, the World Endurance Championship and now, Formula E, which uniquely finishes its season in July and restarts it in October in Hong Kong.

It could be that the summer shut down is good for the teams and those that work in motor racing, but it does create a few problems. One of those is that the pressure on the scheduling is increased on the remaining weekends in the year, leading to clashes that have proven to be unpopular with those competing in multiple race series (such as Formula E and the World Endurance Championship), but another is that news stories tend to die in August. At the end of July, at the Spa 24 hours, for example, there was a juicy news story in that Mercedes was found to have modified its ECU, specifically the ignition timing, across its AMG GT3 cars, and this was discovered when they had locked out the top six positions in the super pole session. I happened to be sitting with series organiser Stephane Ratel with a tape recorder running. The voice file is quite amusing as what could have been a catastrophe for him became apparent.

Ratel faced a particular problem; the balance of performance system that was introduced in his series, to balance the Maserati MC12 against other GT cars back in 2004, has been under a lot of pressure recently. At the Nurburgring 24 hours there was the suspicion that Mercedes was not playing with a straight bat, while at Le Mans, what happened in the GTE balance of performance put added pressure on the whole system. Neither led to any penalty, but Ratel was acutely aware that another BoP controversy would be problematic. With Mercedes locking out the top six in qualifying, Ratel's BoP, used around the world in various series including the Pirelli World Challenge in the US, was under attack. 'Another controversy here would have put the whole concept under a lot of stress,' confirmed the Frenchman, who earlier in the day had announced to a room full of people that, so good was Claude Surmont's BoP system developed for the SRO, that there was no need to ape Le Mans and change the BoP between qualifying and the race.

That looked to be an ill-advised statement, before the Belgian took away the ECUs to be studied. 'I think that Claude did an amazing job,' said Ratel after the discrepancy was found. 'They stayed late into the night, and he was able to put out a report that was evidence of technical infringement and that is a reward of all the effort. With the data loggers, you can come and prove that there are parameters that can be quantified. At some point I heard that it could mean the exclusion of the cars from the meeting so I was a bit concerned, but at the end it was the right thing to do. It showed the strength of GT3 racing, and showed that Claude's BoP is correct, because he monitors it, and knows the Mercedes from Japan and everywhere else. He is not balancing a given car in a given championship with given drivers, he is balancing globally.'

This was a big call, one that clearly showed Stephane Ratel's belief in his own BoP system

Publicly stating that the cars were not in conformity was a brave decision, one I thought showed the strength of the Blancpain series. No fewer than 65 cars started the Spa race, and the six Mercedes not only had their super pole times disallowed, but they also had to serve a five-minute stop and go penalty in the pits at the race director's discretion, and he chose the first half hour of the race live on prime time television. It was a big call, one that clearly showed Ratel's belief in his own BoP system, and that, had Mercedes reacted badly to the decision and maybe withdrawn its cars, then the race would not have collapsed.

The confusion around Mercedes' situation at Spa was why they showed their hand so clearly in qualifying, when the goal is always the race? It meant that the paddock was rife with meetings and comments on Friday evening and Saturday morning before the penalty was announced. It was odd timing and suggests that there were grounds for further questioning but, occurring just before the summer shut down, by the time the cars lined up in Hungary at the end of August for the start of the second half of the year, this will all be largely forgotten.

ANDREW COTTON Editor