The leading motorsport technology publication since 1990

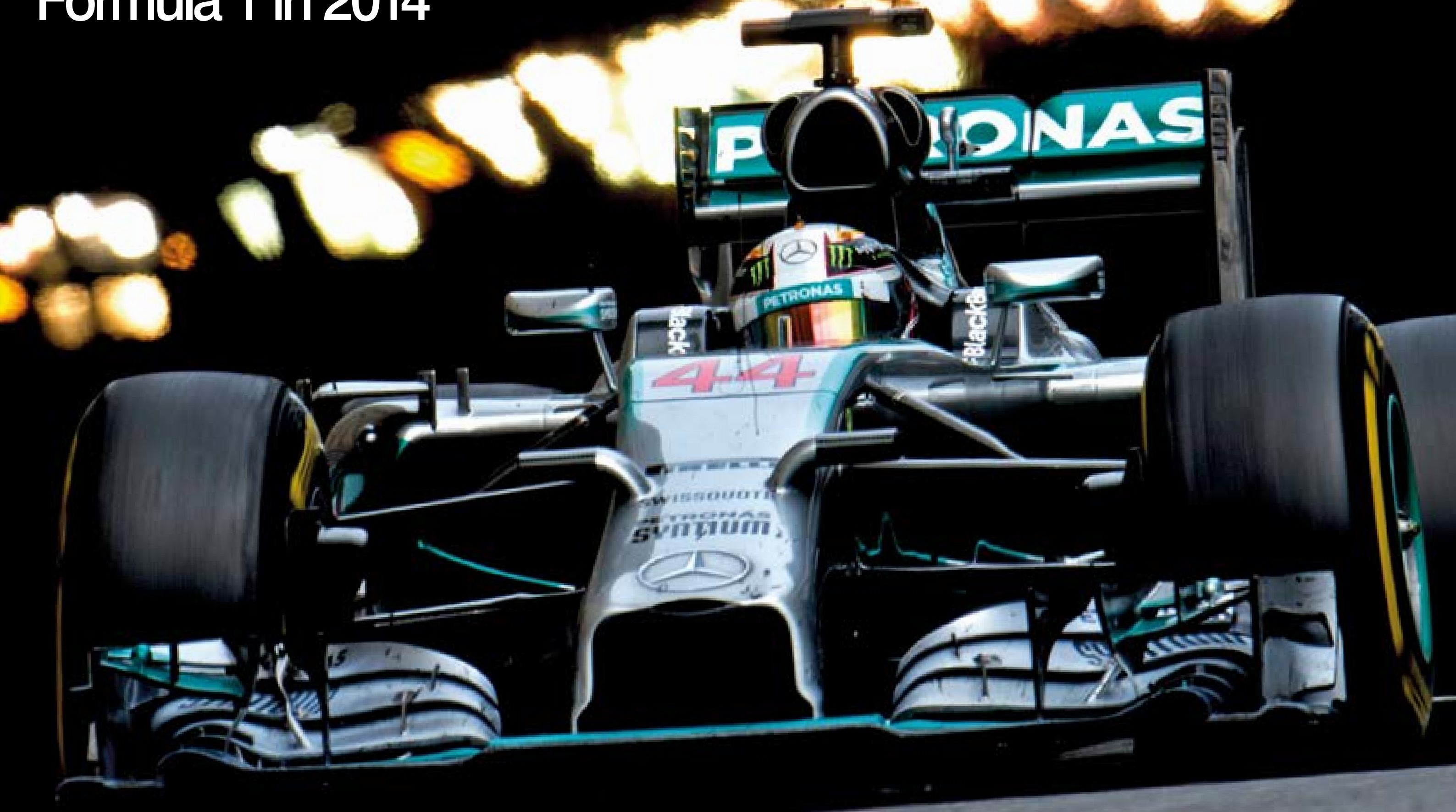
Racecar engineering™

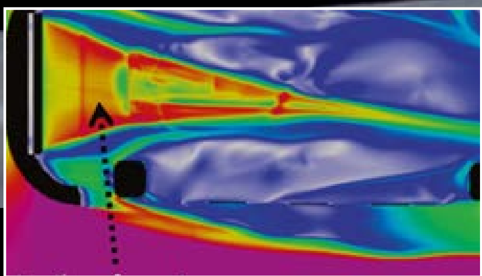
25 YEARS OF INSIGHT

January 2015 • Vol 25 No1 • www.racecar-engineering.com • UK £5.95 • US $14.50

World Champion!

Why Mercedes dominated Formula 1 in 2014





Sauber C33

Swiss F1 team pays the price for late delivery of power units

Aero investigation

NASCAR studies what happens when stockcars slipstream

Scion Racing tC

Examining the technical challenges of US drifting

NEW

The Dry Sump Vacuum Race Hose

ProPLUS Xtreme

A high flowing, smooth bore, PTFE tube with external convolutions for flexibility. No internal convolutions that can cause flow restrictions.

An engineered design with an externally wound stainless steel wire that provides great vacuum support and tight bend capability.

A choice of lightweight braids:
XM - XtraTemp Mono or XK - Aramid

An exceptional achievement in race hose technology... Perhaps perfection.

The evolution in FLUID HORSEPOWER™ continues...

Go to www.xrp.com to learn more about
the complete XRP ProPLUS Race Hose™ product line.

Like us on Facebook/XRPinc

Follow us on Instagram @XRPracing

USA	XRP, Inc. tel 562 861 4765	sales@xrp.com fax 562 861 5503
EUROPE	JLS Motorsport tel 44 (0) 121 525 5800	motorsport@lister.co.uk fax 44 (0) 121 525 4833

XRP®

THE XTREME IN RACECAR PLUMBING

CONTENTS – JANUARY 2015 – Volume 25 Number 1

COVER STORY

8 **Mercedes AMG W05 Hybrid**
Looking at the conception and gestation of Mercedes' dominant Formula 1 title-winning car

COLUMNS

5 **Ricardo Divila**
How to stop cars going 'splat' using wind tunnels

7 **Mike Blanchet**
Why F1 should reduce the engineering influence on the driver

FEATURES

16 **Mercedes High Performance Powertrains**
Discussing the most potent powerplant in Formula 1 2014

22 **Sauber C34**
How a team went from top six to bottom of the heap in 2014

28 **US Drifting**
How advanced are drift machines, and are they really racing?

35 **VW Golf**
Prodrive's Golf Mk VII

TECHNICAL

41 **Consultant**
Spindle inclination splits and driveshaft packaging

45 **Databytes**
Configuring traction control

49 **Aerobytes**
A final look at the Team Bath TBR14

52 **The secret of Mercedes' Formula 1 exhaust**
Cranfield's finest crack the code

63 **NASCAR CFD**
NASCAR's own study into drafting and how to improve the racing

71 **Transmissions**
The latest from the world of geartronics

77 **Danny Nowlan**
Balancing a Formula 3 car using ChassisSim

BUSINESS NEWS & PEOPLE

82 **Industry News**
Red Bull bill eased; Honda F1 hits track; Williams talent search

86 **Racecar People**
Malcolm Wilson; all the latest people moves

91 **Products**
The latest products and services from the world of motorsport

94 **Autosport International Show**
Our four-page preview to Europe's biggest racing show

98 **Bump Stop**

SEE THE ST6 SERIES: **PRI 2014 INDIANAPOLIS** WEDDLE INDUSTRIES **BOOTH 4653**

BORN FROM V8 SUPERCARS

THE ALBINS ST6 SERIES
Strong, compact 6-speed sequential transaxles developed for Australia's V8 Supercars. The ST6 line features roller bearings and straight-cut, profile ground gears that are shot peened and isotropic polished to reduce drag. Standard drop gears allow quick, simple ratio changes. Inspection ports that make for easy checks without disassembly.

The Albins ST6 can be configured to suit many custom applications.

The ST6
Developed for Australia's V8 Supercars, the ST6 is a strong, compact 6-speed sequential that delivers lightning, fast shifts. Standard drop gears allow efficient ratio changes.

For front-engine, rear-transaxle applications

The ST6-i
Robby Gordon's choice for his 2013 Score Baja 500 winning Trophy Truck. Six close ratio forward gears and a heavy duty drop gear set to reduce the overall final drive ratio.

For front-engine, rear-drive applications

The ST6-M
The ST6-M borrows the proven 6-speed sequential gear section from the original ST6, but relocates the ring and pinion to make it suitable for mid-engine applications.

For mid-engine applications

For inquiries, contact:
info@weddleindustries.com | 805 562 8600

WEDDLEINDUSTRIES.COM

WEDDLE INDUSTRIES

Answers in the wind

Wind tunnels were a product of the Wright brothers' ground-breaking work

Lear: *Blow, winds, and crack your cheeks! Rage! Blow!*

One of the perks of being an engineer is that you get to play with cool equipment, like wind tunnels. The tunnels I have had the chance to work with were Dome, CTA, Windshear full scale, Porsche Weissach full scale, Imperial College Honda, MIRA full scale (7.9m x 4.4m), MIRA small, Southampton RJ Mitchell 7ft x 5ft, FondTech, Ruag, St Cyr full scale, Ligier (now ACE), Oppama full scale, GIE S2A.

All of these are dwarfed by NACA's 80ft x 120ft (24m x 36m) wind tunnel at Ames Aeronautical Laboratory, California, the world's biggest. Its largest section is 173ft wide by 132ft high (52m x 40m) where at top speed the air is moving at about 35 to 40 miles per hour. The rapid contraction of the throat speeds up this airflow to more than 115mph in the oval test section (185km/h). The tunnel encloses 900 tons of air, 60 tons of which rush through the throat per second at maximum speed. It is big enough to test a Boeing 737. This uses a common, six-fan drive system. The 40ft-diameter fans have 15 blades and at full power, turn 180 revolutions per minute, using 104 megawatts of electricity or the equivalent of a 225,000-person city. These same fans also power a secondary tunnel with 40ft x 80ft (12m x 24m) test section that can run at 400km/h. Being operated by NASA, and being deemed of national security importance, I doubt I will be working in that one soon.

Coming from an aircraft design background, the wind tunnel is a fundamental piece of equipment, and probably why the Wright brothers managed to get man off the ground first in an engineering way.

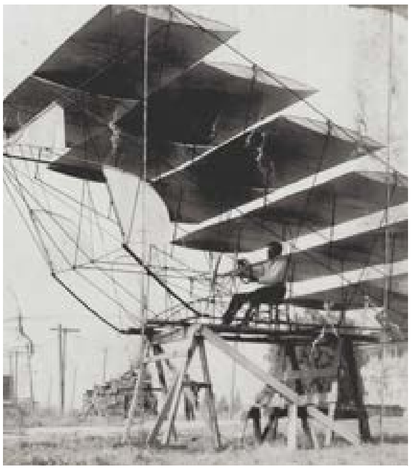
Previous thinking was that, as most animals that can fly have wings, so the thought was about developing strap-on wings. To test a particular design, they'd go to the top of a tall structure, and jump. Wrong assumptions had predictable consequences, otherwise know as 'splat'. The other approach was to create elaborate flying machines, which often didn't survive the testing process.

The Wright brothers approached the problem via a relatively simple, low-risk way to test their assumptions. They built and flew kites. Not only could they build kites more rapidly, but also they didn't risk physical integrity or reduced bank accounts if they were wrong. They speeded the learning process. In 1901, using a wooden box, a hacksaw blade, bicycle-spoke wire, and a fan, they built a six-foot long wind tunnel. One month was enough to fine-tune it and test assumptions about design. It allowed them to see how different profiled wings would perform without losing a complete craft ('splat').

Analysing the data that came from their rapid experiments accelerated the Wright brothers' path to developing a viable flying machine. Wilbur wrote: 'It is doubtful anyone would have developed a flyable wing without first developing this data.'

They tested more than 200 types of wings in two months, including models proposed by other wannabe aviators, carefully measuring the aerodynamic lift of different designs, Wilbur later recalling that they learned that most of the mathematical assumptions used about how different aspect ratios would affect lift were 'full of errors'.

Adding Gurneys to aileron tops solved this, my contribution to general aviation



The Divila-patented flying machine of 1897. No crops were sprayed on this day…

In motorsport this new tool took some time to be fully developed, factors such as Reynolds numbers for scaling up effects, getting a constant flow, boundary layer control and measuring the forces, plus maintaining constant temperature in the vane being small blips in the process. The art of producing scale tyres that mimic the deflection of real tyres is a major art in itself.

All this was still a factor in the 1970s, as on one occasion, while using a tunnel which will not be named, I found that using a primordial computer to process the data in real time, rather than waiting for the data to be processed later on and mailed to us brought up the fact that measurements had a peculiar shift at given times, highlighted on the graphed printout, and coinciding with meal times.

This was traced to the fact that the scales were attached to the floor and also to the ceiling beams, and that having a canteen on the floor above would shift the calibration zeroes given the weight of 80 odd people trooping in and out, correlation being normal during weekends, with no canteen service. As knowledge is power, we simply put in a fudge factor coupled to the time of the day, and let the other F1 teams that used the tunnel merrily go on with their job churning out false data, after all: 'All's fair in love and racing.'

Other issues can cloud results. The CTA tunnel in Brazil was accurate enough, but the depression in the expansion part downstream was enough to suck in water through the porous concrete of the tunnel walls, giving a fog when slowing down after a run if it had rained.

As a side note the aerodynamicists at the tunnel kept assuring me that the Gurney flap was a draggy add-on, but when they grasped that it was due to wing overhang regulations limiting the position of the rear wing and that cars, unlike planes, cannot change incidence for different speeds, so stall speed lowering improved their action.

The resultant excitement of the discovery actually solved a problem on a crop-spraying plane being tested at the tunnel, where the end of a spraying run would make the outer wing run at a higher speed than the inner wing, and the resulting asymmetrical drag on outer wing from the lowered aileron would make the yaw response slow down. Bingo, adding Gurneys to the aileron tops solved all these problems. My contribution to general aviation!

Some other automotive tunnels have had "issues", as cockups are known. An F1 tunnel had a square section and the resonance pulsing of these walls gave very bad flow control. The give-away was that the tunnel was not used by the F1 team that had commissioned it - they testing at Southampton - but a team that rented it had a dreadful year when all the data used was palpably bad, judging by the results.

Southampton was a particularly good tunnel, probably serendipitously, as it had originally been a tunnel to test sailing ships, and consequently the need for a 7ft x 5ft section, which came in very handy when wings and diffusers starting producing a major upwash.

Ultimately CFD will replace tunnels and full scale testing as software improves and Moore's Law adds computing power. Marzotto's optical intuition does not cut it for racing car shapes…

Bob Dylan explained it well:

'The answer, my friend, is blowin' in the wind
The answer is blowin' in the wind'

World wide dealer inquiries invited

PowerStream

GEO

2015 GEO Systems

Motorsports Test Equipment

Electromechanical and Electromagnetic operation

Discovery

Kinematics, Compliance & Dynamics

8 Post 26 Axis

No outdated hydraulic systems utilized

Diagnosis in-excess of 40 Critical chassis and suspension conditions

Clean, Quiet, Safe and Precise

No Data Clipping Required

Fastest DAQ System

Expandable with Full Native Data Integration

Insight

Kinematics & Dynamics

4 Post 12 Axis

- 3 Dimensional Center of Gravity
- Multi-Angle Loading Wheel Pads
- Floating Multi-Axis Towers
- 18" Aero Loading Range
- 36" Vert. Wheel Travel Range
- Road and Track Profile Testing
- High Speed DAQ System

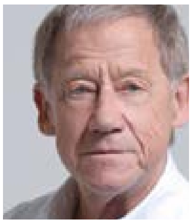
ahead in every measurable way

World's Most Advanced Motorsports Kinematics, Compliance and Dynamics Test Systems

www.powerstreamindustries.com

cmeurett@powerstreamindustries.com

Ph. 704-888-9930



Let's keep it real

Motorsport is in danger of sleepwalking into a driver-engineer imbalance

I offer no apologies for again making F1 the subject of this column, because many technical and sporting decisions made in F1 soon flow downstream to other categories.

There has been criticism, and even some derision, aimed at the FIA's recent curbing of engineer-to-driver radio transmissions that contravene the regulation that 'the driver must drive the car alone and unaided'.

It is true that the measure has been – as unfortunately is so often the case – introduced too hastily and without being thought through, hence a number of retractions and delays until 2015. But those who think it shouldn't be an issue and is a fuss about nothing are missing the Big Picture. Whoever raised the subject with the FIA, whether Bernie Ecclestone or another, has hopefully realised that motor racing at this level is in danger of sleepwalking into becoming overwhelmingly an engineering contest over a driver one. It should surely be a sensible balance of both.

I'm certain I'm not alone in being amazed by the often fatuous radio instructions from engineers to drivers that increasingly have been part of F1 television broadcasts. "It's raining harder, be careful"; "You need to pass the car in front of you"; or another gem – "Push hard but save the tyres"; one gets the impression that some engineers are quite desperate to have their voices heard by the listening millions. Egos are not limited to the stage performers, after all.

Hired to drive

However, this is just an irritation, no doubt to drivers also. These erudite engineers simply need to be "Kimi-ed". What is much more significant is when the driver is being literally told HOW to drive the car – to alter his line in certain corners, how to best manipulate the various power unit and DRS functions now available to him, where he should be able to brake later/accelerate earlier. The argument might be that he can get this data anyway from downloads when in the garage all through practice and qualifying – but the key difference lies in having this information radioed through continually during the race itself, when conditions are changing. A driver of the top rank should be making these decisions unaided, as part of his exercising of the ability and experience for which he has been hired.

The trend of reducing the driver control and decision-making in favour of transmitted computational analysis has been obvious and increasing for a long time, despite some partially-successful curbs being introduced. How much more driver input will continue to be taken away? Already the skill sets that give a gifted driver an advantage over those less endowed have been substantially eroded. Clutch bite points adjusted on the formation lap in preparation for the start is virtually launch control – getting off the line used to be a significant driver skill, not a software battle. No coherent argument for improving automotive technology can be put forward here, and it just increases everyone's costs. Programmes that monitor the changing grip levels during the course of a race so that the same amount of right foot application by the driver is automatically modulated in terms of actual throttle response – isn't this a form of traction control, supposedly banned? – is another. Ultra-fast computational technology now exists to the extent that it can only be a matter of time before sensors will continuously detect the key factors involved in establishing braking distances for each corner, the computer will analyse them in milliseconds and a light on the dash will dictate when to brake. The logical extension of this will be to tell the driver when to turn into the corner and then get back on the gas (assuming that he or she is brave enough to obey). At what stage will drivers, like today's fast-jet pilots, be mainly managing the on-board systems and the tactics while letting the machinery look after itself? An engineer's dream perhaps, but not one for fans, let alone drivers.

At what stage will drivers be managing on-board systems while the machinery looks after itself?

Leading Formula 1 engineer Rob Smedley of Williams contemplates tactics at this year's Bahrain Grand Prix

High-torque iterations

Some drivers and engineers have stated that without all the electronic aids, including live instructions to drivers, F1 cars in their latest high-torque iterations would be virtually impossible to control. I don't recall this being the case during the last turbo era, when boost was much higher and those 1,000bhp-plus engines still used relatively crude fuel injection and throttle systems and any form of traction control other than the driver's senses just did not exist. Yes, rear tyres were wider but tyre technology has come a long way since then, as have levels and characteristics of downforce. You can only conclude there's a lot of bull about, and it is the engineers, admittedly responding to the regulations, who have painted themselves into this corner and if forced to do so would design power units that were less critical in their performance characteristics.

It is to be hoped the FIA will stand firm on restricting live information transfer to drivers, although it needs further thought and revision, so that it may herald additional containment of technologies that detract from the human challenge that should form the basis of all sport.

Meanwhile, relevant to the points raised above, how does the FIA justify allowing a 17-year-old to compete in F1 (the ACO, even more controversially in my opinion, permitting a 16-year-old to race in the Le Mans 24 Hours)? Leaving aside arguments regarding capability, maturity, and the complete undermining of the Superlicence rationale, motor racing will always live a little under the shadow of the 1955 Le Mans disaster. In the wake of Jules Bianchi's horrendous crash at Suzuka and the attention it has drawn, pause for a moment and think of the consequences for motor racing generally if a headline incident occurred that involved such a young driver as Verstappen, wherever the blame might actually lie.

A mandatory 18-year-old minimum age limit for all senior categories of racing must make sense, regardless of ability.

Way out on their own

First out in last winter's tests, the W05 Hybrid took a lead over its rivals that it was never to relinquish

By SAM COLLINS

On a chilly day shortly before Christmas in 2012, a new model was bolted into place in a wind tunnel on the outskirts of Brackley, a small town in the centre of England. That model was to form the basis of what would become one of the most successful grand prix cars of all time, the Mercedes W05 Hybrid.

As other teams struggled to even complete their cars, let alone shake them down, the latest Silver Arrow was the first car to take to the track in winter testing. After watching it drive out of the pit lane, Toto Wolff, head of motorsport at Mercedes-Benz turned to the journalists stood alongside and joked 'now we are leading the world championship!' It was a lead that Mercedes would never relinquish.

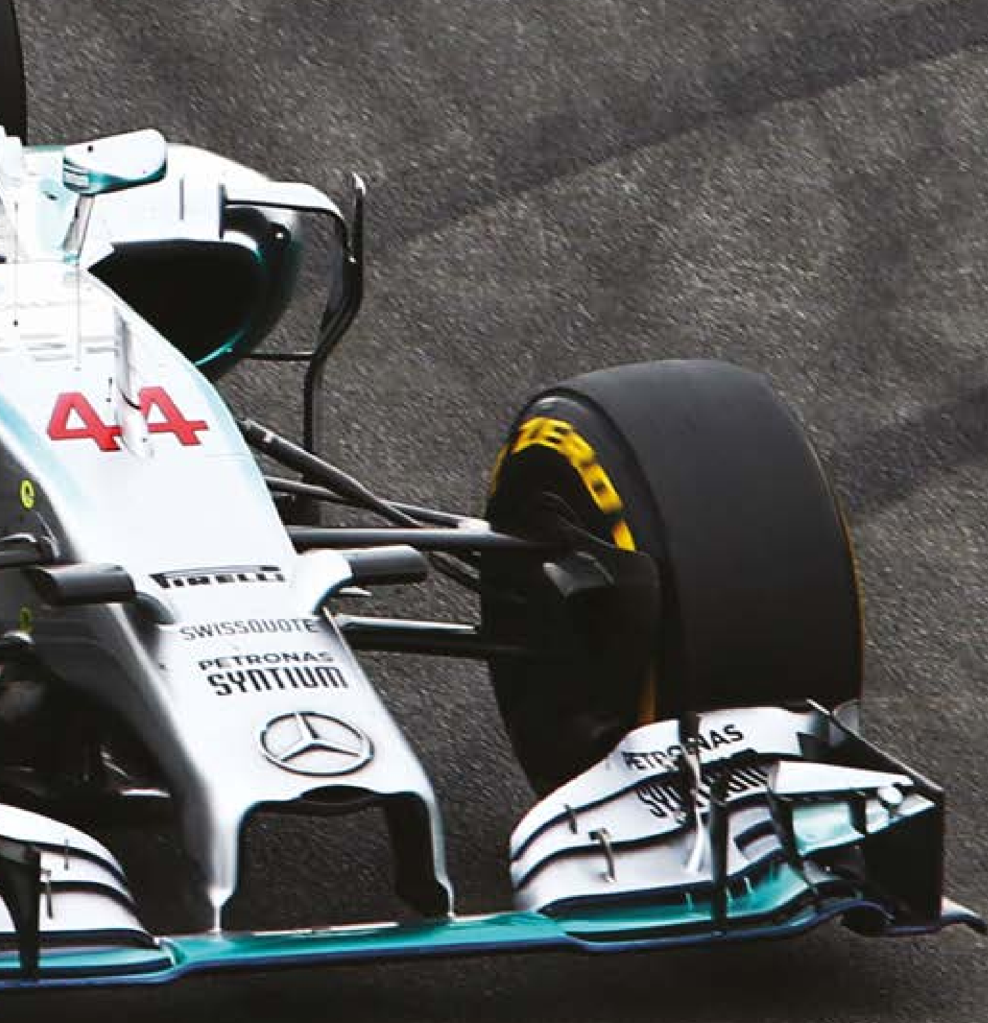
On the face of it, the Mercedes W05 Hybrid is a fairly conventional 2014 grand prix car, with pushrod actuated dampers on the front suspension and a pull rod actuated rear, the composite monocoque chassis carrying the 1.6 litre V6 engine as a fully stressed member driving the rear wheels through an in-house eight-speed sequential transmission. But the detail is where this car has made the biggest gains according to Mercedes AMG F1 team technical director Paddy Lowe: 'It is by far the most complex car I've worked with but at the same time, it is the most elegant.'

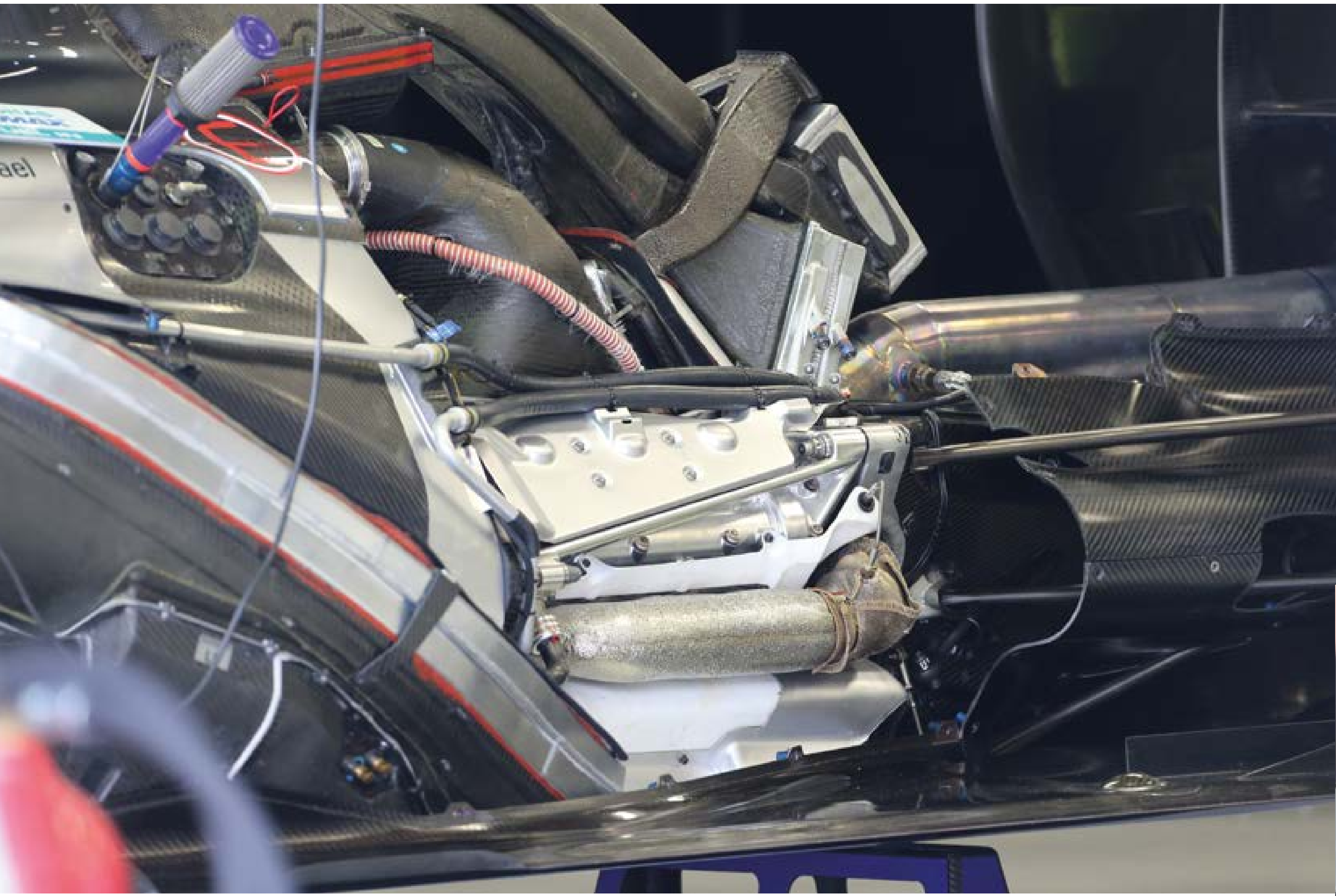
A quick look under the bodywork of the W05 bears that out, where every other car on the grid has a cluttered array of electronic boxes, wiring looms and various plumbing elements scattered all over the place, especially in the side pods, the Mercedes is exceptionally neat and tidy. It is without doubt the most integrated design of the 2014 season with a symbiotic relationship having been created with its power unit designers at Mercedes AMG HPP (see p16).

'Successful cars do not just come from nowhere,' Lowe continues. 'There is a sequence of building blocks that you need. One of those areas was aerodynamics. Putting the team together to get the aerodynamics right was done two or three years ago by Ross Brawn and Bob Bell. In 2012 the Mercedes was not a great car aerodynamically, it was well behind. By 2013, the team was getting pole positions and winning races against Red Bull when engines were not a big performance differentiator. So, that showed our growing aerodynamic confidence and the 2014 aero package was a result of that development. We took the understanding from that and applied it to the new efficiency formula, which gives you a different slant. As a result there is a huge amount of family resemblance between the W04 and W05 Hybrid.'

One of the most distinctive aerodynamic features of the W05 is its low nose. Clumsily written rules for the 2014 season saw many teams adopt oddly shaped front crash structures but Mercedes instead adopted wider low noses for 2014, to the relief of the marketing staff. 'The team looked at all sorts of designs, though I'm not sure they came up with the full range of ugliness. But the solution we have came up with was the best on the numbers in terms of aero, so it was quite pleasing to know that not only is it the best looking but it is also the best aerodynamically,' Lowe chuckles.

"It is by far the most complex car I've worked with, but at the same time, it is the most elegant"





The power unit installation – note also the gearbox cooler mounted at the rear of the engine in typically compact design

The nose that was fitted to the W05 at the start of the season, however, was not the design the team had first intended to fit to to the car. That design did not appear until the fourth race of the year at Shanghai. It had failed its mandatory crash tests, so a similar-looking but less effective version had to be deployed in winter testing and at the opening races.

'We had two or three attempts at the crash test, there are a number of test points, and there is a lot of vibration during the test,' Lowe admits.

'The experiment is noisy because of the vibration, so you can be unlucky in the way the results go, but I don't think that the nose there was any more marginal in terms of safety than the others, which passed first time. It just did not go through on all the measures, so we had to tweak it a bit.'

The team also introduced a third nose at the Belgian Grand Prix which it continued with until the end of the season. While noses are a structural part of the car, serving a safety purpose they are dominated in design terms by aerodynamic demands. The high level of integration of the W05 sees the influence of CFD and wind tunnel runs on almost every part of the car from the exhaust manifold to the front suspension.

Tuning the airflow

The Mercedes suspension layout is conventional on paper with double wishbones front and rear, although the lower front wishbones are quite unconventional when studied in detail. They are solid with no gap for about two thirds of their length before splitting roughly 15cm away from the inboard pickup points, in an attempt to tune the airflow ahead of the side pod. 'Suspension is mostly aerodynamically driven these days – yes it is a structural challenge but it is mainly for aerodynamics,' says Lowe. At the rear, the suspension has had a knock-on effect on the transmission. The W05 Hybrid, like the W04 is fitted with a titanium gearbox case mounted inside a structural composite outer sleeve which is fitted with the inboard suspension mountings. 'One of the features of the casing is that it allows more flexibility of how we configure it,' Lowe continues. 'There are a number of reasons you might want to change things. Changing camber rates is probably the biggest change people do. We have had a couple of variants with ours but not a huge amount.'

"In 2013 we had a car that was able to get pole positions but we were painfully aware of the deficiencies in terms of tyre endurance"

One of the reasons for this approach was to overcome one of the team's main Achilles' heels of recent years, namely how it used the tyres. Using the casing in this way would let the Mercedes engineers change the rear suspension design without having to re-crash-test the rear of the car.

'This team had been pretty poor at getting the best out of the tyres by reputation; that had been the case since 2010,' Lowe admits. 'In 2013 we had a car that was able to get pole positions but we were painfully aware of the deficiencies in terms of tyre endurance. So with this car we have put a lot more effort into that. When I arrived here last year I was incredibly impressed by the degree to which the team had invested in and understood the tyres. The team was unlucky

The W05 Hybrid gearbox features a carbon fibre outer case and titanium inner. Note also rear brakes setup

The space under the sidepod area of the car is exceptionally neat and tidy. Visible are the heat exchanger and the upper and lower side-impact structures, which are common to all 2014 F1 cars

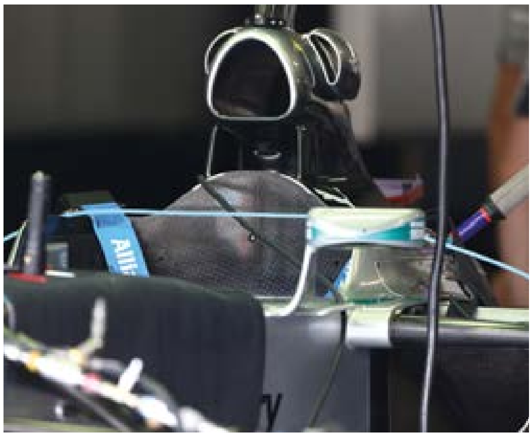
in 2010-2012 because the DNA of the car just did not suit the tyres, but in that context the team built up a much better level of R&D and understanding perhaps than other teams, and through 2013 that was turned to an advantage.

'Into the 2014 season we perhaps make the best use of the tyres in the pit lane, in terms of both performance and endurance.'

While the Pirelli rubber has not been the centre of attention in 2014 in the way it was in other recent seasons, Lowe still believes that one of the biggest advantages his team now has is that understanding of the tyres and how they operate. 'It is not that obvious. Cars, and different aspects of cars, can be good or bad by luck. There are cars that have won championships where people strut around and pretend that they know it all, but in reality they have benefitted from things that are around that they did not really understand and often that is centred around tyres. There are so many parameters on these cars and so little opportunity to test so many of those parameters carry from year to year, they become part of the car's DNA.

'Tyres can make or break championships and that has been the case for 20-30 years,' says Lowe. 'They are the most complex part of the car, just because it is so weird and dynamic and hard to pin down. There was one car very recently that could go very long on tyres, and make perhaps one stop fewer than the rest, but if you asked the engineers behind it they couldn't tell you precisely why it had that characteristic.'

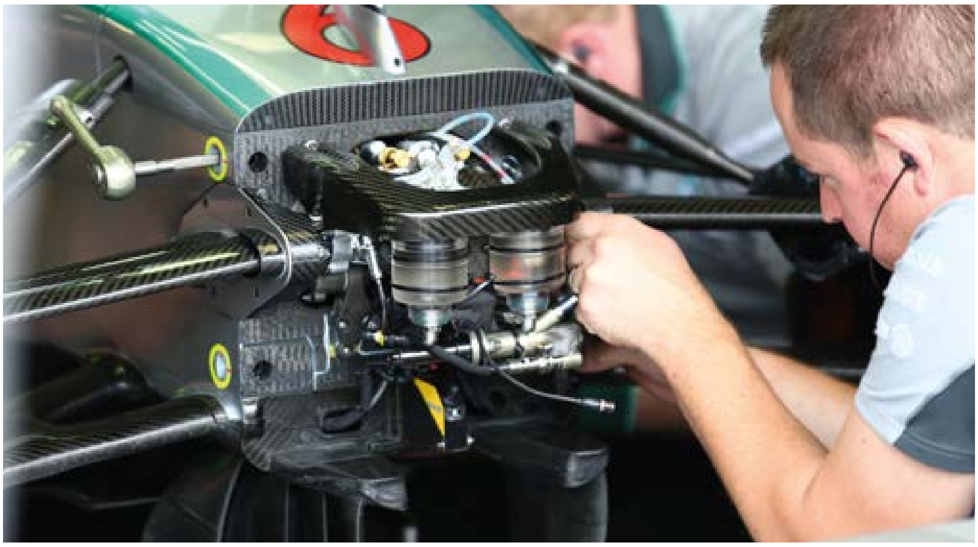
From the beginning of the design phase of



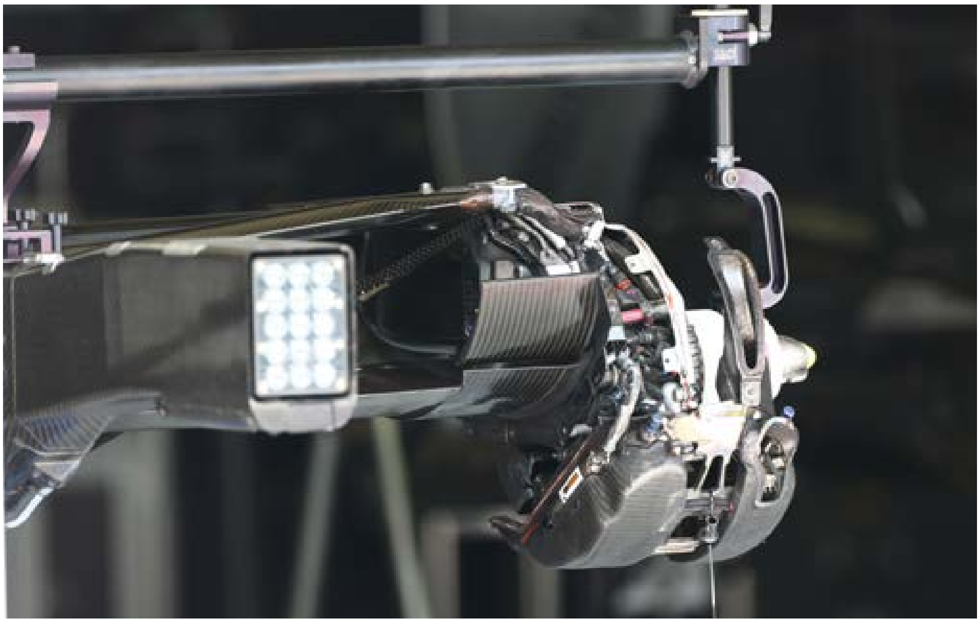
Roll hoop of the W05 Hybrid features the main engine air intake as well as cooling ears for other sub-systems at the rear of the car

The suspension of the car has been defined by aerodynamic factors. Note the unique lower wishbone design

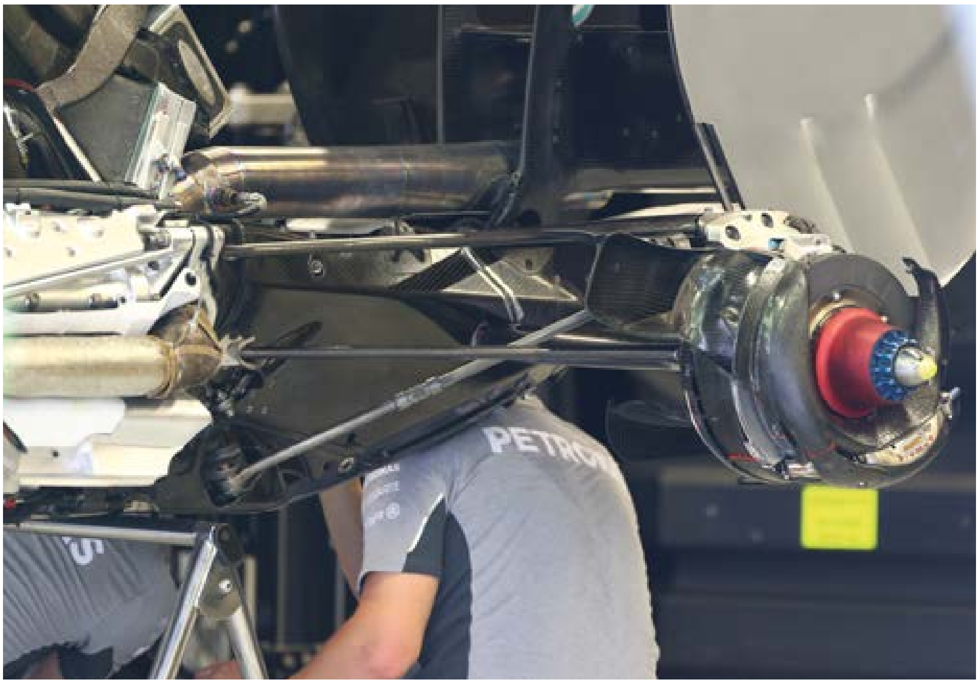
the W05 Hybrid, the chassis was designed to be equipped with hydraulically interconnected suspension (FRIC), something Mercedes had fitted to all of its recent designs. But mid season the FIA issued a statement suggesting that they felt the concept was illegal, despite the fact that every car on the grid was equipped with it. While it was not banned, no team took the risk of running it again, and Mercedes removed the system from the car. It was suggested by the media that this was an a bid to reduce the



The front bulkhead, with master cylinders evident, shows typical clean Mercedes lines



The car's rear brake setup with aerodynamic elements added



Pullrod rear suspension layout with inboard pickup points evident

advantage that Mercedes had over the rest of the field, up to one second a lap at some circuits, but the reality was different.

'Taking it off slowed everyone down to some extent, but it's hard to assess by how much,' says Lowe. 'It may have hurt us more than anyone else slightly, but it's not that clear cut. I think perhaps Williams suffered the least but they may have just been improving anyway.' The systems featured a significant amount of hardware under the bodywork and the removal of it had an unexpected knock-on effect. 'There were things we could put in the space left by its removal in the side pods, so we fully exploited that, but the biggest thing was the weight loss. Secretly all of the teams were a bit happy that it happened because it gave a welcome relief on the weight campaign, which had been pretty intense up to that point,' Lowe admits. Reportedly the drivers very much liked the ban on the systems too, as they were not being pushed too hard on their own weight – Pizza and Haribo reappeared in diets! Up and down the grid, drivers had been given weight targets by the team engineers who had been struggling to get the cars down to the 691kg weight limit while staying within the limited weight distribution of 314kg front and 370kg rear minimum.

Weight predictions

'Weight was a massive challenge,' Lowe continues. 'It's difficult to know who was suffering the most; it was the toughest its been for at least a decade. But we got there and the car is under the limit and inside the weight distribution window, but it's not always that easy, there are always things you can take off these cars that you would rather not. We had to do a lot of close management of components and do more intense and detailed weight prediction exercises than ever before. In accuracy terms we are within several kilos as there are always those things that get heavier or get missed. We are much closer than we have been ever before though.'

The Mercedes W05 Hybrid sealed both Formula 1 World Championships before the season was over and its lead was never seriously threatened. With stable technical regulations for the 2015 season, it has been suggested that the team could carry the car over, as some other teams are considering doing, but Lowe makes it clear that there will be an all-new car coming. 'We won't carry over much directly but a large amount of the car will be redesigned – that's what we do. There will be things like further weight saving, reliability and servicing improvements. The rule change on the nose will change some things aerodynamically too. We could carry over things like the transmission, but if we did it would just be performance we had left on the table, so we will improve the design. I have this theory that if you look at a two-year-old F1 car it looks agricultural. We talk about the W05 and its elegance now, and how it is the

Mercedes ran three separate nose designs over the season, with the final design (above) introduced in Belgium

Brakes and suppliers

The brakes of the Mercedes W05 Hybrid have been a topic of discussion frequently during the 2014 season, especially as it is one area that differentiates the team's two drivers. Mercedes uses friction material from two suppliers; Brembo, which also supplies the calipers used on the cars, and Carbone Industrie.

'We have been mixing and matching brakes all year, as all teams do,' explains Lowe. 'There is no perfect carbon material out there. All of the materials around have some advantage and disadvantage. It depends on the circuit, the weather, the duty cycle and even the driver.' At the German Grand Prix one of the Mercedes W05s suffered a catastrophic failure of one of its brake discs ahead of the race forcing the team to switch material in parc fermé, to the consternation of some of its rivals.

A statement from the team later suggested that the reason for the failure was the way the disc was fitted to the car and the structure of the brake material. 'Both parties can now confirm that the quality of the disc material was not a contributory factor – instead, extensive analysis and experimentation has demonstrated that the specific interaction between the structure of the brake material in question and the brake mounting on the F1 W05 Hybrid was at the root of the failure,' the statement read. 'Counter measures have already been applied to both the disc geometry and the mounting to ensure there can be no repeat of the failure.'

Indeed the failure never re-appeared though other brake issues did crop up from time to time with both material suppliers used on the car. 'One of the issues with Brembo material is that it is not as strong as the CI material' Lowe says. 'If you ally that to the increased cooling demand on the front axle, this due to the fact these cars are lower drag so can have higher speeds; end of straight things can be marginal. At the front it is a balance between structure and cooling volume with the discs. With that design that failed in Germany there were elements taken it too far in terms of the mounting, but we fixed it.'

Mercedes has used two different brake material suppliers throughout 2014

best car that has been seen. But once we have done the W07 we will look at this car as crude and old fashioned; that is Formula 1.'

So, the Mercedes W05 Hybrid will never be the most successful Formula 1 car of all in terms of race wins, a title still held by the Lotus 72 with 20 victories. As good as this car was, Lowe says that its successor should be even better. 'You can't pin down why it is, but it is – all the engineers here, their spirit of innovation and pushing the boundaries is why the Mercedes W06 will be a more sophisticated and better car than the W05.' The dominance of the Silver Arrows looks set to continue.

TECH SPEC

Chassis construction
Monocoque carbon fibre and honeycomb composite structure

Front suspension
Carbon fibre wishbone and pushrod activated torsion springs and rockers

Rear suspension
Carbon fibre wishbone and pushrod activated torsion springs and rockers

Transmission
Eight speed forward, one reverse unit with carbon fibre maincase

Clutch
Carbon plate

Dampers
Penske

Wheels
Advanti forged magnesium

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

Brake system
Brembo carbon/carbon discs and pads with rear brake-by-wire

Steering
Power-assisted rack and pinion

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
FIA SECU standard electronic control unit

Cockpit
Removable driver's seat made of anatomically formed carbon composite, Sabelt six-point driver safety harness, HANS system

Engine
Mercedes-Benz PU106A hybrid
ICE capacity 1.6 litres, six cylinders, 90deg bank angle, 24 valves
Max rpm ICE 15000rpm
max fuel flow rate 100 kg/hour
(above 10500 rpm)

Fuel injection
High-pressure direct injection
(max 500 bar, one injector/cylinder)
pressure charging: single-stage compressor and exhaust turbine on a common shaft
max rpm exhaust turbine 125,000rpm

ERS
Mercedes AMG HPP

Dimensions
Overall length: 4800mm
Overall height: 950mm
Overall width: 1800mm

The Mercedes power unit is full of innovation including split turbo concept (above) and log-type exhausts

Mercedes-Benz has dominated the 2014 Formula 1 World Championship, and the headlines have all been about the title winning Silver Arrows cars. However, the unit created to power it also powered three other chassis, all of which performed well during races. It is, according to some, the most efficient gasoline combustion powertrain of all time.

'At the start we simply did not have a clue where we were compared to the others – in hindsight though it's gone exceptionally well, but we have had a few wobbles,' says Andy Cowell, managing director of Mercedes AMG High Performance Powertrains. 'Exceptionally well' is quite an understatement, the Mercedes-Benz PU106A Hybrid powered every pole position lap of the year, a feat only achieved once before by the Ford DFV in 1969. In qualifying terms, the PU106A Hybrid is the strongest F1 engine of all time. Its overall performance was so strong that some called for a return to the obsolete V8 engines of the previous decade just to level the playing field.

The arrival of the new technical regulations that led to the creation of the PU106A Hybrid was convoluted, though the basic elements remained broadly the same from their first public discussion in mid 2008.

'At the start there were lots of hints from the FIA with regard to what the new regulations would be,' Cowell says. 'So we, like all manufacturers, did basic literature reviews and book research. You can have a couple of guys working on it but you don't really put effort in until you get final regulations and the project is signed off.'

When those final regulations were signed off it was clear that there would be some major changes. For the first time in years, grand prix engines would be ahead of their production car counterparts in some technological areas, while they would also follow the industry trends of downsizing and turbocharging. The FIA rules abandoned the high revving, normally aspirated 2.4 litre V8 engines that used port injection, in favour of a 1.6 litre four cylinder engine featuring direct injection and forced induction. It was initially meant to be an extension of the global race engine concept, first proposed by Volkswagen, but when that brand decided not to pursue a Formula 1 project moves were made to switch the engine configuration back to a V6. As many, including Mercedes, had started serious work on the four cylinder engines, the introduction of the new power units was delayed a year to 2014, so that they could start work again, this time on a six cylinder engine.

'This was many, many times harder than KERS or developing the V8, going from normally aspirated to highly boosted engines, and regulations going from rewarding volumetric efficiency to conversion efficiency,' Cowell reveals. 'We started with the key parts of the regulations, things like the 100kg/h fuel flow limit and the energy and power restrictions such as the MGU-K output, as well

Sharper **power**

Behind the resounding 2014 success of the Silver Arrows lies an incredibly efficient gasoline combustion powertrain

By SAM COLLINS

The Mercedes-Benz PU106A Hybrid powered every singe pole position lap of the year

as the system schematic that was given. You then look at the combustion process. That 100kg/h fuel flow rate sets the maximum chemical power level which equates to about 1,200kW. So if we managed to get 100 per cent thermal efficiency, we would have 1,200kW propelling the car along. We are not quite there. You start with things like that, then break it down. You know it has to be six cylinders, so one sixth of that; then you look at the balance of turbocharger back pressure and MGU-H harvest and how you do it for the best overall lap time. All the circuits are different, but the ERS energy numbers are lap based, so Monaco (the shortest circuit) is quite different to Spa (the longest). But you want to win the championship, so you have to look at what the average is. Then there was lots of optimisation broken down into smaller systems, 1/6th of the ICE. That optimisation was all based around winning the championship, not a specific race. We then create specification documents with big hairy audacious goals.'

From those calculations, plus other details in the regulations which define much of the engine's architecture including the V-angle, cylinder bore diameter, centre of gravity and even the crankshaft centreline height, you can define the architecture of the engine.

'We had a target performance that stretched every single area; once it's broken down to system level you have experts in those fields driving the creation and development of those systems. You encourage ambitious thinking and sit in performance meetings when you say we need to try and get there and nobody has a clue how they are going to do it.

'We got pretty close to the targets we set. We probably set higher targets than the others as we very much have an attitude of 'shoot for the stars and you will clear the trees'. As long as you are giving it everything to hit a stretched target that's ok,' Cowell enthuses.

In addition to the internal combustion engine an advanced hybrid system would have to be developed, using a unique variant of turbo compounding. It gave the engineers researching the project something of a difficult task.

'Mechanical turbo compounding is used a lot in the truck world because they spend a long time at high power outputs, so people like Cummins have done work there but an electrical turbo compound like this is unique,' Cowell continues. 'E-booster systems are coming into the road car world though, where there is a trend of downsizing engines and down-speeding them, then boosting them to get the power level up to a level that the driver finds acceptable. The turbos in turn are getting bigger to get that power, but the driver would find the level of lag unacceptable, so electric motors are used to drive the compressor to augment the inlet charge pressure before the turbo kicks in, but these are a handful of kilowatts – ours are a lot more!'

Mercedes took a decision to bring all of its hybrid development in house early on in the

The PU106A Hybrid was installed in four different chassis – McLaren, Williams and Force India (above), but was fully optimised around the Mercedes chassis

project, something that led to major changes to the home of Mercedes HPP in Brixworth. 'This is a real hybrid. In the summer of 2010 the decision was made that KERS would return in 2011, but at that point we had also started the SLS AMG electric drive, and the decision was taken to invest in the facilities here to do the SLS and the KERS so the learning from both would go into what was then a 2013 power unit,' Cowell says. 'The knowledge of engineering high efficiency electric machines, the power electronics to go with them, the high power and energy density of a battery system, that knowledge was ingrained in the business. You need guys who know what state of the art is and how to push it. You need to turn that into CAD models and circuit diagrams. You also need a supply chain infrastructure which can make it or buy it, and manage the quality of that. Finally you also need the infrastructure to test it and you also need guys to keep it working at the track.

'So doing KERS in '11, '12 and '13 with six cars helped embed that. It is really a mechatronics project – this blend between mechanical and electronic engineering. The people from both sides had slightly different personalities but we have a blend and understanding that gives the best of both of them.'

While Cowell is not willing to disclose much detail of the MGU arrangement on the PU106A Hybrid it is known that the MGU-H is mounted in the V in the centre of the ICE, while the MGU-K sits under the left exhaust manifold. The installation and location of these components hint at one of the main driving forces behind Mercedes development of the new power unit.

'This is a Silver Arrows car that has been created by one group of engineers that happen to be in two places,' Cowell explains. 'They work incredibly closely together to think about ideas and innovate together. It is all about the integration, the decision to be a team rather than an engine supplier. It was one group of engineers with one mission; make the fastest car. It was all about combining the best of all of the parts, and that is hard to split out. If you isolate things then perhaps they can't be seen in context. If you lose a bit of downforce by putting a bump in the bodywork to accommodate some sort of widget to give you an extra 10bhp, is it better to have the extra power or the extra downforce? There are lots of trade-offs like that, so it's incredibly hard to look at the power unit in isolation from the chassis.'

This led to many runs backwards and forwards between the Mercedes chassis organisation at Brackley and the engine organisation a few miles away in Brixworth. 'When you are creating a system there are a handful of things that every technical director on the chassis side wants,' says Cowell. 'He wants lots of power, he wants it there all of the time, he does not want it to be overweight, the centre of gravity needs to be as low as possible and the volume you take up in the car needs to be as low as possible. In addition the heat rejection needs to be as low as possible, and normally the fuel consumption needs to be as low as possible, although it is not an issue in 2014 as the regulations dictate it. Those things have not really ever changed. You chase all of those things while trying to have little impact on the rest of the car. Chasing all of those things with these rules gives you some novel features.'

Brand new design

One of the first and most discussed novel features of the PU106A is its turbocharger, which splits the compressor and turbine, the former mounted at the front of the engine block and the latter at the rear with the MGU-H sat on a clutched shaft between the two sides.

'The engineers loved going right back to first principles, we can do maths, we can read papers, we can do physics. They were all up for learning, and innovating,' says Cowell. 'There were only about two people here who had ever worked on turbochargers before, and nobody had designed one before. Yet we designed our own for this power unit because we realised it was going to be a performance differentiator. The guys doing the design work also worked very closely with Daimler and their turbocharger expertise, and there are some strong relationships now on both the thermodynamic side and the dynamics and the mechanical design. It's a truck turbocharger in size terms.'

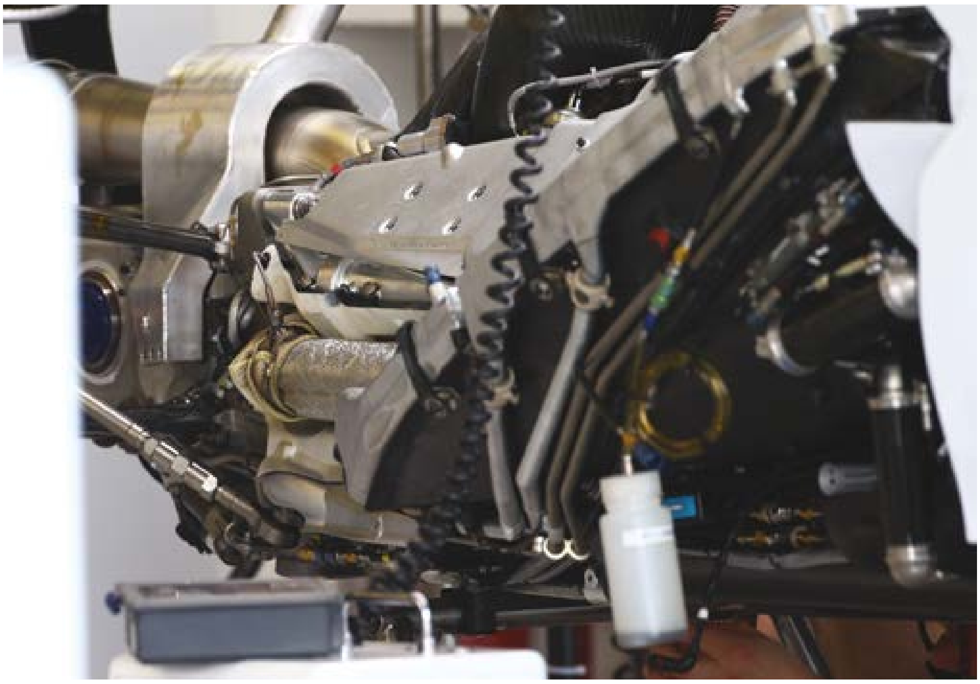
It is thought to give a cooling benefit as well as an installation benefit, but Cowell will not be

"Every technical director wants lots of power, he wants it there all of the time, and he does not want the engine to be overweight"

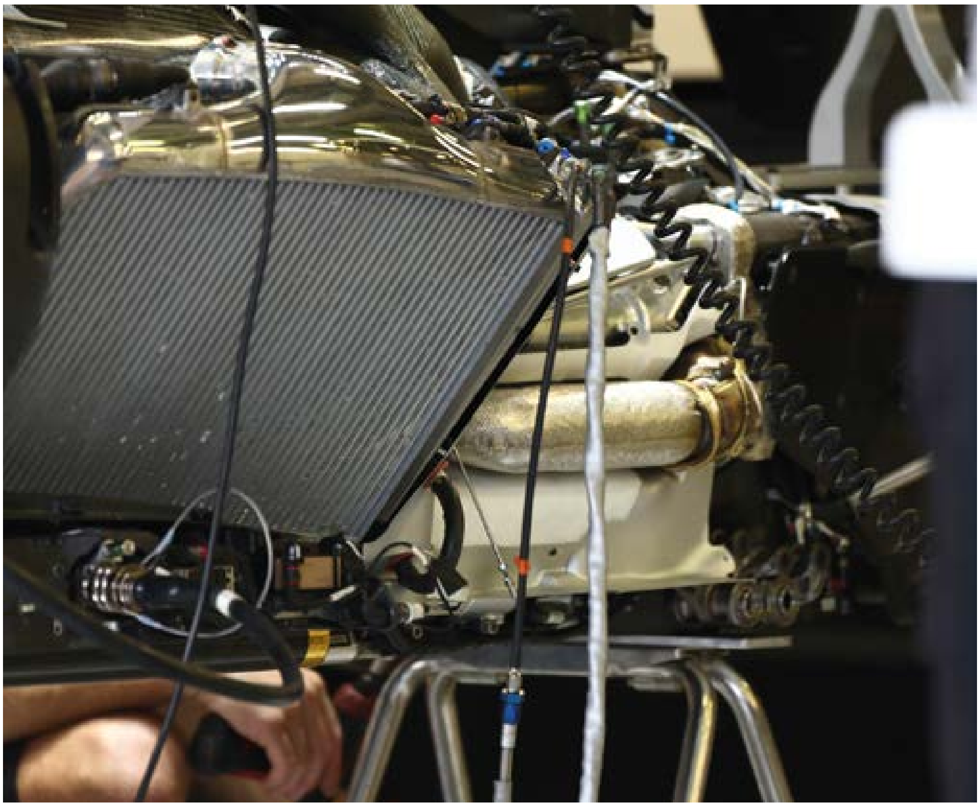
drawn on the specifics of the design. 'If you are creating a power unit you want people looking at it to go "Is that it? Is it that simple?" That's one of the reasons there is not a turbo poking out of the back. The engineers behind it though are an incredibly tenacious group and they really got stuck in. It made me smile when I first saw it.' While much has been written in the mainstream media after this layout was first revealed in RE V24N4 about the split turbocharger being the reason for the Mercedes advantage, according Cowell there are many other equally novel solutions in the power unit. 'Some things like the split turbo and the exhausts are visual so there is lots of discussion about them, but there are dozens more things buried below the surface,' he explains, but understandably declines to elaborate.

While the power unit was designed to be fully integrated with the 2014 Mercedes chassis it was also supplied to McLaren, Force India and Williams. These customer teams, have reaped the benefits of Mercedes' engineering work, but they are aware the focus is always on the works team.

'The customer's input is always encouraged and always welcomed, but the final decisions about the power unit are made around the information coming from Brackley, with the aim of making the fastest Silver Arrows car,' Cowell continues. 'But 90 per cent of the time that will suit the customer too. We made the call that everyone gets the same when we started out, so at winter testing this year everyone had the same specification. That also helps as it multiplies the amount of data you get by four and that was a help.'



Mercedes HPP embedded staff into its customer teams to advise on installation of the power unit, and the results were quite varied, especially in terms of cooling as can be seen with the Williams solution (above) and the McLaren (below)



Notably, one of the customer teams, McLaren, needed some additional work on their power unit. Mercedes developed the PU106A Hybrid to run on specially developed Petronas fuels and lubricants while McLaren stuck with its long term partner, ExxonMobil, and it has been suggested that this has caused something of a performance deficit for the Woking based team. But Cowell explains that a special project was undertaken to ensure that the McLaren performance was the best that it could be. 'We have had a really long relationship with Exxon Mobil, and it was clear that McLaren would continue with them so we did a separate project to our Petronas programme.'

There is a rumour in the F1 paddock that Mercedes has never run the PU106A to its full potential, and that it has always left a little in reserve. 'It is difficult to define full potential, is that over one lap and then it is dead or the whole engine life?' asks Cowell. 'As part of normal development we create something, then prove it out. As part of proving it out we run a few to death so that you have a lot of data points to create a reasonable statistical accuracy with how you run safely at the race weekend.'

Despite exceptional performance on-track, not everything was perfect. 'We did lots of running in the tests at Bahrain and lots at the factory, but when we got to Melbourne, the drop tube between the coil and the plug got a small split that the spark jumped through on the parade lap,' he says. During the year all engine manufacturers are able to make upgrades to the otherwise frozen specifications of their power units on the grounds of reliability, safety or cost and all of them have taken advantage of this. 'We have done some reliability and cost based updates. In all our submissions we say that there is no impact on performance,' Cowell admits. 'What you can do is look at reliability. Ferrari has been very reliabile, Renault has had lots of issues and I think that they were amazed that they had any cars finish in Melbourne. But the rate of fixing issues has been phenomenal.'

This means work has not stopped at Brixworth. And, while the PU106A has been described as the most efficient gasoline powertrain ever, the reality is that it is not. Sat in the dyno test cells at Mercedes is a more efficient and more potent power unit built for the 2015 F1 season. Having been built on the already strong foundations of the 2014 design, it will be hard to beat.

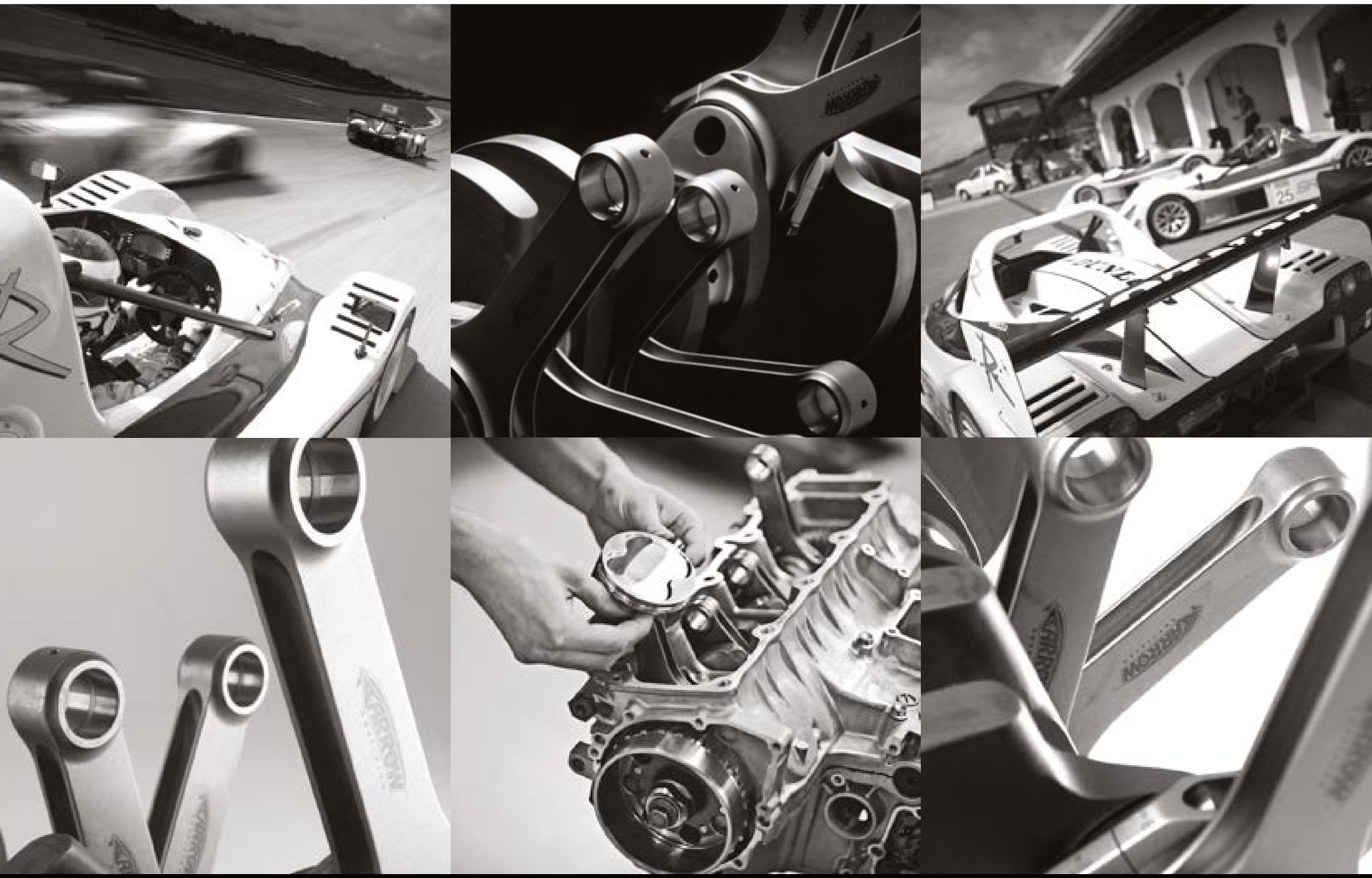
AT THE HEART OF THE WORLD'S MOST POWERFUL ENGINES.

ARROW PRECISION

Our commitment to engineering precision performance cranks, rods, cam followers, and other components has allowed Arrow Precision to supply the world's top motor manufacturers, tuners and engine builders. Give us your requirements and we will find a high-performance solution, no matter how extreme.

+44 (0) 1455 234 200

www.arrowprecision.com



BRITISH DESIGNED.
BRITISH ENGINEERED.

visit us at:

PRI 2014 Indianapolis
December 11-13, 2014
Indiana Convention Center • USA

AUTOSPORT INTERNATIONAL Engineering Show
8-9 January 2015 NEC Birmingham, UK

Penalty clause

Sauber has paid the price for the late delivery of the power units pre-season, and has struggled to catch up since

By ANDREW COTTON

Without prior knowledge of the power unit or its cooling requirements and weight, the team was flying blind

It wasn't so long ago that Sauber appeared to be knocking on the door of a top-five place in Formula 1 with Kamui Kobayashi and Sergio Perez, who propelled the team to sixth in the standings in 2012. Things could not have been more different in 2014, as the team propped up the standings and like Caterham, was unable to score a single point all season.

Sauber was, in many ways, the team caught out by the introduction of the new regulations. Without prior knowledge of the power unit or its cooling requirements and weight, the team was flying blind in the design of its car and, although it met its initial targets of running reliably, quickly realised that the performance was not there.

'When you have such a bad season it is not so straightforward to find a single cause,' says chassis designer Giampaolo Dall'ara. 'Normally it is a concurrency of things that go wrong. I think we have identified most of them. Some could be addressed, some could not and that is why we still sit at the bottom of the rankings.

'A year ago we had a fairly late start to the project. We had a late deal signed with Ferrari and we had to design the car around information that was obsolete. When the updated information came after the finalisation of the deal, some things had gone wrong. Then we got to Jerez, and the first test of the season was with a car that was not complete. Our strategy was to try to hit the track, but the changes to the previous year's car was huge, largely due to the regulations.

'The power unit was new, not only the hardware but the concept too. There was a job list on the testing side that extended from pure functionality and reliability tests to training the team what was going on.'

While the major challenge was getting the power unit, including the exhaust and transmission which all came from Ferrari, to work in the customer chassis, there was also the business of designing a car to the new aerodynamic regulations and, while the team believes that it lost some of its advantage of the rest of the field in the high speed corners, the car had a stable aero platform.

The new regulations stipulated that the width of the front wing be reduced from 180cm to 165cm, and clearly there was the drama of the new noses at the start of the year. The lower rear wing was also removed and the manipulation of the exhaust gasses was heavily restricted

The Ferrari 059/3 1.6 litre six cylinder single turbo power unit

Roll hoop with lights and camera housing. 'The need for cooling on these cars is remarkable compared with the past'

The Sauber sidepod with bodywork removed showing upper side impact structure – but with the lower removed. 'On the car side of things, we had a bad season'

with the position of the exhaust now more precisely defined. All of these measures reduced downforce and, therefore, decreased cornering speed. The minimum weight was increased from 642kg including the driver to 691kg, but Sauber still had an issue meeting the new weight limit. It had achieved it with one car by Barcelona, with the lighter Esteban Gutierrez, but even then it was so marginal that the team could not play with the weight distribution as much as other teams, which further hampered comparative performance.

'Another big performance penalty was the weight initially of the car,' says Dall'ara. 'There something went quite wrong, partly in the communication with Ferrari, not only the weight of the engine alone, but also the exhaust, the cooling, which is partly Ferrari and partly from us. The need for cooling on these cars is remarkable compared to the past and we had a conventional approach to the whole system, which meant quite a bit of weight on the car, plus other parts that were designed conservatively because of the new concept.

'The biggest difference from last year was that we needed more cooling lines, if you leave aside traditional water and oil for the engine, gearbox, hydraulics which is already four, you need water and oil for ERS and water for the intercooler so that is three more. It is more complex, and we didn't use anything exotic; we have an intercooler on top of the engine which is a position dictated by Ferrari, and two smaller coolers at the back of the car for gearbox and hydraulics, so nothing unconventional.'

One of the big issues over the tail end of 2013 and through the winter of 2014 was the threat of overheating engines, and a struggle to get the radiators for the cars in time. Gauging the competition was, said one engineer, like training for a football tournament with all the teams in different stadia. No one knew what to expect when the cars turned up for the first test in Jerez at the end of January, what compromises were made by other teams, and indeed what was needed to make your own car work, and then be competitive.

Some teams went for outright performance, others for reliability and putting miles on the car. Compromises and targets were set for the first test, and then for the second in Bahrain, where Sauber fully realised the trouble it was in.

Changed concept

'The regulation changed some other aspects of the car, less significantly but enough to change the concept of the car,' says Dall'ara. 'For example, the nose of the car which affected the car aerodynamically. The rear of the car was limited in how to generate downforce as the lower end of the rear wing was by regulation reviewed, and there were also a number of unfinished parts that weren't available by test one. The car we ran there was aerodynamically unfinished and was just to run and learn things.

'We were unhappy with the performance of the car, but in terms of reliability we expected to spend some time and work it out, but at that time we were not really concerned. The big hit was the Bahrain test. We had eight days to get to a reasonable level of performance and we felt that we were too far away. We were far away in straightline speed, and we are still carrying that today. It has characterised our season.

'It was a topic that we could work to some extent, but jointly with Ferrari because it was coming not only from the car but mostly from the power unit. They accepted that, compared to other PU suppliers we paid a penalty, but even understanding what went wrong, they are still limited in what they can do by the homologation. This was one of the reasons why we were, and are, slow.

'On the car side of things, we had a bad season. The aero performance of the car is not level with some of the significant opposition, and our development capacity this year has been limited, and this cost lap time. Some of our strengths from the past have gone, such as the high speed corners, we had trouble [with] low speed corners, braking and stability.'

The switch to a powerful ERS meant that teams were forced to adopt brake by wire systems, which modulates the brake pedal feel for the driver as the ERS aids braking until the system is fully charged. 'The brake by wire took a while to sort out,' says Dall'ara. 'It is a new system for all, but for us it was very difficult to get it to work as a system, and then get it to communicate properly with the ERS, which acts on the braking. We were sorted by the Monaco Grand Prix, the sixth race of the season which is quite late. Esteban is a bit more sensitive to the consistency of the braking performance, but on the functional side of things, the other parts have been sorted in the last few months.

'Maybe the last point to mention is the way that we were using the tyres initially, which got better and better throughout, but we only really got sorted by Hockenheim. We worked on the rear suspension, introduced step two in Monaco and this was also an improvement. A lot of stuff gave us 1.5-2 seconds but still we sit quite a way from the midfield.

'On one side of things we have reached the bottom of what the homologation has allowed on the power unit, on the car development we have more ideas what to put on the car, but at some point you have to draw a line under what to put on this year's car.'

"Something went quite wrong, partly in the communication with Ferrari, not only the weight of the engine, but the exhaust and cooling"

The Sauber chassis, fully built up but with rear end and nose removed. 'The car overall as a package is our worst in a while'

Sauber's transmission, as supplied by Ferrari, with rear crash structure removed

The team did experiment with coated exhaust headers at Monza, but the risk of fire outweighed the small advance in performance that it brought and so the team elected not to take the experiment any further. 'Probably if we were closer to the competition we would take the risk, but right now we are more interested in reaching the finishing line than improving by half a tenth. Definitely it is an improvement but it is a small one,' says Dall'ara.

With a close eye on the budget, the team has had to turn its attention to the C34 and establishing what can be carried over. The team knows that the Ferrari package will improve and it is up to them to make the car better too.

'Most of the time we come back at the end of lap one with positions gained, and we reach the end,' says Dall'ara. 'Our other strengths, compared to our traditional competition, are that we are not losing much in cornering, compared to some the cars. Even to the Renault where we don't think that we lose much in qualifying, we are struggling in the race. It could be us doing something wrong with the energy management, or it is a Ferrari thing. The car overall as a package is our worst in a while and we are trying to learn from it.

'I would like to say we would like to have a proper quick car different to the slow car we have at the minute. However you cannot change everything just because you are slow. There are some good points in this car, for example if we stick to the aero performance, it is not as unstable as other cars in the past, but it lacks downforce overall so maybe we would chase more downforce without losing the smooth flow that allows the stability. I cannot say for the overall situation that we are in that we can bring a completely revised car or a new car. We need big steps and we have to take the risks.'

The challenges faced for next season includes cooling, which has to be improved, and the base weight of the car. That will rise by 10kg next season, but even that may not be enough. The team could hit the weight limit, but still won't be able to play with the distribution. It is going to be a tough winter for the team.

'In terms of sheer aerodynamic performance, this is something that we have to do on Sauber's side, and expect Ferrari to reach the level, or is closer, to Mercedes and Renault.'

The team may not be fighting for race wins in 2015, but it does expect to get back to challenging for points on a regular basis.

TECH SPEC

Chassis construction
Carbon fibre monocoque

Front suspension
Upper and lower wishbones, inboard springs and dampers activated by pushrods (Sachs Race Engineering)

Rear suspension
Upper and lower wishbones, inboard springs and dampers activated by pullrods (Sachs Race Engineering)

Transmission
Ferrari 8-speed quick shift carbon gearbox, longitudinally mounted, carbon-fibre clutch

Wheels
OZ

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

Brake system
Six-piston brake calipers (Brembo), carbon fibre pads and discs (Brembo)

Steering
Sauber F1 Team

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
FIA SECU standard electronic control unit

Engine
Ferrari 059/3 1.6 litre six cylinder single turbo. V6 90 degree. Bore 80mm, stroke 53mm, 4 valves per cylinder, 500 bar-direct injection

ERS
Battery energy per lap 4MJ, MGU-K power 120kW, MGU-K max revs 50,000rpm, MGU-H max revs 125,000rpm

Dimensions
Overall length: 5300mm
Overall height: 950mm
Overall width: 1800mm

Track
Front 1460mm, Rear 1416mm

Doing it sideways

Is it real racing? It is certainly a test of driver skills at the edge of adhesion. *Racecar* assesses Formula Drifting

By DON TAYLOR

'Drifting? Well, that's not real racing.' This is the typical comment made by traditional racing enthusiasts about the sport in which pairs of cars slide around sideways, creating billows of smoke as they spin their tyres, while running in close formation, and are scored not on speed but on drift angle, accuracy of the line followed, and style. And that score is produced by three judges, doing it (mainly) subjectively. Generally credited as being started by the Japanese, drifting has been growing internationally at a slow but steady pace in the last decade.

But is it real racing or not? It certainly is a test of driver skills at the edge of adhesion, and there is an immediate winner and a loser, as drivers are eliminated in a ladder format. A drift driver must have great car control, ability to run close to, and mirror the movements of, another car, and perform under the pressure to hit points perfectly in a short, intense run. And their young fans tend to know what to look for, and show wild appreciation of these skills when they see them applied.

But is it real racing? We can debate that for a long time. Maybe some of our 18-33 year old millennial readers can chime in.

Either way, given that you are reading *Racecar Engineering*, and knowing the high standards of technical journalism held to by the publication, the more important question is this: Is drifting 'real racecar engineering'?

Do the drift cars require the application of scientific thinking? Do they feature high powered engines, and sophisticated suspension geometries? Do teams use tools such as data acquisition, and analyze the numbers to improve performance?

Let's take a closer look at what's involved, and examine the car of a top team, but not before we mention that we are looking at the sport from a US perspective, where Formula Drift, called Formula D or just FD, is the king of drift series. Preparing for its 12th year, FD began after D1, the Japanese series, made its debut in the US in 2002. Since then, the Formula D has grown in the US to a national, seven race Pro series, and its organisers, led by Jim Liaw and Ryan Sage, have gone on to establish management of the three-race Formula Drift Asia Championship series. All ten of these events will be included in a world championship starting in 2015. Meanwhile in the UK, the Maxxis British Drift Championship will continue to operate its own successful series.

The cars and rules are pretty similar worldwide, and the mix of car brands is broad. A US event will likely include Nissan Z cars, Mustangs, Subaru BRZs, and many other models. However, the most popular drift car has been the long-discontinued Nissan S13 and S14 series model: with its lightweight, rear drive, and well-suited rear suspension geometry, it's perfect for drifting. It's the iconic drift car wherever you go, with many aftermarket, bolt-on parts readily available.

But it's the newer model cars being built today that tend to have more thought in their

Drivers are under pressure to hit points perfectly in a short, intense run

design and execution. The car we examined in its home shop is a current-production Scion (a Toyota 'youth' brand in the US). It's a Scion tC to be exact, which receives some support from Toyota/Scion marketing, but not engineering assistance. Across the entire FD field, there is little if any factory technical help, keeping the sport in the hands of the hardcore enthusiasts.

The car is built and fielded by Papadakis Racing team owner Stephan Papadakis, a Southern California native, who is a veteran having been behind the wheel, behind the wrench, and behind the laptop, in front-wheel drag racing, time attack, and other pursuits in the "tuner" world.

The Scion

The 2014 race-winning, championship-runner-up, Hankook Tyre/Scion Racing tC Formula Drift Car, driven by Fredric Aasbo, a Norwegian, looks similar to many road course race cars. Outside: wider tyres and wheels, a wide-body fender kit, and lowered. Inside: stripped interior, racing seats, roll cage. The full multipoint cage extends to the rear cross member, but stops forward at the firewall, per the rules. The chassis may not be as rigid in bending or torsion this way, but it meets the rules which are aimed at preserving the production car structure.

To this end, no modifications to the production chassis structure are allowed between the forward most and rearward most suspension mounting points. And, bolt-in cross members must be retained, without being moved or rotated from stock location.

Replacement carbon fibre hood, doors, deck, and roof are used on the drift Scion, while the front and rear bumper facias remain stock. A stock windshield is in place, with wipers for the rain, in which the cars sometimes run. While this car has a deck lip spoiler, a wing is optional in the series.

Although the FD rules are open for engine swaps across brands, and many teams do so, the Papadakis Scion team retains the original engine. This allows them to be eligible for manufacturer championship points. To the delight of Scion Marketing, Scion won the 2014 FD Manufacturer's Cup.

The Scion's production engine, a 2.7-litre, four-cylinder, 16 valve, DOHC design was turned 90 degrees to allow rear wheel drive (thanks to a few "clearance" mods that were permitted to the tunnel). The stock powerplant has undergone some modification with the addition of a Borg Warner turbocharger, and an as-needed, nitrous system. Internally, Stephan has replaced pistons, rods and so on, and reworked the head. He's convinced that 'without engine limitations, our 800HP engine program is less expensive than say a 500HP rally engine.'

Popular with many of the teams that swap engines is an American V8, such as one of GM's LS engines, most often left naturally aspirated. This option has allowed teams with smaller budgets and older cars to economically make competitive horsepower.

The Scion tC's G-Force GSR transmission was selected for its durability, as there is a lot of driveline shock in drifting. It mates to a Mk 4, Toyota Supra rear, via an aluminum drive shaft.

Rules state suspension mounting points must remain in their original locations. Arms may be replaced, but the builder is limited to the car's original geometry. Replacement hard bushings allow a bit of leeway for tuning. The Scion has a McPherson front strut, with a double arm, plus trailing arm, arrangement in the rear.

The Scion's longitudinally mounted turbcharged engine runs on nitrous oxide

The wheel. Brakes are not heavily taxed so can be light-duty

Brakes are not heavily taxed, nor subject to extended use in the short laps, so they can be light-duty. The drift Scion uses Wilwood's Sprint Car (open-wheel, oval racer) brake calipers and 3/8 inch thick solid discs.

Steering racks may be moved from their production location. In this case, the rack from a Toyota Supra is placed in front of the Scion's axle line. Replacement lower arm and strut are required to achieve the 65-70 degrees of steering angle required in drifting. Yes, you read that right, 65-70 degrees of steering angle. Quite alarming when you first see the hardware rotated over that far!

But enough about the basic hardware. No real surprises there, except for the steering angle. The real magic that makes the Scion into a competent, win-capable drift car is how it is set up for its unique mission, and in its fine-tuning. Papadakis' broad experience from his background as driver, builder, and tuner, all contribute to how he sees the challenge in drifting. 'Often when people think about drift, they remember while growing up, sliding around in an icy parking lot. But that's not what we call drifting. The cars are sideways for sure, but there is a lot more to it in competition."

First we need to understand what the car has to do to score in drifting. The cars are judged by: 1. Line – following an ideal path, having close proximity to designated points, 2. Angle – degree of slip/drift angle achieved and held, and 3. Style – the smoothness and excitement of the run while performing 1 and 2.

Steph says; 'There may be compromises made to get the best score. If you had a car that was just oversteering all the time, it would have angle, but be undriveable around the course. It would spin out all the time, especially if you want to slow down into a corner or connect the whole course without straightening. We're trying to get to a continuous arc on the judges' preferred line, and get to the next arc with smooth transitions.

'There's a lot of skill beyond just 'drifting' the course. Some new guys can go out, do well, and stay sideways. The hard part is driving on the preferred line, getting close to the wall (while sideways), and then having close proximity to the clipping points, all while chasing the competition and staying close to them (or being chased), even while that other guy may be driving unpredictably. That's a whole new level of difficulty. All these levels of skill get it further away from the parking lot, drifting around with the handbrake up. The way we set up the cars, we actually use the rear wheel speed to initiate the drift. That's why we use nitrous, to have power when we need it. We get to the wheel speed we want, then drive it with the throttle.'

This means the tyres may be turning equivalent to say, 120mph, while the car is moving at 80mph. Lateral Gs are in the 1.1-1.4 G range, lateral to the direction of vehicle travel that is, not to the direction it's pointed.

Engine tuning plays a role in keeping the car on line once in a drift. Says Steph; 'we have a very peaky torque curve, and we want the torque to drop off early. We want horsepower to peak a couple of thousand rpm before redline.' The driver will typically have the rpms past peak power most of the time. If the car gains traction while sliding and the engine bogs down, there will be power in reserve at the lower rpm near the torque peak. 'He can use throttle to reach equilibrium. Like a boat with the right prop. We've had other combinations with a flat torque curve, and they didn't drive as well. The engine was either sitting at the rev limiter or bogging.'

First turn dash

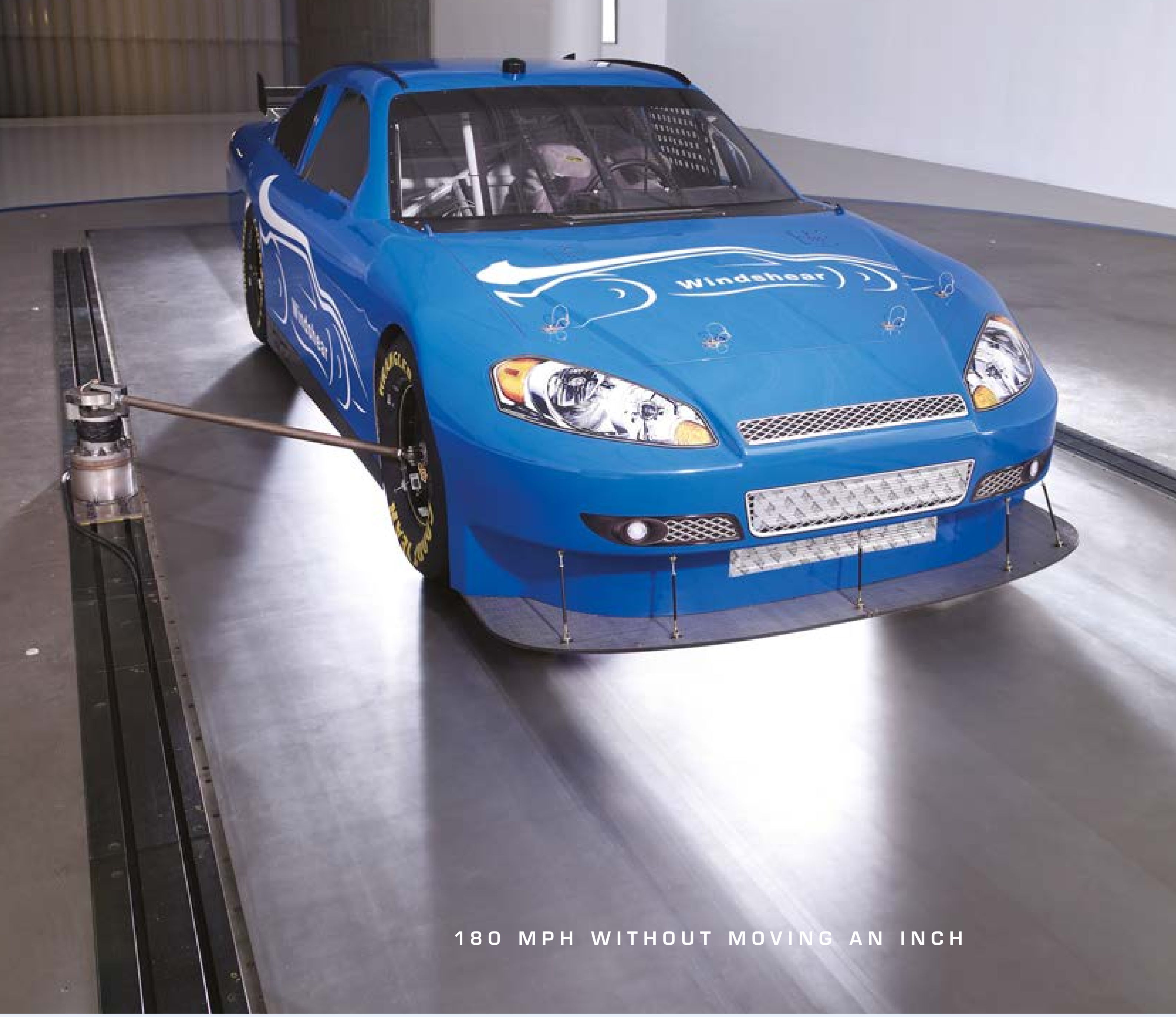
Chassis tuners want the tyres to stay flat on the start, as there is a bit of a drag race to get to that first turn. The chase guy wants to stay close to the lead guy, and lead guy wants to pull ahead. 'We'll have a couple degrees of static negative camber in the car, and run camber gains about half degree per inch of travel.' Generally the car uses four inches of travel in roll, of the five inches available. 'We run a really soft suspension. It's a pretty understeering car with our spring setup, soft rear suspension, and pretty low rebound in the shock, but the car can still do some pretty snappy transitions.' Roll steer? 'We run a static toe in with no bump steer in the rear, to reduce the number of variables.'

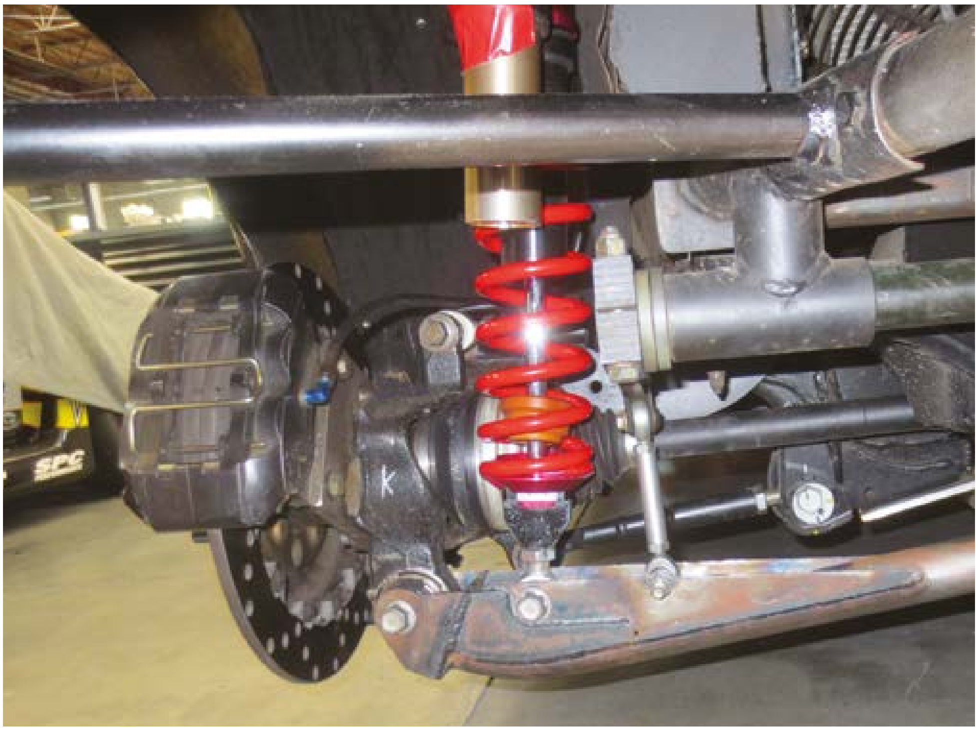
The high yaw attitude of the car in drift mode requires strong counter-steering. As mentioned, massive steering angle capability is built into the front geometry, some 65-70 degrees. But what about the attitude of the front tyres to the ground, when the steering is cranked over like this? While the car is being steered by the throttle, the front must supply grip, stability, and predictability, to keep pointing roughly in the direction of travel.

The Papadakis team has put a lot of thought into the interactions of caster angle, trail, tyre scrub radius, camber, bump steer, and ackerman as the car rolls, and the steering goes from straight ahead to reverse lock.

The handbrake may be used to help in braking the car down, and in getting the spinning rear wheels to gain some grip. 'If wheels are spinning all the time, you might pull the handbrake, to get the tyres closer to the ground speed for that moment, to slow rotation, to get the angle you want, and then get back on the throttle. Everything happens really quick.'

"Some new guys can go out, do well, and stay sideways. The hard part is driving on the preferred line – getting close to the wall"


Windshear
180 MPH WITHOUT MOVING AN INCH



Rear suspension showing spring damper unit and brakes

TECH SPEC

Hankook Tire/Scion Racing tC Formula Drift Car

Competition Venue: Formula Drift Pro Championship
Driver: Fredric Aasbo, (Norway)

Manufacturer: Toyota Motor Company/Papadakis Racing

Engine: Toyota 2AR
Type: 4 cylinder, turbo-charged, nitrous
Cubic capacity: 2.7-litre
Number of valves: 16
Position: front, in-line
Number of cylinders: 4
Fuel: E85
Power: 800+ hp, 700+ ft. lb. of torque (recorded at the wheels)
Maximum revs: 8,400rpm

Top Speed: 105mph

Transmission
Type: 4 speed
Gearbox: G-Force GSR
Clutch: 3 disc ACT
Flywheel: ACT

Chassis
Vehicle: 2014 Toyota Scion tC
Frame: production, steel uni-body
Rollcage: 4130 steel tube

Body
Bodywork: production steel, with carbon fibre roof and hood by Seibon Carbon
Body kit: wide fenders by Rocket Bunny

Suspension/brakes/steering
Suspension front: Macpherson strut
Suspension rear: IRS, double wishbone, with semi-trailing arms

Steph believes that 'aero works in these cars, not so much in creating downforce, given the low speeds, but like feathers on an arrow, when you have lots of side plate area. With a large polar moment car, you're able to hang it out and keep it there (balancing against the aero force moment created by the wing's side plate). Our driver likes how the Scion handles without aero aids, depending on the track.' Large side plate area can make it harder to drive, by fighting the yaw rotation of a relatively lower polar moment car, like the Scion.

Papadakis is not worried about lift or downforce, and doesn't want it to be variable with speed. 'We're not going that fast; most of our turns are about 50mph. The initiation might begin at 90mph, and you want to go wide, back off the throttle, and not have the aero straightening it out (losing drift angle) with the wing end plates.'

Other teams do run rear wings, which if nothing else adds to the drift car's looks. Front splitters have also appeared on some cars, with claimed improvements in front grip. Aero may be in it's infancy in drifting, and we'll likely see more attention paid to it over time.

The Papadakis Scion uses the AEM Infinity ECU with data acquisition. 'It has tons of sensors, plus we run the AQ-1, which is their chassis data logger. We'll record accelerations, suspension travel, steering angle, and GPS. The rules are quite open, but what they (FD) don't allow are drive shaft speed sensors, wheel speed sensors, or traction control.' So with all of the car rotation going on, going from extreme drift angle one way to the other, should the ideal drift car have a high or low polar moment of inertia? Says Stephan; 'we go for a lower polar moment with a more centered mass, which tends to be quick to rotate. A longer wheelbase and higher polar moment makes it easier to drive, but slower getting started on a transition, and it takes more work.'

As FD courses are large with more sweeping turns, a high polar moment car may have an advantage and be more stable, at a wider range of speeds, than a low PM car. The deciding factor for the driver is being able to stay behind somebody closely, improvising his driving style as needed, and have the car respond.

The FD rules require minimum weights based on each model of car. Along with that comes a tyre width-to-weight formula, to not advantage the naturally lighter cars with the widest tyres.

'Rotate-happy'

What about F/R weight distribution? What's good? The Scion is 52 per cent on the front, but with as much mass over the back axle as possible. 'If the weight is too far behind the rear axle, a higher polar moment results, and the car can get rotate-happy'. There is no weight distribution requirement in the rules.

Last but not least, there is the black art of the tyres. With six different manufacturers competing aggressively in FD, any tyre performance differences are quite close. The tyres must be street-legal, and available in retail stores. The FD sanctioning body looks closely at tyres, and sometimes will do rubber analysis, taking tyres from a team, impounding them, checking durometer, and comparing them to store-bought tyres to ensure that there is no development on-going.

To get maximum tyre contact patch on the ground, tyre pressures are low, with initial settings in the 10-15 PSI range. As there is no allowance for pressure adjustment between laps, or for pressure bleed-off devices, teams must accept living with increased pressures as tyre temps rise. Just as a point of interest for these cars, rear tyres last for one round of competition (2 laps), while fronts may last the whole weekend. It's a good thing that most FD Pro teams are on a free tyre "deal", or at least a discount scheme!

So, in conclusion, there is more engineering in these cars than one might assume at first, much of it being application of basic vehicle dynamics knowledge, hardware, and tuning practices. But, there's enough quirkiness in the challenge of keeping a wildly out of control vehicle, in control, as the familiar tyre friction circle goes up in smoke, and with the front the wheels continually steering 'the wrong way' at angles familiar only to shopping trollies.

This seems to me to be a good assignment for a motorsports engineering programme student. Who wouldn't want to go down to the local drift event, write a simulation program for the front suspension, and thereby help advance the level of racecar engineering already being used in drifting?

Key role for hosing

Bespoke service provides high-performance hoses with short lead times are fuelling SamcoSport's reputation

When it comes to the extreme conditions for racing engines, particularly turbo and intercooler systems on racing machines, SamcoSport, a subsidiary of Silflex Ltd, produces both off-the-shelf and bespoke fibre-reinforced silicone hoses to allow the maximum performance to be extracted from a high-performance engine.

'Hosing is often an afterthought when it comes to extracting the full potential from a high performance engine and, in many cases, there are huge gains to be found from properly designed and high quality hosing,' says Peter Ingleby, engineer from Silflex Ltd.

Samco's Xtreme turbo hose range is an aramid fibre-reinforced silicon hose and has been specifically designed for the most demanding motorsport requirements. These hoses are used for high temperature turbocharger and intercooler applications and can also be made with an oil resistant fluorosilicone lining if required.

Samco Xtreme is the only range of high temperature hoses available on the market, with a working temperature range anywhere from -50degC to +250degC, which also benefits from a unique lightweight yet strong construction pioneered by SamcoSport.

When building a race vehicle, lightweight design is of paramount importance in the highly competitive world of motorsport and is at the top of the requirement list for all components. 'With our many years of experience as a market leader, these are the challenges that we thrive on, and manufacturing high temperature, light weight, strong and intricate hosing designs to the highest accuracy and quality for our motorsport customers is our forte,' concludes Ingleby.

To maintain these very high standards, Samco uses a select number of suppliers for its silicone and reinforcing fabrics, and every material batch supplied to them is tested in-house to ensure the highest quality and consistency is achieved across every batch.

Further rigorous testing is also carried out on every finished hose to ensure it meets the desired specification. Samco's high quality bespoke service and its ability to turn components around with very short lead times is highly valued by its motorsport customers and due to this, Samco has customers across the industry from Time Attack through to Formula 1, as well as supplying some of the world's leading high-performance OEM brands.


What's the
secret
about the new 911 GT3 Cup's
new brakes?
It's Quicker.
PFC
PORSCHE
OFFICIAL PARTNER
PORSCHE
MOTORSPORT
PFC
BREMSE
www.pfcbrakes.com
1.800.521.8874

Right place right time

A chance meeting between FAW-Volkswagen Rally Team of China and Prodrive's Richard Thompson led to the latest VW Golf rallying car

By CHRIS EYRE

When Subaru pulled out of World Rallying at the end of 2008, Prodrive turned its attention to scoping out the 2011-onwards B-segment 1600cc turbocharged FIA World Rally Car regulations. Fast forward half a decade and using that knowledge, plus their MINI Countryman WRC experience, the Banbury outfit has just produced a FAW-Volkswagen works-sanctioned two-litre turbocharged Golf. These C-segment cars will compete in the Chinese Rally Championship.

It's a project that arose by chance. FAW-Volkswagen Rally Team of China, a subsidiary of FAW Group, the major shareholder of Volkswagen in China, already run front-wheel-drive VW Golfs in the Chinese Rally Championship. At the end of last year, FAW were looking to step up their 2015 involvement to the 'super' rally car four-wheel-drive class and required WRC 4wd expertise to create a challenger. Volkswagen Motorsport Germany couldn't service it. With five-door Golfs required for Chinese domestic marketing purposes, not Polos, Hannover simply didn't have a car available or the capacity to create one.

A chance stage-side discussion with Prodrive senior engineer Richard Thompson and FAW-Volkswagen Rally management led to what we see here. As Ben Sayer, Prodrive's public relations manager explained; 'he was stood on the last stage next to one of the guys from FAW and just got talking and it went from there.'

This 4wd Volkswagen Golf, is a 2.0-litre turbocharged car built to suit the freer-than-WRC regulations of CRC, but with the 'spirit of the WRC' embodied throughout its engineering.

Prodrive was up against an appreciable schedule with just months to deliver the first cars. With chassis, engine and drive train all to design or commission, the Banbury outfit would obviously draw on its considerable rally experience and prior research and development. Wind the clock back to early 2009 of course, and Prodrive conducted their generic rally car design process for the 2011-onwards WRC regulations. That design and technology was then applied to the MINI Countryman WRC. Unsurprisingly this Golf draws on that expertise and iterates it further forward with

A production-based 2.0-litre four-cylinder VW engine powers the car. **Prodrive have used all their experience to create this rally Golf. Post-MINI, it's clearly evolved – and it's got a bigger engine**

the experience gained since then. As Lapworth explains; 'this has been done completely independently from VW. We started with a clean sheet and used the best ideas.' The Golf design team was headed by Paul Eastman, head of Prodrive's rally engineering. MINI design parallels are evident including the lightweight steering column support system, neatly bridged off the roll cage and an AP pedal box with a single in-series cylinder braced directly off the floor pan with no separate frame required.

Prodrive have combined their wealth of experience to create this rally Golf. They've had time for reflection, post-MINI, it's clearly evolved – and it's got a bigger engine. Lapworth: 'The thing to remember is the MINI is a good car. This [Golf] is lighter, more powerful, less draggy and anything that we felt wasn't optimised on the MINI, we've had a chance to do it again.'

With the short project timescale, obtaining body shells in white on an 8-10 week lead time wasn't a practical route – only recently have Volkswagen Motorsport in Germany been informed of its existence. Instead two left-hand-drive road-going 5-door Golfs were collected on return from a Le Mans test in early June 2014, before being dismantled and the body shells sent to Enviro Strip to remove all paint and under seal, in readiness for shell preparation on the Banbury surface plates. 'We've had to reverse engineer,' says Sayer. 'We've had to scan the body inside and out to get CAD data because there was no data on the body shell.'

A Dmack tyre on an ATS wheel – the Golf's exterior panels are mainly Volkswagen steel, with flexible resin composite panelling used on the bumpers, front wings and lower rear wheel arch extensions

When the MINI Countryman WRC was designed, efforts were made to arc the safety door bars outwards for increased occupant protection, and they actually passed through the B-pillar. The same design cues can be seen on the CAD tested and FIA-specification Golf roll cage, although it is a wider car and the bars pass inside the B-pillar.

In such a short timescale, it wasn't possible for Prodrive to start an engine development programme from scratch. The outward choices would be perennial VW-Audi-SEAT-Skoda works engine suppliers Lehmann Motorentechnik of Lichtenstein or ORECA of France, and here it's Lehmann. The transverse wet sump engine is based on a commonplace EA114 iron-blocked unit from the Volkswagen Group stable.

Their compact Volkswagen 88mm bore distance four cylinder in-line unit is already complete with components from Mahle and Pankl and it is the same base engine used in Mattias Ekström's World Rallycross Audi S1. Undressed blocks complete with inlet manifold were then supplied, complete with a sump which outwardly appears to be the Skoda Fabia S2000 item, to cater for a canted back engine. And this is a port-injected engine – the Chinese rules don't mandate direct injection – which reduces the cost of the fuel system.

Prodrive then designed the exhaust manifold and anti lag system, and added a Cosworth MQ 12 ECU – as used in the M-Sport Fiesta WRC and MINI Countryman WRC– rather than the Bosch Motorsport controller traditionally coupled with Volkswagen-Audi race units – and a specific Garrett turbocharger to suit a 35mm restrictor, as per Chinese rally regulations. The engine calibration is achieved using FIA rally specification fuel.

David Lapworth noted that; 'we know exactly what we want, we gave them [Lehmann] all the specification, we were able to define exactly what we needed, and we've taken responsibility for mapping the engine, developing the anti lag – that's all Prodrive. We've taken the engine, we've put it on our dyno and our engine guys have come up with that [calibration]. All the software is Prodrive. It's not the Lehmann engine management system, it's all Prodrive Cosworth, so that is completely

MINI design cues can be seen on the CAD tested and FIA-specification Golf roll cage

The Garrett turbocharger sits on top of the 16-valve engine – the specific turbocharger is designed to suit a 35mm restrictor, as per Chinese rally regulations

our responsibility. In time maybe we'll start building the engines here but they [Lehmann] build those engines out of well-proven components so we looked at it and said, 'Why don't we just taken that product and we'll dress it?' We do the exhaust manifold, we dyno the engine, we put our electronics on it, we map it and it's our responsibility. It gets rid of any grey areas. Our engineers have spent a lot of time on it to get the calibration right.'

Nominal engine power isn't stated though David Lapworth indicated it's 'well over 300 horsepower' and qualified the point with the fact that the 35mm restrictor itself implies an upper ceiling of around 400 horsepower. The radiator package is carried across from the design fitted to the MINI Countryman WRC.

For the transmission, the start point was the market-ready WRC Xtrac gearbox and differential package, used in the MINI Countryman WRC, but also Polo and Fiesta WRCs, with a sintered twin-plate clutch, plated front and rear differentials and a standard Xtrac rear differential rear release system, with direct hydraulic actuation. The WRC similarities extend to a steering column-mounted gearshift, to the right of the steering wheel.

Torque from the extra 400 cubic centimetres doesn't threaten transmission component strength. Indeed the 1600 MINI RX car ran with 450-500 horsepower.

'Lehmann build the engines out of well-proven components so we looked at it and said, 'Why don't we just take that product and we'll dress it?''

'Our experience is the gearbox has a bit of headroom in it,' says Lapworth. 'We've developed the engine, so we selected the turbo and came up with a specification for the engine knowing that this gearbox hasn't been designed for massive torque. What you need is a nice wide power band and that's what this has got, but we didn't chase after maximum torque. It's got adequate torque and plenty of power.'

With regards to durability, Lapworth notes that 'one of the good things that's happened – and people forget how much progress we've made in the last ten years – is the WRC regulation for the gearboxes, the homologation, puts some fairly tough targets in there, so if you were Xtrac, you wouldn't take the risk of going super lightweight because you're homologating the gearbox for use in multiple cars and you're claiming it's going to do 5,000 kilometres as a target life for the main components. If you're going to put Sebastien Ogier in a car and do two to three rallies on the same gearbox, you need a bit of headroom. The WRC are restricted on gearbox quantities in a season and that's quite tough. It's pushed it to a point where if you then come back to a national level, or a rallycross car, it's plenty strong enough. It clearly reduces the life when you run it at 500 horsepower, the life comes down, but it's got the torque capacity.'

An addendum to this would be that the pre-2011 two-litre turbocharged WRC cars had a wider torque band which meant that just five gears were previously commonplace.

The suspension design is McPherson front and rear, utilising Ohlins-Prodrive dampers with remote canisters on the body. These are further iterated from the type used on the MINI Countryman WRC, and designed specifically for use with the Golf. As with the Polo R WRC ZF units, they utilise hydraulic compression stops, 'a scientifically developed bump stop, rather than a piece of rubber that changes dramatically in characteristics between hot and cold'.

The front and rear uprights are interchangeable, as seen in the WRC generic rally car design concept applied to the MINI Countryman, in order to reduce the quantity of spare parts the team carries. Being the lightest current homologated WRC upright, thus there was no reason to re-invent it. With a previously-noted Prodrive view that that extensive wheel travel generates its own kinematic issues, Lapworth discloses that the Golf has 'a bit more than a MINI' but 'probably not quite as much as a Polo R WRC car, the latter previously noted to have 180mm on tarmac and 275mm on the loose (RE V23N5). 'There has to be a limit to 'more is better' and we think we're probably at that point where we don't actually want any more [travel],' says Lapworth. 'We are perfectly

Cockpit and control systems show how MINI design parallels are evident including the lightweight steering column support system, neatly bridged off the roll cage

happy with what we have got, but also we don't want to stretch any boundaries with this car because that's not the job.' That's not to suggest for the car is under-developed, however. Current WRC 2 driver Jari Ketomaa was reported to be 'very complimentary' when he drove the car on the second day of a recent Welsh test.

The hydraulic steering is unique to Prodrive. 'We develop a whole system,' comments Lapworth. 'The pump is a proprietary item to our specification and the steering rack is ours with a steering partner. Everything about the steering rack was done to our requirements.'

The AP brakes are again to WRC specification, front and rear, with a carry over of the AP in-series pedal box system from the MINI Countryman WRC, which dispenses with the weight of a carrying frame, instead mounting directly to the body shell. 'The reason the pedal box is carried over is because we designed it for the MINI and AP racing now make it, so you can buy that pedal box as an off the shelf package,' says Sayer. 'We designed it, AP racing made it for us and they now sell it.'

Lapworth is suitably brief on the subject the aerodynamics and the carbon composite rear wing: 'Internally we do our own CFD in collaboration with TotalSim. It's bespoke a unique wing to this car. We took cues from wings we knew worked and it delivers the figures that it needs to.' Despite the lack of horizontal front splitters permitted on WRC-type cars, he also emphasised the aero importance of the outer front bumper areas.

CFD saves a significant amount of time, logistics and cost. 'We don't go in the wind tunnel very often these days, even with an Aston Martin. We only go in a wind tunnel maybe once a year to make sure that the CFD is giving the right answers, but we don't do any of our development in a wind tunnel anymore - or even straight line testing. And the CFD can do things that you can't do in a tunnel.'

The Laurel Hill tunnel is used in America to validate and correlate findings, and test deltas, with the results underwriting the CFD approach.

The Golf's exterior panels are predominantly Volkswagen steel, with flexible resin composite panelling used on the bumpers, front wings and lower rear wheel arch extensions. The impact resistant flexibility of the front bumper material is product of five years experience, experimenting with materials.

The steel bonnet is lightened, devoid of its skeleton, and is fitted with the usual raised cooling aperture leading edges, whilst protective body-colour plastic sheet is affixed to the rear doors to extend their durability. 'If we were really, really, really seriously competing and talking about minimum weight, running this on the WRC, we wouldn't run that, but we would fit new doors after every rally,' says Lapworth. 'Without that on it, it will only last one rally. Now at a national level, is it justified to rip the door to shreds in the length of one rally? That is their [FAW-Volkswagen's] call, but we will recommend it. It's 500 grams or thereabouts, but it means the rear doors will probably last three rallies rather than one.' The cars run to a 1,150kg regulation, and practical weight will be under 1200kg in rally condition.

So far the first car has been tested for 270 kilometres. An initial shakedown at MIRA plus two days in the forests of Wales, the first being driven by seasoned Prodrive test driver Terry Kaby and the second day by current WRC 2 driver Jari Ketomaa, and then a final sign off installation run before shipping at Turweston.

Once in China, Australia's Chris Atkinson drove one of the cars to victory on the Longyou Rally and was scheduled to take part in another round at the end of November. Domestic drivers likely to be announced in due course.

The two cars were shipped to China, one in loose surface specification, one in tarmac and a third is likely to be commissioned alongside plans to build more in early 2015. In China, it is designed for conditions from minus ten to plus 40degC. The seventh version of the Golf is set to be sold in China until 2019, and Lapworth predicts more cars will follow, likely if the FAW-Volkswagen rally team follows the route of servicing privateer requirements too.

Thirty years since Prodrive was established, and as the foundations are laid for their new headquarters near the M40 motorway, it's good to see the firm back to its roots in the rally game again, with promise from the east.

‘You need a nice wide power band and that’s what this has got, but we didn’t chase after maximum torque. It’s got torque and plenty of power”

TECH SPEC

Volkswagen Golf 7 SCRC

Engine
Type: Straight-four EA114 16-valve engine with Garrett turbocharger, port fuel injection mounted in front of the front axle
Displacement: 2000cc
Power output: Exceeding 224kW / 300bhp
Air restrictor: 35mm (Chinese Rally regulation), 2 bar maximum boost
Engine control unit: Cosworth MQ 12
Gearbox: Xtrac 633, 6-speed sequential, transversally mounted
Final drive: permanent 50:50 fixed front/rear torque split four wheel drive. Plated limited slip differentials (front and rear axle), handbrake rear differential release

Clutch: AP Racing sintered twin plate clutch

Suspension: Prodrive-Ohlins McPherson 3-way adjustable struts (front and rear)

Steering: Prodrive-designed hydraulic rack and pinion, power-assisted

Braking system: AP Racing 4 pot calipers, ventilated disc brakes (front and rear 300mm on gravel, 355mm on tarmac), Prodrive AP Racing pedal box

Wheels: Gravel: ATS 15” x 7.5”
tarmac: ATS 18” x 8”

Tyres: Gravel: Dmack 215/65 R15
tarmac: Dmack 225/40 R18

Chassis/bodywork:
Volkswagen Golf 7 bodyshell with Prodrive FIA conformant roll cage
Steel Volkswagen panels with flexible composite front and rear bumper, front wings and rear wing extensions

Dimensions and weight
Length/width: 4,268mm/1,820mm
Minimum weight: 1,150kg (Championship dry weight, excluding crew)

Performance
Acceleration: 0-100km/h in approx 3.5 seconds
Top speed: up to approx 200km/h (depending on gear ratios)

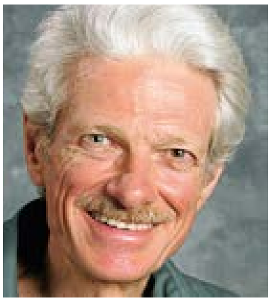
QUALITY AND RELIABILITY

HIGHER FLOW RATES
LESS FRICTION
MORE POWER

With more than 40 years of experience manufacturing high performance racing valves, Supertech utilizes the finest material and design to make available the most durable, high performance racing valves on the market today. Supertech valves are forged, CNC machined, and hand polished for strength and reliability.

All Supertech parts are measured against the strictest tolerances in the industry and utilize finite element analysis, enabling us to provide a high performance product, without sacrificing durability. Regardless of your high performance needs, Supertech is the best choice for you if quality, durability and performance are vital to your needs.

SUPERTECH 3580 Charter Park Dr. San Jose, CA. 95136 USA (408) 448-2001
www.supertechperformance.com



Spindle and steering axis inclination

Racers and engineers put their questions to Mark Ortiz

Question

Can you explain the effects of king pin angle and king pin angle split from one side to the other (how it would jack weight when turning each direction)? I know that different oval track chassis builders are playing a lot with spindle inclination.

The consultant says

The basics of this are simple. However, it gets a bit more complex when you try to be really exact about it. First of all, the terminology is a bit confused. I prefer to call the front-view angle of the steering axis with respect to the spindle pin the spindle inclination, and call the angle of the steering axis with respect to ground vertical the front-view steering axis inclination, or SAI. The term kingpin inclination can mean either of those, which means that it has to be interpreted in context and can sometimes be ambiguous.

When we buy a spindle for an oval track car, we are usually buying a single piece comprising the stub axle or spindle pin (which by itself is sometimes called a spindle, especially if it's a separate piece) and the upright. The inclination then is the front view angularity of the steering axis relative to the pin axis, or more precisely to a perpendicular to the pin axis.

When caster and camber are zero, the SAI equals the spindle inclination. When we add some caster, it still almost does. When the upright leans back, it is slightly foreshortened in front view, so the actual inclination in a front view projection increases very slightly. However, this effect is very small and we usually ignore it. When we adjust in some camber, the steering axis tilts with the wheel. Camber is conventionally negative when the tilt is inward at the top; SAI is conventionally positive top-in. Therefore SAI is approximately equal to spindle inclination minus camber.

For oval track we generally tilt both front wheels to the left: negative camber on the right wheel, positive on the left. Depending on the class of car and the track, camber can be three degrees or more. If the right and left spindles are the same, that means the SAI can easily be different on the right and left by six degrees or more. So the most common reason for running unequal spindle inclinations is simply to get the left and right SAIs more nearly equal. Common spindle inclination angles are five, eight, and eleven degrees. With three degrees of tilt on both wheels, and a five degree spindle on the right and an eleven degree on the left, you get about eight degrees SAI on both sides.

But suppose we want to be a bit more creative and ambitious, and consciously use SAI split to produce specific weight jacking effects. How would we understand how it all works and what to then expect?

Assuming the wheel has a positive scrub radius or front-view steering offset (contact patch center outboard of the point where the steering axis intercepts the ground plane), with zero caster but some SAI, the geometry jacks the car up when we steer either direction from centre. When there's some caster, things get a bit more complex, but basically adding SAI makes the corner of the car at issue jack up when we steer either way. Caster, in contrast, makes the corner jack down when the wheel toes in and up when the wheel toes out.

The most common reason for running unequal spindle inclinations is simply to get the left and right SAIs nearly equal

A NASCAR stock car spindle manufactured by CRP Group

Other things being equal, making one corner of the car jack up loads that wheel and the diagonally opposite one, and unloads the other two. If we jack more than one corner up or down at once, the effect depends on the relationship between them. If we jack both front corners up or down equally, it does essentially nothing to the wheel loads.

If we add caster to the right front, the car de-wedges more (loses percentage on the outside front and inside rear) when the wheels steer left and wedges more (gains percentage on the outside front and inside rear) when the wheels steer right. If we add SAI to the right front instead, the effect is similar when the wheels steer right but opposite when the wheels steer left. The car wedges more when we steer either way.

If we add caster to the left front, the effect is similar to adding it to the right front: the car de-wedges more when we steer into the turn and wedges more when we counter steer. If we add left front SAI instead, the car de-wedges more when we steer either way.

There are also effects on camber. When we add caster, the wheel leans more in the direction we steer it. When we add SAI, the wheel goes toward positive camber more when we steer either way.

There are effects on steering feel. When we add caster on both sides, we increase the steering's tendency to seek inertial center. When we add caster on just one side, we create a pull in the steering toward the opposite side. Adding SAI on just one side does not do that. Adding SAI on either or both sides just makes the steering seek car centerline center more. The weight jacking effects from caster and SAI increase as we add scrub radius.

Cancelling driveshaft torque with tight packaging constraints

Question

I have just read your latest *Racecar* article on live rear axles. I run an MG V8, 477 rwhp in circuit racing and we are currently upgrading roll cage and chassis stiffness, and putting a 9in live axle with a Trutrac LSD. Space and packaging in an MG is tight, so your comments on having a four link with birdcage one side are intriguing in terms of eliminating all of the negative forces, but I don't have the room. So, I researched the three link I was planning and I find reference to torque steer and wedge in roll. The offset design of the C Type Jaguar, though, seems to even this out and some are reporting that it eliminates these forces in acceleration. I found two references to the system having problems with braking, so my question is: if I ran a three link, top link offset to the right from the rear of the car, with the brake caliper on the left attached on a floating birdcage which has a link to the chassis, would I be achieving the same result as your four link? Or do I have to have a decoupling top link to allow the freedom for the floating brake side to work?

My issues with packaging are that the MG has a very narrow chassis, rails converging from bottom side rails in front of wheels to inside of wheels. Distance between rails at wheel centreline is 800mm. Attached is a photo and sketch of what I think could work if a birdcage with such a long tube in it would be acceptable (at 380mm long I would have to use thin wall chrome moly tube). The lower links are 1000mm apart and the top links would be 630mm apart. Rear track is 1480mm with 335 x 660 x 18 tyres and 3.7 gears. Also I have already put some steel in the chassis to stiffen, but I can cut that out and revise.

The consultant says

The questioner sent a nice .pdf of a cad model. The axle is shown, with a Panhard bar and provision for four trailing links. The links themselves are not shown but the brackets for them on the axle are, and so is one of the unibody rails. The top two links are indeed much closer together than the lowers, and they have to be to clear the rails. A long birdcage on the left is shown, per my recommendation in other articles.

This allows compensation for driveshaft torque without creating roll and wedge in braking, by functioning as a three-link under power and a four-link under braking.

The weight of the birdcage shown is probably not a major concern. Compared to a layout with a shorter piece of tubing, the weight penalty is perhaps three pounds. A nine-inch rear axle with wheels and brakes weighs at least 250 pounds, so the difference is not highly significant.

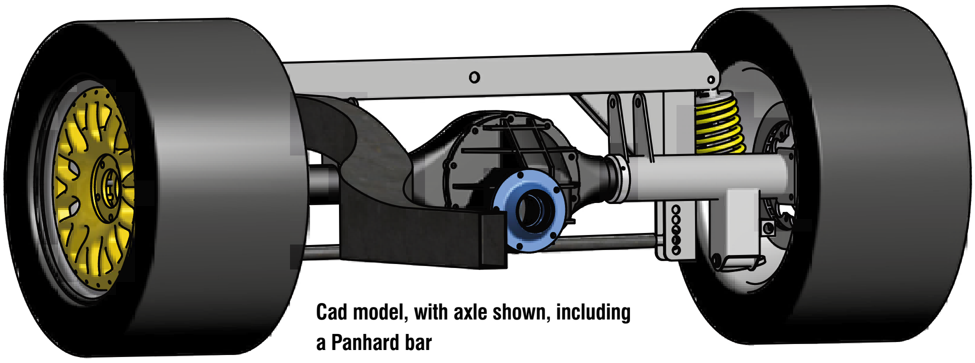
The real problem is the amount of anti-squat the system would have to have in order to get full driveshaft torque cancellation and also minimal roll steer.

For minimal roll steer with the axle configuration shown, the side view instant centres need to be around axle height. The tyre loaded radius is just over a foot. The lower link pivots are about half a foot above the ground, or half a tyre radius below the axle centerline. The uppers are about half a foot, or half a tyre radius, above the axle centerline. So for every 100lb of thrust at the tyres, there's about 150lb of compression on the lower links and 50lb of tension on the right upper link, which is a little more than a foot off centre. Axle torque is just a little more than 100lb ft, so driveshaft torque is about 28lb ft. To counter that, the upper link needs to make around 25lb of lift with a tension of 50lb – it needs a slope of about 1 in 2. In side view, the upper link's centerline reaches axle height about two feet ahead of the axle. If the instant center is at axle height, and the side view swing arm length is only two feet, the car has something like 300 per cent anti-squat. That's likely to create wheel hop problems.

For this configuration the side view instant centres need to be axle height

If the left upper link is on a brake floater (birdcage with only one link) instead, and the left lower link is welded to the axle tube, then the lower links need to be close to horizontal, and the side view instant center ends up being only about half as high, and twice as far forward of the axle. That's much better. The anti-squat is now only about 75 per cent. The upper link is still at the same angle and under the same tension, but the heavily loaded lower links aren't making lift force. The problem would be how to have a brake floater that reaches in to the upper link bracket, while still allowing the lower link bracket to be rigidly attached to the axle tube. That's not an insurmountable challenge, but it would call for a two-piece floater of some kind, to permit installation and removal.

A brake floater usually has a trailing link above the axle, but it might be possible to have the link be the lower one instead – that is, have two upper links rigidly attached to the axle housing and only one rigidly attached lower. That single lower link would see some big loads under power, but it could be made strong enough, and it wouldn't need a lot of inclination, while the upper links would need to be roughly horizontal for minimal roll steer. This upside down three-link isn't as good structurally, but it would fit, and the floater could be one piece.



Cad model, with axle shown, including a Panhard bar

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.
E: markortizauto@windstream.net
T: +1 704-933-8876
A: Mark Ortiz
155 Wankel Drive, Kannapolis
NC 28083-8200, USA

SIN R1 GT

ENGINE
LS7 7.0L V8 - 500 HP
Dry Sump. Motec M800
ECU, Drive by wire
Custom intake / Exhaust
Traction control system

SUSPENSION
Fully adjustable pushrod
system, Nitron 3-way
adjustable shocks

BRAKES
AP Racing 6 piston calipers
378mm disks - font and
rear with fully adjustable
pedal box

GEARBOX
Albins sequential
(optional paddle shift)
Triple plate ceramic clutch

WHEELS
Central lock
Front wheels 10jx 18″
Rear wheels 12jx 18″

DASHBOARD
Motec C125
Full carbon body

DRY WEIGHT
1200 KG

SIN R1 GT4

ENGINE
LS3 6.2L V8 - 400 HP. Dry Sump
Motec M800 ECU, Drive by
wire. Custom intake / Exhaust
Traction control system
* rest of specification is same as SIN R1 GT




SIN R1 Road

ENGINE
LS3 6.2L V8 - 450 HP
Dry Sump
Motec M800 ECU,
Drive by wire
Custom intake / Exhaust
Traction control system

SUSPENSION
Fully adjustable pushrod
system, Nitron 3-way
adjustable shocks

BRAKES
AP Racing 6 piston calipers
378mm disks - font and
rear with fully adjustable
pedal box

GEARBOX
Albins sequential
(optional paddle shift)
Triple plate ceramic clutch

WHEELS
Central lock
Front wheels 9jx 18″
Rear wheels 11jx 18″
Front Tyres 245/40/19
Michelin PS Cup 2
Rear Tyres 305/30/19
Michelin PS Cup 2

PERFORMANCE
Top speed :
>300 KM/H (>186.5 MPH)
Acceleration 0-100 KM/H
(0-62 MPH): 3.5s

OPTIONAL
Full carbon body
Air conditioning
Navi/DVD/Radio

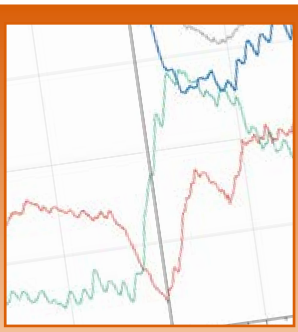
DRY WEIGHT
1200 KG

www.sincars.co.uk

SIN CARS UK Ltd - Wharf Farm, Coventry Road, Hinckley LE10 0NB | E: office@sincars.de | www.sincars.co.uk
T: +44 (0) 1327 311 660 | T: +44 (0) 1455 615 517 | M: +44 (0) 7719 999 848 | M: +44 (0) 7870 601 672


-35mm
Worlds apart
Our technology centre is the most advanced in Europe.
That is how we can achieve a negative radius of up to -35mm. Extreme engineering and precision that other performance cam manufacturers in Europe cannot match. All our camshafts and ancillaries have been developed by the best to be the best.
№1 Kent Cams – the best in Europe:
No.1 for product development expertise
The greatest performance increase of any single modification
The widest range of camshaft ancillaries produced on site
The most advanced technology:
Negative radius to -35mm
CBN wheels with constant surface speed
Multi-angle lobes with CNC dressing
Marposs 3D C and Z axis position probe
Microphonic wheel dressing
Lotus Concept Valve Train software
KENT CAMS
HIGH PERFORMANCE ENGINEERING
www.kentcams.com
Cams + Pulleys, Belts & Chains
Valves & Valve Springs
Performance Cam Kits & Valve Spring Kits
Followers & Tappets


Call us first...
Trident
Racing Supplies
MasterCard
VISA
Unit 31 Silverstone Circuit Towcester Northants NN12 8TN
T: 01327 857822 F: 01327 858096 www.tridentracing.co.uk



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

Getting to grips with traction control **Part 1**

Traction aid can be complex but where allowed is a useful racing tool

Traction control systems have been around now for quite some time and their benefits are well understood in racing. This has meant that, in many race series, any form of electronic traction aid is forbidden. There are however plenty of high-profile motorcycle and car racing series that allow traction control and in those instances there tends to be a lot of on track development and fine tuning in order to make the most of it.

From the outside, a traction control system may appear to be a fairly simple tool. All you do is compare the speed of the driven wheels to the un-driven and limit the output of the engine accordingly.

The reality, however, is that configuring traction control is a somewhat involved task and requires multiple sensor inputs, calculations and contributions from both driver and engineer.

Looking at the basic items necessary to make good use of traction control, first of all we need to be able to influence the output torque of the engine. This is normally done through ignition cut or fuel cut. Other parameters that also influence the torque are ignition retard and engine throttle (if a drive-by-wire throttle system is used). The latter two options tend to give minimal feedback to the driver and are therefore more difficult to use efficiently.

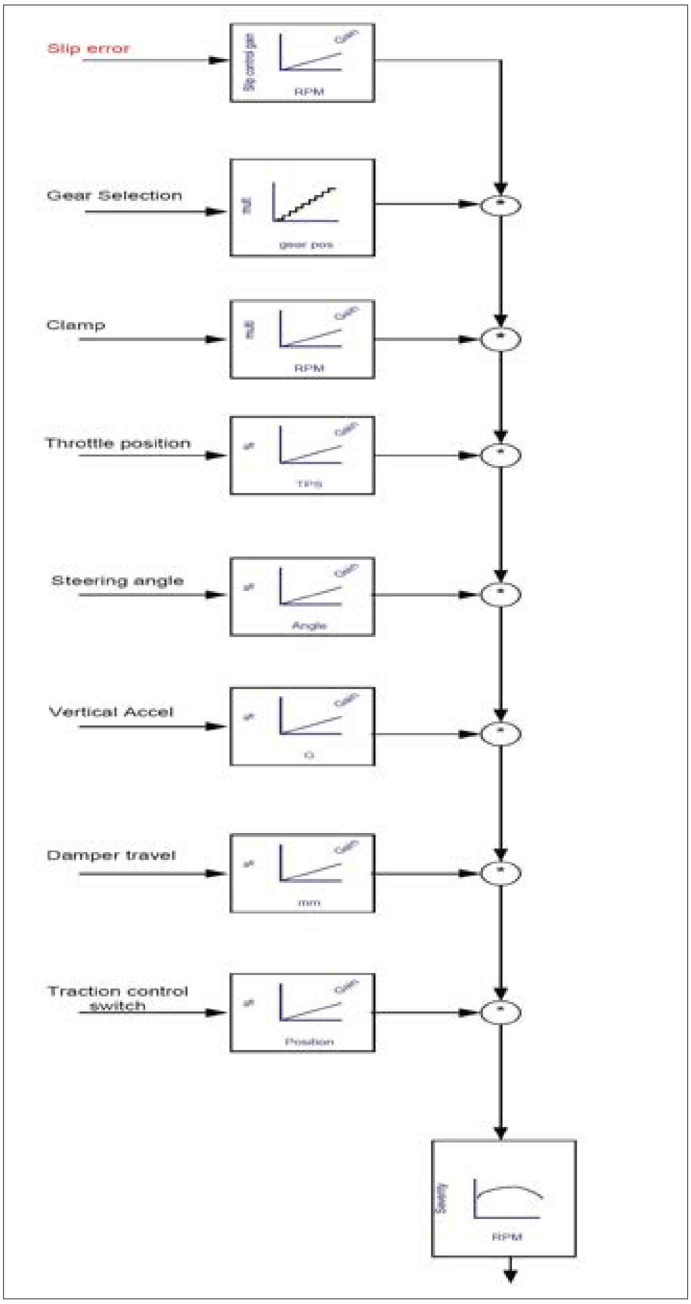


Figure 1: different multipliers that can be used to influence traction control strategy

The ultimate goal for the control system is to constantly be at the limit of the traction circle

Torque reduction

The parameter that is the end result of the traction control strategy is termed torque reduction, as our calculation tells the engine control unit how much less torque should be applied at each point in time. We then need a trigger to decide when to apply the traction control strategy and when not; normally this is termed slip or wheel slip. In order to determine slip we need a reference speed and the speed of the driven wheels. In most cases the reference speed will be the un-driven wheels, but this is not always a viable solution, for example in rally cars when the car is hardly ever going in a straight line and all the wheels are slipping most of the time. In those cases either a ground speed radar or GPS may be the solution and in some cases it is possible to use the rate of change of RPM to detect loss of grip.

There can be multiple factors that we want to include in the ultimate torque reduction goal should they be available. Shown here – see **Figure 1** – is an example of a system diagram that shows different multipliers that can be used to influence the traction

Table 1: torque reduction

Gain factor	Value	Cumulative torque reduction
Clamp	80	80
Throttle demand	100	80
Steering demand	50	40
Lateral acceleration	100	40
Damper position	80	32
User control	95	30.4

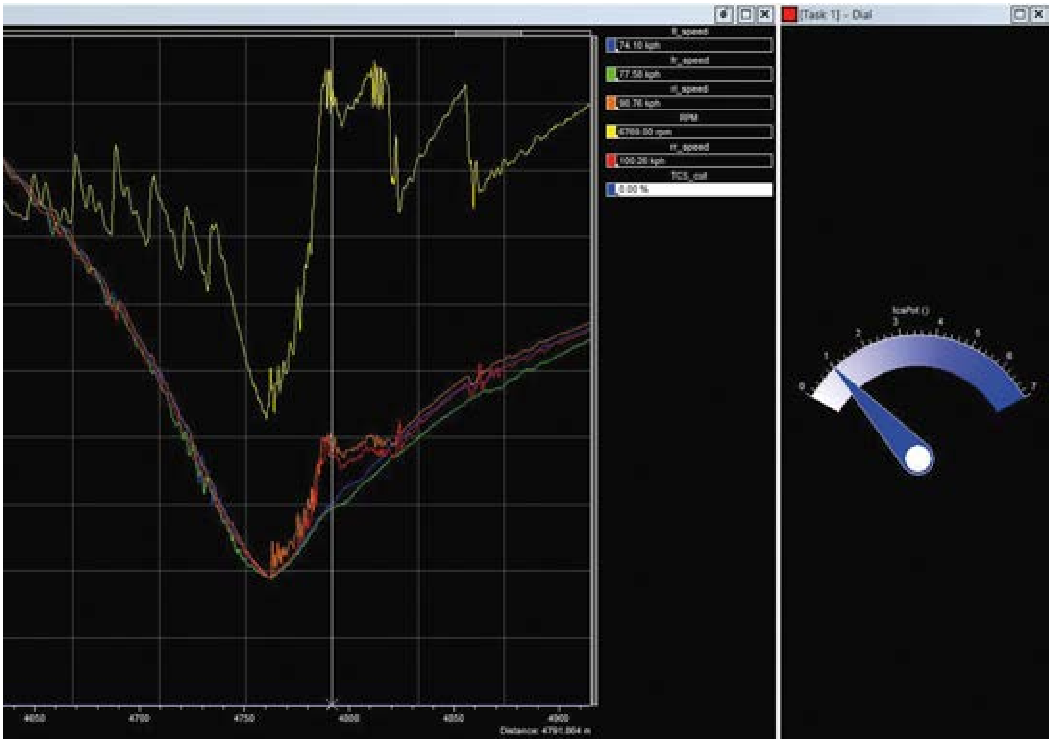


Figure 2: traction control inactive

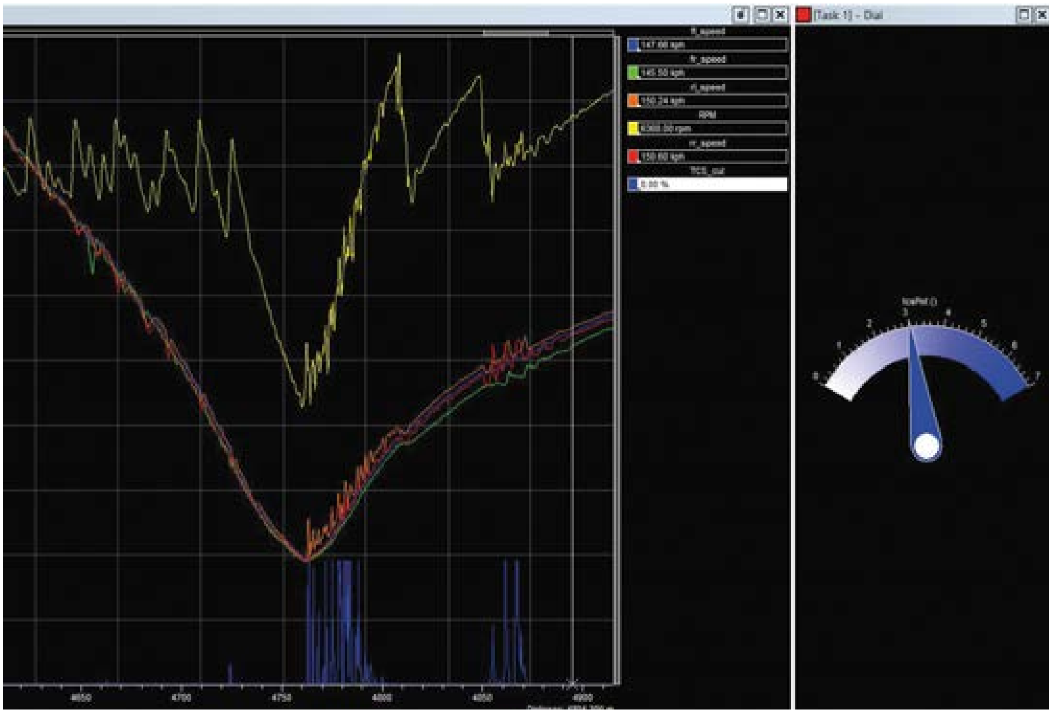


Figure 3: traction control active, in position 3

control strategy. The ultimate goal for the control system is to constantly be at the limit of the traction circle.

By looking at the possible multipliers we start to get an idea of what inputs we need and what channels to monitor.

Ideally the data logger built into the ECU should be used to do traction control analysis, as this eliminates any delay that could possibly come from external devices.

Similarly the sensors most critical to the traction control should be connected directly to the ECU. The clamp gain is a very important factor in the torque reduction calculation as it dictates the maximum value of the torque reduction.

This value allows us to set a limit of torque reduction available. Left is a sample calculation of the torque reduction value, all figures show percentage and they are applied in order. See **Table 1.**

In this case we would end up with a torque reduction of 30.4 per cent.

Tight corners

The effects of traction control can often be quite dramatic and the below dataset shows clearly how much of an impact the traction control has on the grip level available going through a tight corner.

In the first image the traction control map switch is in the off position, meaning the traction control is inactive. We see a major wheel spin on the rear meaning the car is quite upset at this point. The second image shows the same corner with the traction control in position 3 – the wheel slip is limited and we can see the torque cut demands from the traction control status channel helping to maintain optimum grip. **Figures 2** and **3.**

Next month we will go through an example of how the traction control is monitored and tuned during a trackside test and look at some of the calculations and the feedback required to set the traction control system up efficiently.

COSWORTH

Produced in association with Cosworth
Tel: +44 (0)1954 253600
Email: ceenquiries@cosworth.com
Website: www.cosworth.com


Forward thinking
NEW
zero 360
Fire suppression system
ALL PRODUCTS DESIGNED & MADE IN THE UK.
The new Zero 360 is a prime example of how a manufacturer, in touch with the objectives of the sport's rulemakers, stays ahead of the game.
• Bottle mounts directly to the vehicle
• Mechanical or electrical operating heads
• Plug and play electrical wiring
• Operates in any orientation
• 2.25Kg and 3.0Kg variants.
Fire suppression
Zero Zero
AWARD WINNING
Zero 2000
Zero 2000
Rally Packages
and safety products
RACE MIRRORS
Formula, Touring, Sports and GT. Conform to FIA and MSA requirements.
QUICK RELEASE STEERING BOSSES
Formula, Touring, Rally. Available with pre-wired 8-way electrical connector.
NEW
HIGH INTENSITY RAIN LIGHT
Machined from billet aluminium with sealed-in high intensity, low energy LEDs, our new rain light is suitable for ALL racecars.
• Flashing facility
• Greater viewing angle
• Brighter
• More compact
See us at the following shows:
PRI, Indianapolis
Booth no. 1355
(Sube Sports)
AUTOSPORT
NEC, Birmingham
Stand no. E185
lifeline®
www.lifeline-fire.co.uk
Champions of Safety
Tel: +44 (0)24 7671 2999 Fax: +44 (0)24 7671 2998 E-mail: sales@lifeline-fire.co.uk


MOCAL
OIL COOLERS
• THE MOST POPULAR COMPONENT IN MOTORSPORT
• COMPREHENSIVE RANGE OF COOLING ACCESSORIES
• BRITISH DESIGN & MANUFACTURE
FOR THE BEST IN OIL COOLING SYSTEMS...
...MAKE IT MOCAL!
WINNING RACES SINCE 1967
Worldwide enquiries go to:
www.mocal.co.uk
USA enquiries go to:
www.mocal.us
0208 232 3525
Like Us

The effects of positive yaw

Concluding our probe of the University of Bath's FS contender

Team Bath Racing's 2014 Formula Student contender was selected for a session as *Racecar Engineering*'s guest in the MIRA full-scale wind tunnel after TRB 14 had caught the editorial eye at the Silverstone Formula Student competition in July 2014. In the final instalment of our aero session, we examine yaw response and the front wing in more detail.

In the previous three parts we have looked at comparisons with 2014's Formula Student car from the University of Hertfordshire, and at topics such as speed sensitivity, wheel lift, rear wing adjustments, front wing Gurneys and ride height adjustments. Time permitting, it was always intended to try some yaw angles on the car, but with just a few minutes of the session left there was time only for two positive (nose to the right) yaw angles to be evaluated. Nevertheless the data, shown in **Table 1**, was certainly thought-provoking.

Changes between configurations are shown in 'counts' where 1 count = a coefficient change of 0.001. [194] The key points then were: drag decreased, total downforce increased, front downforce decreased, rear downforce increased notably and balance shifted to the rear. Efficiency (-L/D) also increased markedly at yaw.

Looking at drag first, keep in mind that drag force is measured in the axis of the car and the turntable it rests on, not in the direction of the wind. Furthermore, not shown in **Table 1** are the side forces, which naturally also increased with yaw. Calculating the windward direction component of the drag and side forces and adding them together, so they are also independent of the effectively changing frontal area, produced the data in **Table 2**, which shows that the total force in the windward direction did in fact increase with yaw, as would have been expected.

Perhaps the most puzzling aspect was the gain in rear downforce at yaw. Or is it so puzzling? The University of Hertfordshire Formula Student car also showed an increase in rear downforce at positive yaw (up 3.6 per cent at 5 degrees yaw compared to 2.5 per cent at 6 degrees with TBR 14), although the response at negative yaw was the opposite, and this was ascribed to the car's asymmetric sidepods affecting the rear wing differently at positive and negative yaw angles. So, possible contributors in this instance could be; the feed to the rear wing was enhanced as yaw was added; side force on the large, high-mounted rear end plates generated a roll moment that produced a net increase in downforce across the rear axle; lift reduction occurred over the rear of the car as yaw was added. Further speculation will best be done over a drink!

The front wing

As reported in the September issue, (*RE* V24N9) one of the talking points of July 2014's Silverstone Formula Student competition, and rightly so, was the front wing on TRB 14 (**see Figure 2**). Aerodynamics team leader Francisco Parga explained the thinking behind the design: 'The reduced ground clearance at the centre was mostly a packaging constraint. If we went any higher, we would have had a tiny centre section as the nose was in the way (the wings were designed to fit the nose and not vice-versa...). We could also run slightly lower in the centre as our worst case scenario for ground-strike was for the wing tips in roll plus pitch.

'In planform shape, the wing diverges outwards [towards the rear] to compensate for some of the losses incurred by the centre section. The inboard part of the wing was losing a bit of performance relative to the outboard part due to the centre section arrangement.

Figure 1: TBR 14 showed some interesting behaviour when at yaw…

Figure 2: The front wing was a talking point among the Formula Student fraternity and certainly warranted close attention

Table 1 – the effects of positive yaw on TBR 14

	CD	-CL	-CLf	-CLr	%front	-L/D
Previous config	1.412	2.404	0.989	1.415	41.15	1.703
+6 degrees yaw	1.400	2.578	0.984	1.594	38.17	1.841
Change	-12	+174	-5	+179	-2.98	+138
+12 degrees yaw	1.338	2.683	0.894	1.789	33.32	2.005
Change	-74	+279	-95	+374	-7.83	+302

Table 2 – total windward direction forces at yaw – 60mph

Yaw angle	Windward direction total force, N
0	650.7
6	666.8
12	696.2

Figure 3: The upper surfaces of the front wing and end plate diverted air over and around the tyres

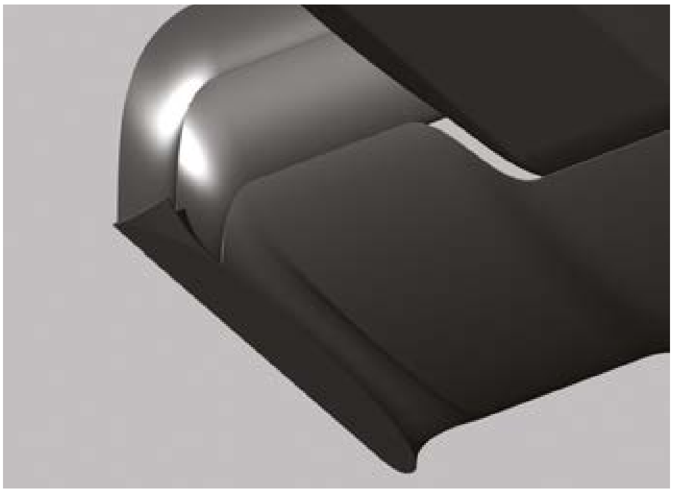


Figure 4: Viewed from below the shape of the outboard channel in the wing is clear

Figure 5: Large losses in total pressure (blue zones) reveal where vortices were beginning to form; those under the end plate footplate and wing channel are the important ones

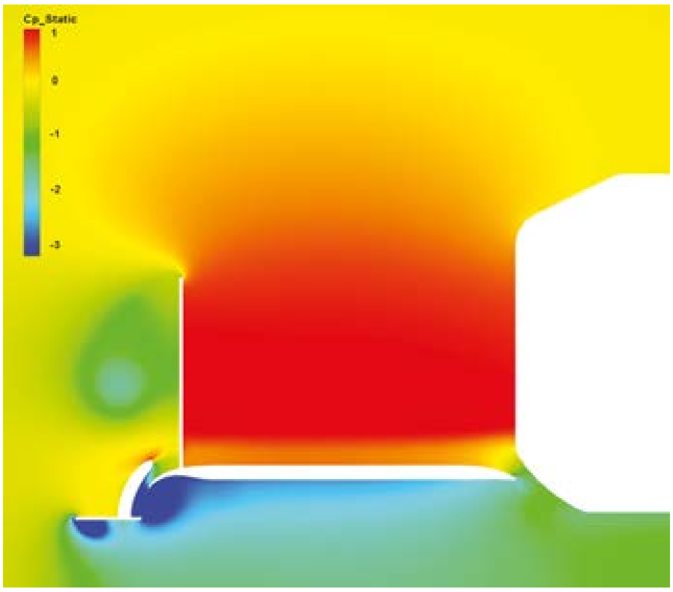


Figure 6: Areas of low static pressure associated with the vortex cores enhanced the wing's performance

Additional images are courtesy: Francisco Parga

By diverging at the endplates, we gained some of the load back at the centre section. Arguably, this is something we would have done anyway, even if we did not have issues with the inboard part of the wing, as it seemed like a pretty strong tweak.

'The divergent shape towards the rear also tied in with trying to keep the tip vortex from bursting too early. 'The channel just inboard of the footplate catches the initial footplate vortex, and allows it to grow – and seal the low pressure under the wing from the higher pressure in the surrounding air without bursting and leaving a lossy area of total pressure on the outboard section of the wing.

'As the vortex grows, we needed to expand the channel to grow with it. The divergent planform made this relatively easy (**Figure 3**).

'Once we had a wing we were fairly happy with, we noticed some separation on the outboard side of the divergent channel. (At this point we were running a more standard endplate configuration.) We decided to incorporate flaps into the endplate to cure these separations. Once the endplate was "flapped" it made sense (from a structural perspective) to combine the main flaps with the endplate flaps.'

The front wing was both taller relative to the wheels and wider (equal to the car's width) than many categories permit, and it was evident that this directed air over and around the front wheels, potentially a useful benefit. But the behaviour of the underside of the front wing is best visualised with CFD. The CAD rendering in **Figure 4** better shows the shape of the wing's underside. **Figure 5** shows a transverse plane at 15 per cent of the front wing chord revealing where there were losses in total pressure; the beginnings of various vortices are apparent.

The vortices under the wing's channel and end plate footplate are the important ones, as **figure 6** demonstrates. This is a static pressure plot just ahead of the first slot gap and the vortices have now developed to create performance-enhancing low pressure regions.

Racecar Engineering extends its thanks to the staff and students at Team Bath Racing, and to MIRA for the use of their wind tunnel. Subscribe to Racecar Engineering to keep up to date with further studies. In our next study, the BTCC comes under the spotlight.

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

Produced in association with MIRA Ltd

MIRA

Tel: +44 (0) 24-7635 5000
Email: enquiries@mira.co.uk
Website: www.mira.co.uk

Good recovery?

Efficient energy recovery is of paramount importance for the hybrid power units introduced to Formula 1 and WEC in 2014

By RUDOLPH VAN VEEN

Formula 1's current technical rulebook had something of a protracted gestation, especially in terms of the innovative latest power units that all teams now use. From its first proposals back in 2008 to the homologation deadline in early 2014, there was plenty of time for the engineers developing the new units to work out all the best solutions, and as a result there would be some sort of consensus. But, as the cars rolled out for the first test, it was clear that very different avenues had been explored, particularly by Mercedes High Performance Powertrains (HPP).

One of the biggest areas of difference is the layout of the exhaust headers, turbocharger and exhaust gas energy recovery system (MGU-H). The three power units utilised in the 2014 F1 season each featured a different layout and each performed very differently. This is a crucial area of performance for the new power units, because the amount of energy recovered by the MGU-H has a big impact on the unit, and in turn the whole car's overall efficiency, and as a knock-on impact of the new rules, efficiency equals performance.

Cranfield University student **Rudolph Van Veen** set out to find out more about the different teams' layouts, and armed with detailed images of the exhausts of both the Ferrari and Mercedes design wrote his thesis titled 'The effect of exhaust manifold volume on the amount of recoverable energy out of the exhaust gasses in an F1 application.'

The following article is entirely based on that thesis and its findings.

More energy

This study, focused on the exhaust system, has shown that the log-type manifold used by Mercedes has significant benefits over the equal length manifold design used by Ferrari and Renault Sport.

It has also shown that the log-type manifold is more capable in terms of retaining the exhaust pressure and temperature. This results in a higher pressure ratio across the turbocharger turbine, which will allow a MGU-H to extract more energy from the exhaust gas.

The benefits of a log-type manifold design are not limited to having a greater pressure ratio and a greater temperature ratio across the turbine. This design also allows for a more compact design of the exhaust system. A more compact design benefits packaging greatly as can be seen with the Mercedes powered cars, especially considering the emphasis placed on efficient cooling by the new regulations.

One of the first things to look at is the design and application of the turbochargers in 2014 F1 cars, Ferrari, Mercedes AMG HPP or Renault Sport. The F1 turbochargers are similar to regular turbochargers but there is a difference: the electric motor (MGU- H) is connected to the shaft. This allows for energy harvesting as well as velocity control, which in turn makes for a more efficient turbine operation, as it's operating at or near the most efficient point. In some, presumably F1, applications separate control of the compressor and turbine is possible, which would further increase efficiency of the turbocharger. This would greatly increase the complexity of the unit as well as the required control systems. It is worth noting that the actual designs of the turbochargers vary greatly, with Mercedes and Ferrari placing the MGU-H between the compressor

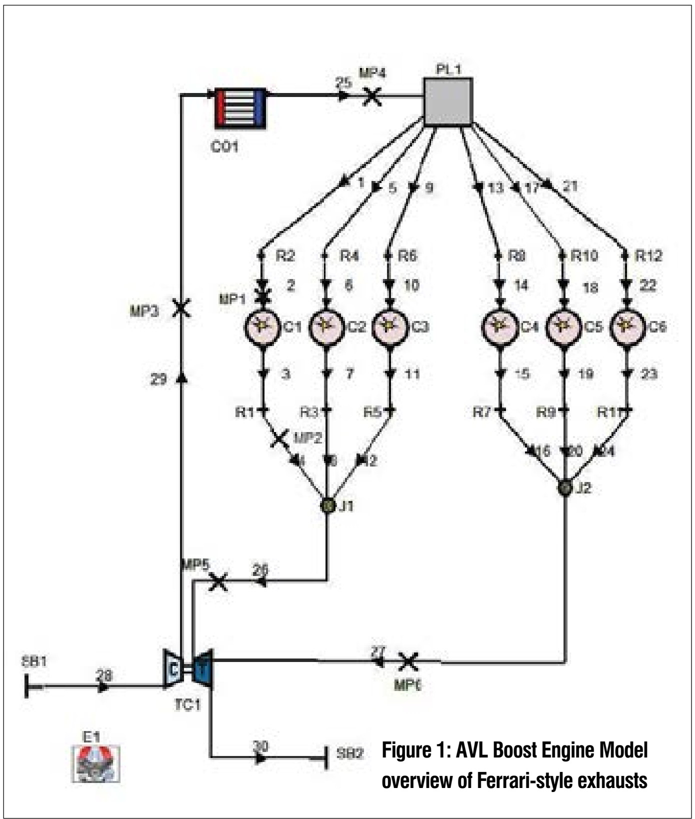
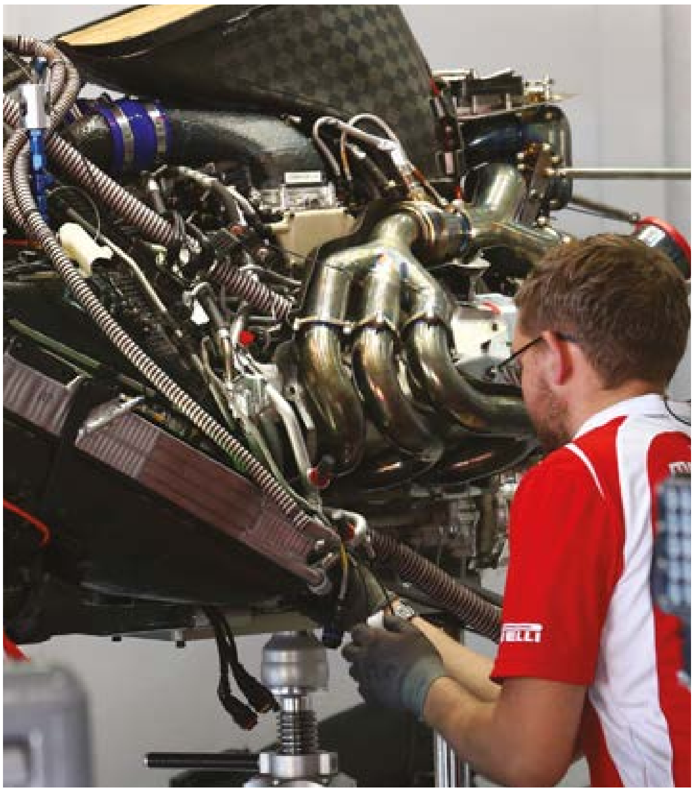


Figure 1: AVL Boost Engine Model overview of Ferrari-style exhausts



Ferrari-style exhausts as seen on the Marussia MR03. Note lack of thermal barrier

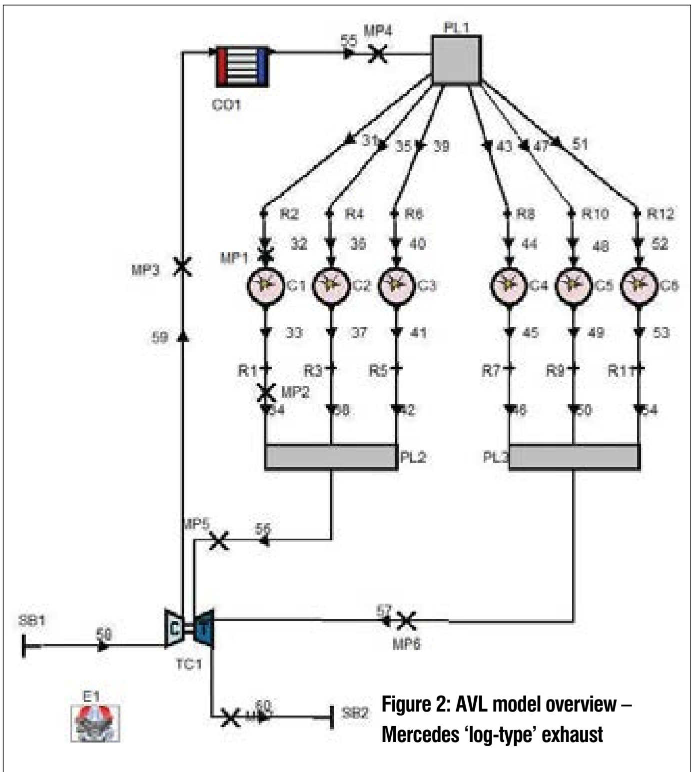


Figure 2: AVL model overview – Mercedes 'log-type' exhaust

Mercedes Pu106A Hybrid engine showing log-type exhaust

and turbine, while Renault utilises a conventional turbo layout with the MGU-H mounted on the shaft on the compressor side.

In this study, the turbine wheel and housing are considered as a "black box", as analysing the interaction of the turbine blades with the transient exhaust gases is outside of its scope, though a study of this would be rather interesting for further work. The "black box" approach obviously results in some inaccuracies, but for the purpose of this study it should be sufficient. As a result the effect of turbine blades on the exhaust flow is ignored.

Turbine efficiency is dependant on the temperature and pressure drop across the turbine. For that purpose there are, basically, two exhaust manifold design strategies. The constant pressure exhaust manifold and the pulse charged manifold. Both have their respective advantages and disadvantages.

The constant pressure design consists of a large volume exhaust manifold, which is used to dampen out any pulses. The aim of this is to have the turbine operate as close to a steady-state environment as possible. A major disadvantage of this type of manifold is that it doesn't deal well with transient situations, such as acceleration and deceleration. Hence this type is reserved mainly for marine diesel applications.

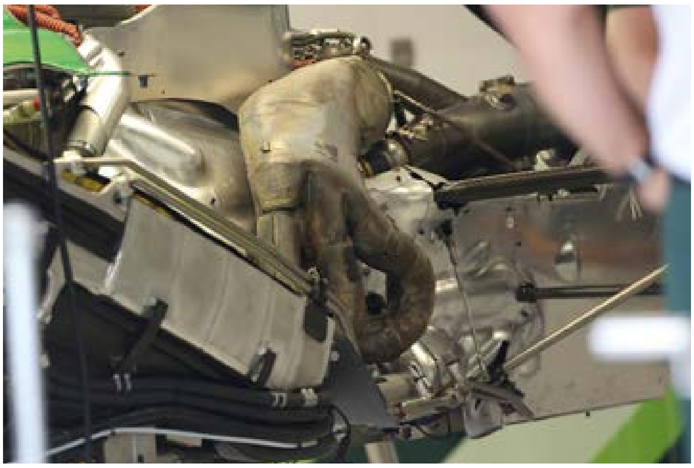
Pulse charged type manifolds are designed in such a way that they transfer the kinetic pulse-energy in the most efficient way to the turbine. This results in more energy being presented at the turbine inlet.


The Renault RS34 V6 engine showing clearly its turbocharger

Table 1: equal length manifold parameters	Length (mm)	Diameter (mm)
Port	80	41
Collector-turbo	230	57
Primaries	270	41
Primaries TestRun1-1 case1	270	30
Primaries TestRun1-1 case2	270	41
Primaries TestRun1-1 case3	270	50
Primaries TestRun1-2 case1	270	25
Primaries TestRun1-2 case2	270	35
Primaries TestRun1-2 case3	270	45
Primaries TestRun1-3 case1	270	22.5
Primaries TestRun1-3 case2	270	27.5
Primaries TestRun1-3 case3	270	32.5


Exhaust manifolds removed from Ferrari 059/3 V6 engine

Table 2: pre-volume log-type parameters	Length (mm)	Diameter (mm)
Port	80	41
Collector-turbo	230	57
Primaries	100	41


Renault RS34 exhaust manifolds believed to use Sulzer-type GDR

The turbine is unable to convert this unsteady supply of energy in an efficient way. A relatively simple way of improving the pulse charge manifold is to group the cylinders (already done by all F1 powertrain manufacturers mentioned earlier).

Some turbochargers could potentially further increase the energy extraction through use of the variable turbine geometry. When comparing a VG turbo with a regular, non-VG turbo, it is necessary to have a turbine flowmap for each setting of the VG-vanes, as each vane-setting basically changes the turbine efficiency as well as the flow and pressure characteristics. This type of technology is not currently permitted by the Formula 1 technical regulations, but is currently used in LMP1 engines.

Even within the pulse charged manifold, there are several design possibilities, as there are multiple factors to be considered when designing the power unit, such as packaging and harmonics. Depicted in the images on these pages is a comparison between a Mercedes, Ferrari and Renault power unit.

As can be seen, the differences are quite significant. The Mercedes power plant is, going by the images available, aiming to keep the exhaust system volume as low as possible. It is likely this is governed by two reasons, the first being the transference of energy to the turbine, and the second being the packaging requirements of the complete power train and overall car (see Andy Cowell on p18).

The significant difference between exhaust manifold designs can't go unnoticed, unfortunately (and understandably) neither Mercedes or Ferrari were willing to discuss the exact details of the internals of their exhaust headers or turbocharging layout. So the question arises: what can't we see?

Based on writings of Winterbone and Pearson, the exhaust system of turbocharged engines should have gas dynamic rectifiers (GDRs), or pulse converters, in the system. These are used for the purpose of directing the kinetic energy to the turbine in the most efficient manner, as well as to decrease the adverse scavenging effect brought on off tune pressure waves. Considering Figures 8, 9 and 10, the study comes to the conclusion that the Birmann-type GDRs are used by Mercedes, while Ferrari and Renault use Sulzer type GDRs. In the study the GDR's themselves were not modelled, but the joints were, albeit in very basic way and without losses, the only option without more detailed imagery in the public domain.

To evaluate the different solutions seen so far in F1, the study utilised Cranfield's 2014 F1 engine model developed and validated by graduate Cranfield student Tom Kempynck, powertrain control engineer at Lotus Cars. The software package used is the 1D engine simulation AVL Boost, which is capable of simulating a variety of engine configurations and types, as well as different fuel types.

The engine model is based on the 2014 F1 technical regulations, without the MGU-H as this study is aimed at extracting energy from the exhaust gases through the manipulation of the exhaust manifold volume. **Figure 1** provides an overview of the model used. It is assumed to be correct and validated, as its main purpose is to provide simulated pulsating exhaust gas through the exhaust system into the turbine. As such, the engine itself is not recalibrated for each setup, as this would significantly change the gas dynamics. For this study any turbocharger would suffice, as it was

Variable turbine geometry could further increase energy extraction

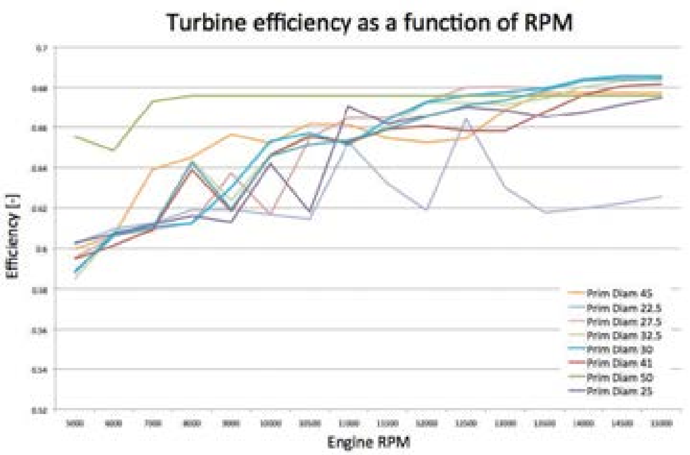


Figure 3: Equal length manifold turbine efficiency

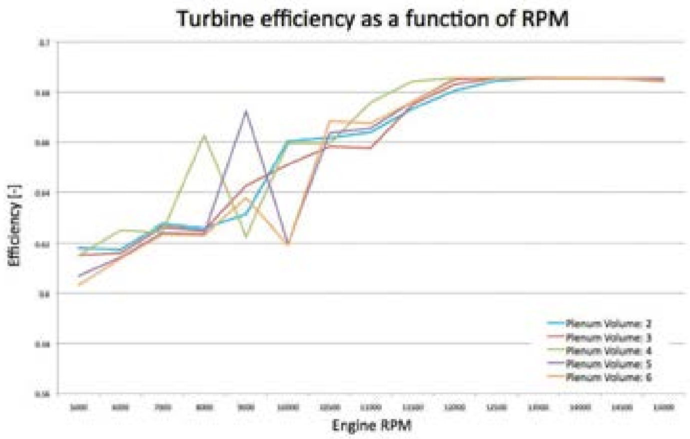


Figure 4: Log-type manifold turbine efficiency

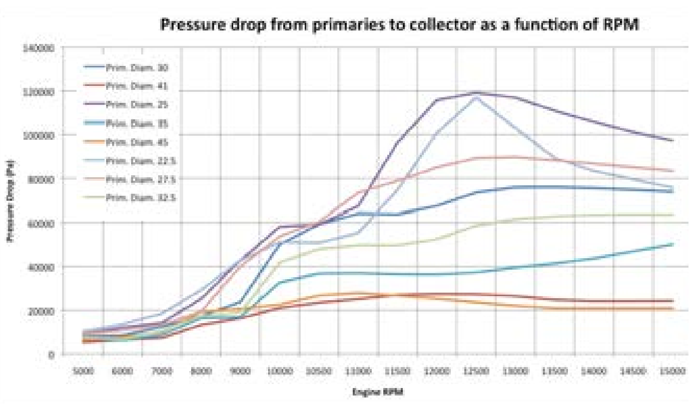


Figure 5: Pressure drop from primary into collector (turbine inlet), equal length manifold

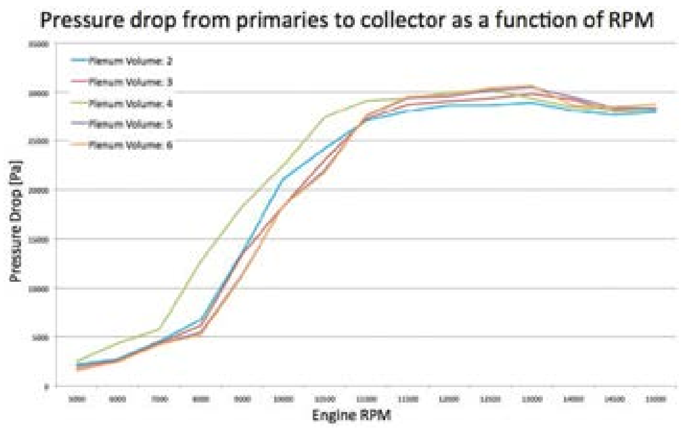


Figure 6: Pressure drop from primary into collector (turbine inlet), log-type manifold

solely used to analyse the effect of the exhaust design on the turbine work, efficiency and rotational velocity.

In order to keep the complete engine as validated as possible, the complete Cranfield-Kempynck AVL model was used. With a number of details of the systems used in F1 fiercely guarded secrets, exact results are very difficult to achieve. In addition, the software used, AVL Boost, is limited in its capability in dealing with pulse waves.

So the study aimed to establish a trend between exhaust manifold volume and the recoverable amount of energy in the exhaust gas, and possibly quantifying the potential performance gain. I have used as much of the available data is possible, though in order to do so it is required to have a good understanding of the exhaust system, its design, design consequences, pressure waves and how to influence those.

Two general exhaust manifold designs were studied; the Mercedes style log-type design which is assumed to use Birmann GDRs, and the more traditional Ferrari layout which is assumed to use the Sulzer solution.

In the model, the exhaust manifold design was modified from the supplied equal length type to a log-type by removing the existing primaries and using volumes in order to simulate the primaries ending in a common pipe. An alternative method of simulation could have been by means of a pipe and changing its volume, which is connected to the primaries through junctions. This resulted in speed of sound errors in the simulation, which couldn't be prevented through modifying the diameter of the common pipe. **See Figure 2.**

The volume of Ferrari style manifold, without significantly affecting the harmonic tuning of the manifold, was modified in AVL through adjusting the diameters of the primaries. The values are shown in **Table 1**. Choosing which primary diameters to simulate was based on performing a sweep around the original primary diameter from Cranfield-Kempynck model.

The configuration of Mercedes style manifold is significantly different from an equal length manifold. It is therefore required to estimate the primary lengths which connect to the volume (or the log as it often called), as no hard data, or any images of the design with the heat shield removed, has appeared to date. The primary lengths were estimated from the images available, which are numerous and scaleable. The scale was determined based on the assumption that the exhaust has a diameter of a 100mm. The estimated parameters are shown here in **Table 2**.

Pressures and temperatures are of great significance when analysing the turbocharger turbine performance. The pressure and temperature drop across a turbocharger turbine reflects how much energy from that exhaust gas has been converted, assuming that there are no other significant losses. **Figures 3** and **4** show the differences in turbine efficiency.

Figure 3 shows the variety in turbine efficiency as a function of engine rpm. The most obvious differences are in the lower rpm-range. However; this is focused on a F1 application the focus is limited to the rpm-range above 10,500rpm. What is clearly shown in **Figure 3** is that a primary diameter mustn't become too small. Most configurations show turbine efficiencies between 65 per cent and 68 per cent from 11,000 rpm onwards. The only two configurations with a lower efficiency than 65 per cent at

Two manifold designs were studied, the Mercedes style log-type design and the more traditional Ferrari solution

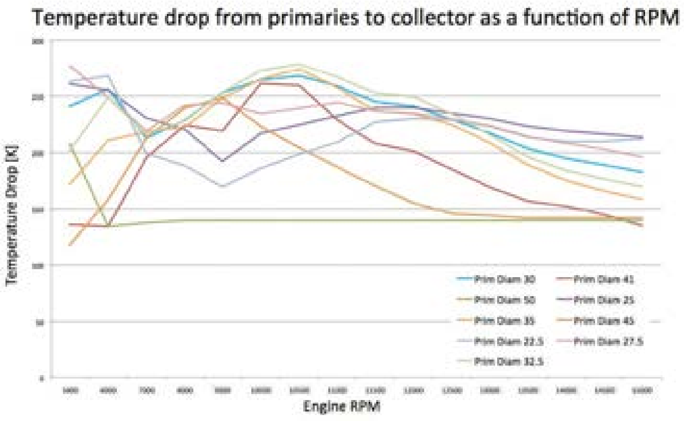


Figure 7: Temperature drop from primary into collector (turbine inlet), equal length manifold

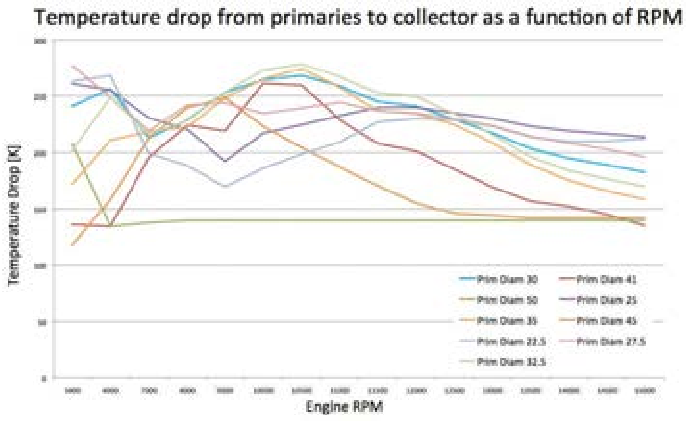


Figure 8: Temperature drop from primary into collector (turbine inlet), log-type manifold

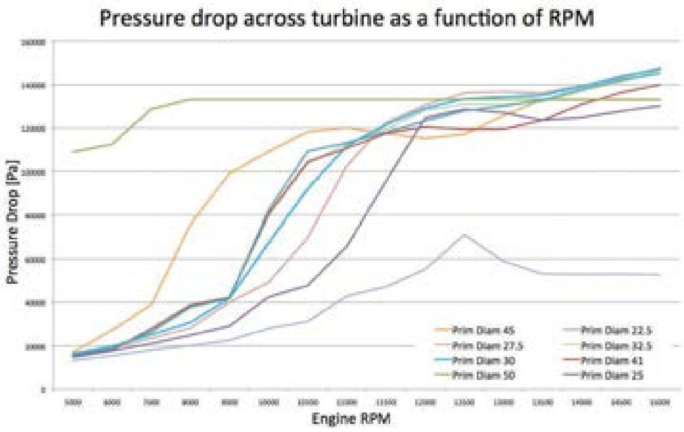


Figure 9: Pressure drop across turbine, equal length manifold design

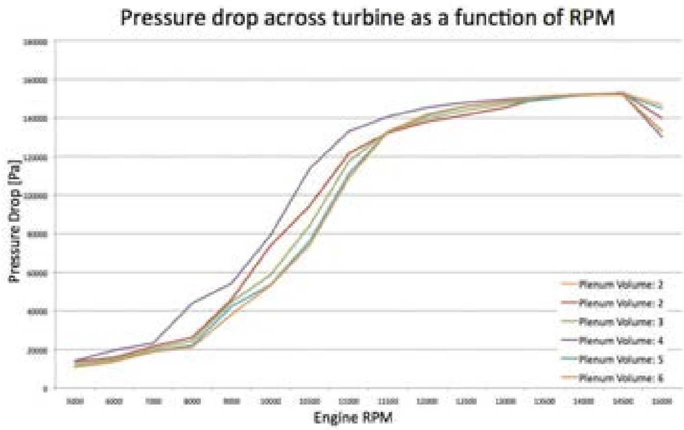


Figure 10: Pressure drop across turbine, log-type manifold design

10,500 are with primary diameters of 22.5 mm and 25mm. Considering that 41mm primary diameter is the original value, 27.5mm shows a significant improvement from 10,000rpm onwards.

The efficiency curves of the turbine connected to the log-type manifold differ quite substantially. The first thing that catches the eyes is the "plateau", starting from 11,500 to 12,000rpm. As the focus rpm-range starts from 10,500rpm, the plenum volumes of 5 and 6 litres don't seem suitable for this application. All the simulated volumes do reach the maximum turbine efficiency of 68 per cent.

As stated before, in a turbo charged application, it is of great significance to maintain the pressure waves in order to transmit as much gas kinetic energy to the turbine wheel as possible. In order to analyse this, the pressure drop across the system was evaluated in two sections. The first is the pressure drop from a primary into the collector (turbine inlet); the second being the pressure drop across the turbine.

The simulated log-type manifolds seem to, over-all, perform better than the equal length manifold, when it comes to maintaining the pressure within the exhaust system. With the exception of 41mm and 45mm diameter primaries, the equal length design seems to be incapable of maintaining the pressure in the exhaust system, which then results in a reduced pressure ratio across the turbine. See **Figures 5 and 6**.

Pressure and temperature are two inseparable parameters when studying the exhaust system and the turbine. A decrease in temperature, in a closed volume, will cause a proportional decrease in pressure. Thus, it is very important to reduce the temperature loss throughout the system. Curiously, with this in mind, it is worth noting that while both Renault and Mercedes teams tend to utilise extensive heat shielding and other thermal barrier technologies on the exhaust headers, the Ferrari runners such as Sauber (see P22) and Marussia tend not to.

Figures 7 and **8** show the temperature drop (temperature loss) from the primaries into the collector. The log-type manifold seems to be better capable of maintaining the temperature in comparison to the equal length manifold.

All log-type plenum volumes have a temperature drop of less than 200K when the engine is operating above 10,500rpm. The 4 litre plenum volume has less temperature drop across the rpm-range up to 13,500rpm. After 13,500rpm, the other volumes have less of a temperature drop, though in 2014 the engines rarely exceeded this level. See **Figures 9** and **10**.

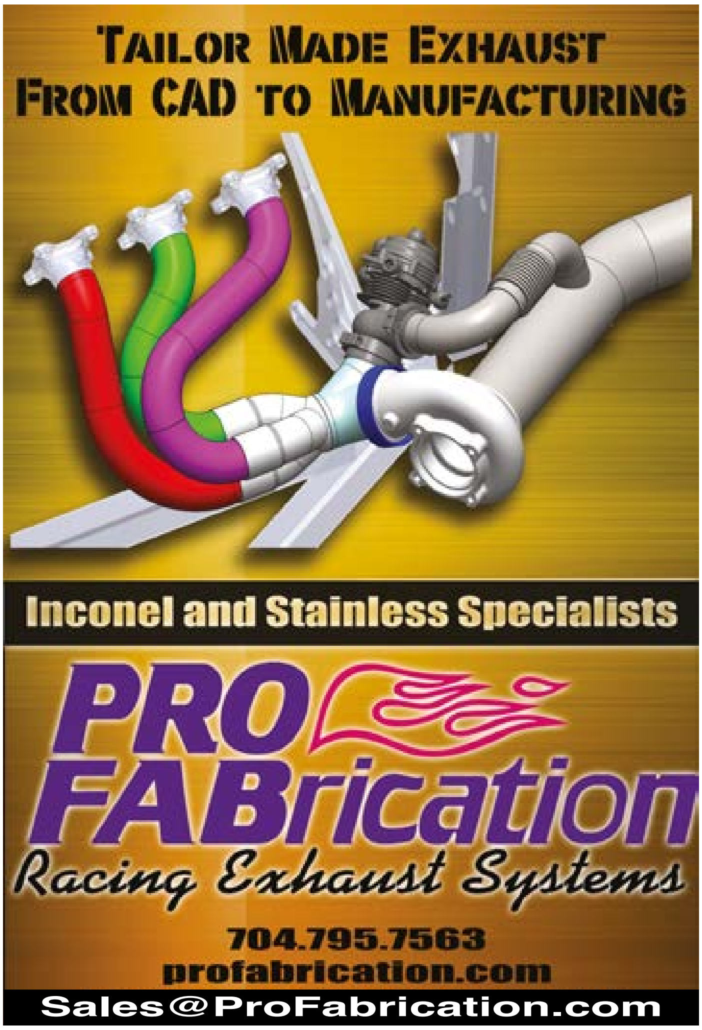
What is especially interesting to note is that the peak pressure drop across the turbine is much more stable and higher with the log-type manifold design. This would imply that with this design, the turbine is better able to convert the energy presented.

Overall the study concluded that the log-type manifold is more suitable for an F1 application, due to its capability to maintain the temperature as well as the pressure in the system, which in turn gives the MGU-H more potential energy to recover. But the study also highlights the need for further research, especially into the design and application of GDR's through means of CFD analysis, which it concludes could greatly benefit overall power train design, as the application of GDRs is not limited to Formula 1.

Formula 1's three power unit suppliers, as well as those using turbocharged power units in other categories, such as Porsche and Audi in LMP1, will all likely be studying applications of GDRs and general header design, and it is probable that a number of them will also test the Mercedes style log exhaust in 2015 if, that is, they can work out exactly how it functions.

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


COOL IT Thermo Tec
Racing Products
LEADING EDGE HEAT CONTROL.
LESS HEAT EQUALS MORE HORSEPOWER.
• IMPROVES PERFORMANCE & EFFICIENCY
• EASY TO APPLY
• UNIVERSAL PRODUCTS
EXHAUST INSULATING WRAP
FLOOR INSULATING MAT
ADHESIVE-BACKED HEAT BARRIER™
COOL-IT™ PLUG WIRE SLEEVES
Call (800) 274-8437 or visit www.thermotec.com for a FREE CATALOG, technical support or a distributor near you.


TAILOR MADE EXHAUST FROM CAD TO MANUFACTURING
Inconel and Stainless Specialists
PRO FABrication
Racing Exhaust Systems
704.795.7563
profabrication.com
Sales@ProFabrication.com


PERFORMANCE & RELIABILITY
Penny + Giles maintain their lead in motorsport position sensing from 50+ years of experience in aerospace, where performance and reliability under extremely hostile conditions is paramount. Our sensors have set the benchmark in motorsport, helping every winning constructor in the Formula 1 championship since 1986.
With a comprehensive range of linear and rotary position sensors offered with contactless or contacting technologies, we can rapidly supply standard products or custom design for the more challenging applications.
Engine - throttle position - hydraulic reservoir level
Gearbox - clutch/ gearbox actuator and gear selector position
Chassis - suspension position and steering angle - throttle, clutch and brake pedal position
Brakes - pad/disc wear indication and balance measurement
To receive our Motorsport Sensors technical data today
Call: +44 (0)1202 409409 or Email: sales@pennyandgiles.com
Joysticks+Sensors+Solenoids
www.pennyandgiles.com
Penny+Giles Controls Ltd 15 Airfield Road, Christchurch, Dorset BH23 3TG, UK.
CURTISS - WRIGHT


THE NEW EVOLUTION IN TE'S MOTORSPORT MICRO CONNECTORS
DEUTSCH
AS Micro XtraLITE HE Connector
Ultra lightweight
• Compact size 2 shell
• No need for backshells for boot termination
• 6 x AWG24 contacts
Fast, easy installation
• Suitable for blind mating
• Positive locking coupling mechanism
• 6 keyway orientations
TAKE THE LEAD WITH THE DEUTSCH AS MICRO XTRALITE HE CONNECTOR WITH 6 CONTACTS
TE Connectivity (TE) introduces its DEUTSCH AS Micro XtraLite HE connector – one of the market's smallest diameter, lightest AS connectors for when space is at its most restrictive. Able to complement the ASX-3 and -5 options, this high performance interconnect helps to give you the edge in an environment where even the smallest component can be a true game changer.
Learn more at www.te.com/deutsch
TE connectivity
DEUTSCH
©2014 TE Connectivity Ltd. All Rights Reserved. DEUTSCH, TE Connectivity and the TE connectivity (logo) are trademarks.


VAC MOTORSPORTS
World Leading BMW Performance
Clutch & Flywheel Kits
Tilton Metallic & Carbon Clutches
Twin & Triple Disc Options
5.5" & 7.25" Clutches
Includes Lightweight Flywheel
ATI Harmonic Dampers
Reduces crankshaft vibrations
Reduces internal engine wear
Releases horsepower & torque
VAC Exclusive (BMW M50, S54, & more)
BMW Valve Train
VAC High Performance Valves
High Performance Valve Springs
A must for High HP cars
For BMW N54, S65, S54 and more
www.vacmotorsports.com
+1.215.462.4666
sales@vacmotorsports.com

Taking stock

From short tracks to super speedways, NASCAR has always recognised the importance of aerodynamic research

By ERIC JACUZZI

The National Association for Stock Car Auto Racing, or NASCAR as it is more commonly known, is the sanctioning body for the premier stock car racing series in the world. Since it was founded in the late 1940s, the emphasis has been on the quality of the racing for fans. This continuous drive to make racing as exciting as possible, while ensuring fair and equitable competition among drivers and teams, is at the fore of the work done by the team at the NASCAR Research and Development Center in Concord, North Carolina.

While Formula 1 is viewed by many as the pinnacle of aerodynamic development, regulations in NASCAR have permitted such development within a narrower technical window utilising scale wind tunnels, full scale wind tunnels, and Computational Fluid Dynamics (CFD).

The region around the Charlotte area features two racecar-specific full scale tunnels, the 130mph Aerodyn wind tunnel and the 180mph rolling road tunnel of Windshear Inc. Teams build specific cars for superspeedway tracks that emphasise low drag, while intermediate cars are built for maximum downforce and side force.

NASCAR has always realised the importance of aerodynamics, with specific sets of rules for the various tracks that the series runs on. Short tracks are typically defined as those tracks less than one mile in length, with more emphasis on the mechanical grip due to lower speeds. Superspeedways, such as Daytona and Talladega, utilise restrictor plates to limit horsepower, resulting in pack racing that emphasises drag and drafting as the key performance differentiators. Intermediate tracks (1-2.5 miles) make up the majority of the schedule, consisting of tracks such as Charlotte Motor Speedway, which is 1.5 miles in length and features banking of 24 degrees in the corners. The unique aspect of intermediate tracks is that they are essentially maximum handling tracks that are heavily dependent on both mechanical and aerodynamic grip.

Apex speeds can range from 160-190mph, with top speeds from 195-220mph. Understanding the aerodynamic behaviour of the cars in traffic is crucial to ensuring the cars do not become overly aero sensitive and limit the racing quality.

Intermediate car aerodynamics

The aerodynamics of an intermediate track NASCAR Sprint Cup Series car are dominated by three primary forces: downforce, sideforce and, to a lesser extent, drag. The magnitudes of these forces are shown for the baseline 2014 CFD model. It should be noted that the reliance on an older chassis and the lack of development on the outer body means the CFD model is 15-25 per cent lower in downforce than a current race car in optimum attitude. However, the performance mechanism and flow structures are more than adequate to study vehicle performance in traffic conditions. See **Table 1.**

Downforce is primarily generated by the underbody of the car. The front splitter and 43-inch wide radiator pan are the largest single downforce generating system on the car, accounting for 700-1,000lb of downforce depending on setup.

The angles of attack of the splitter and radiator pan are adjustable for the teams. Typical aerodynamic downforce balance is between 45-50 per cent front downforce, due to the extended/near steady-state cornering the cars experience on typical intermediate track corners.

The splitter and radiator pan form a diffuser surface that works to accelerate and concentrate the air coming under the splitter nose into a strong central jet. The attachment effectiveness of this jet and its expansion is heavily dictated by the pressure conditions under the centre and rear of the car. These areas are maintained at as low pressures as

Table 1: downforce, sideforce and drag

Description	Lift Total [lbf]	Outerbody Lift [lbf]	Underbody Lift [lbf]	Lift Front [lbf]	Lift Rear [lbf]	Sideforce Total [lbf]	Front Sideforce [lbf]	Rear Sideforce [lbf]	Yaw Moment [lb-ft]	% Front	L/D
2014 CFD Baseline	-2,367	+1,416	-3,817	-1,092	-1,275	-524	-209	-315	115	46.1%	-2.05

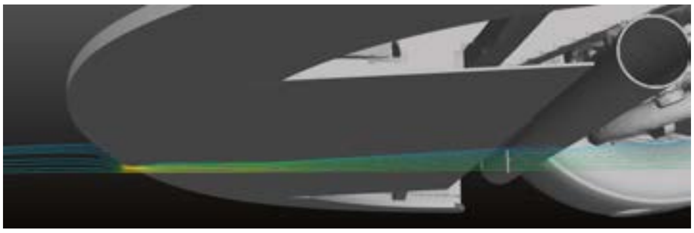


Figure 1: splitter and radiator pan with streamlines

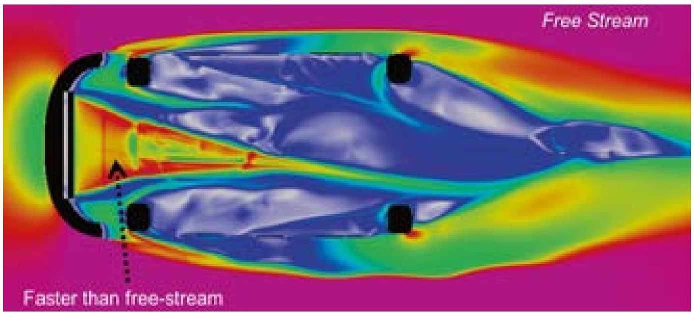


Figure 2: underbody flow structures. Purple represents free stream conditions, while the red of the central jet indicates faster-than-free-stream

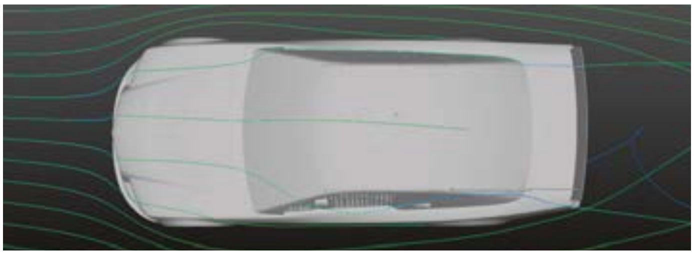


Figure 3: overhead view of CFD model with tail offset visible

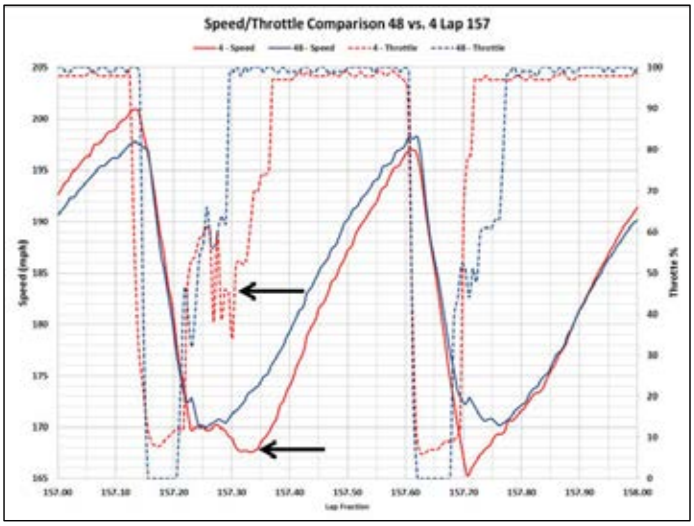


Figure 4: Lap 157 telemetry from number 4 of Kevin Harvick and number 48 of Jimmie Johnson. Throttle traces are shown by dashed lines while speed is indicated by solid lines. The lap is divided by fraction (0.00-1.00) with 0.01 of a lap equating to 0.015 miles

possible via the low base pressure created by the spoiler and maintained by the side skirts. This is why typical optimum ride height in mid-corner is around 0.5in splitter gap and the skirts of the car as low to the track as possible. See **Figures 1** and **2.**

Sideforce is dominated by the asymmetrical body shape of the car. Not immediately apparent to the untrained eye, the right side of the car is straight from the front wheel back, while the left rear quarter panel is cambered towards the right by 4in.

This gives the top view of the car a subtle aerofoil shape. The ratio of front and rear sideforce is the main driver of the overall yaw moment of the car. As expected, the rear sideforce is greater than the front to allow the driver to confidently yaw the car in the range of 3-5 degrees. While sideforce forms a lesser component of overall cornering force than the downforce magnitude, sideforce acts directly on the car without acting through the tyres. This means that the 500lb of sideforce is directly translated into lateral acceleration, while 500lb of downforce is at the mercy of the chassis setup and tire friction coefficient at that particular track. CFD results, as well as driver feedback, indicate that sideforce variation may be more critical than any loss in downforce. See **Figure 3.**

Drag is the least important factor for present power levels on an intermediate track. The pursuit of downforce and sideforce allows drivers to apply throttle incrementally earlier on corner exit. With power levels approaching 900 horsepower, this vastly outweighs the narrow band of drag gains that teams can achieve. And while the iconic images of NASCAR races are the large drafting packs of cars at superspeedways like Daytona and Talladega, the reality is that the 100-150lb drag advantage of a trailing car at an intermediate track is not enough to outweigh any on-throttle disadvantage due to car mishandling in traffic.

A sample of telemetry from a lap demonstrating this is shown in **Figure 4**. In this case, the number 4 car of Kevin Harvick (red traces) is trailing the number 48 car of Jimmie Johnson (blue traces). The 4 car drops in behind the 48 car on corner entry, trailing behind by 2-3 car lengths. On corner exit, the 4 car attempts to apply throttle as ususal but the car understeers up the track and Harvick is forced to modulate the throttle heavily. He is then at approximately 50 per cent throttle for several hundred feet of the lap, while the leading 48 car is at full throttle. The 4 car is then slower at every point on the track until the next corner, losing 0.2 to 0.3 seconds from this incident alone.

The largest drag item on the car is the 8in spoiler. The relationship between drag and spoiler height is almost perfectly linear, with 1in of spoiler accounting for 40 drag horsepower at 200mph. Drag horsepower is the industry standard measurement for aerodynamic drag.

Aerodynamics programme

In 2012, NASCAR embarked on its first CFD study of the problem. Previously, the sanctioning body had relied on occasional team support for one or two car runs, but with the scale of the problem requiring substantial personnel and computational resources, the assistance was valuable but limited in scope and timeliness. The need for a well-funded CFD study was too great to ignore any longer. To help facilitate this, NASCAR turned to TotalSim, a US-based company that provides software and engineering solutions to the motorsport, automotive and aerospace industries. TotalSim support and develop OpenFOAM®, an open source CFD software package, and has experience in applying it in every professional racing series in motorsports. NASCAR was able to leverage this expertise and within a few weeks was able to have a fully functioning CFD capability of its own running out of its Concord R&D center.

Baseline model

The R&D centre in Concord owns several older cars with bodies representative of the current field in the Sprint Cup Series. Complete scans were made of both the outer and underbody and pre-processed in Beta-CAE's ANSA. Since ANSA converts native CAD and scan data into the Standard Tesselation Language (STL) format, it saves substantial time in CAD cleanup by allowing quick corrections and rebuilds of poor surfaces into quick, watertight CFD geometry. The car is broken into approximately 30


Rapid Electronic Solutions Worldwide
dce
Lightweight Wiring Looms
Power Assisted Steering
Bosch M4 ABS
Sensors
Pneumatic Paddle Shift
Data Acquistion
Engine Management
www.dcemotorsport.com
sales@dcemotorsport.com
Mooresville, NC
USA: +1 (704) 230 4649
Maldon, Essex
UK: +44 (0) 1621 856451
PERFORMANCE PARTNERS
turning power into performance
See us at PRI booth 4128


Motorsport. Redefined.
STACK
STACK
STACK
HIGH OIL TEMP
Actual Screen Images
GPS
The STACK LCD Motorsport Display is the next evolution of driver communcation and data acquisition. Designed specifically for the harshest of environments, the carbon composite housing is IP67 sealed against water and dust intrusion and will easily withstand 20 g of continuous vibration and 50 g of shock. Our 7" LCD panel ensures easy visibility under all circumstances with a retina level pixel densisty, unmatched brightness and an optically bonded lens for extreme glare suppression. The display layout is fully configurable to your individual specifications. The system will accomodate four programmable data bus channels (2 CAN and 2 serial) in conjunction with a nearly limitless amount of discrete analog sensors and its integrated 3 Axis Accelerometer. Data collection can occur at up to 1 kHz and the internal memory allows for practically infinite recording time. User defininable warnings take advantage of super bright, multi-coloured LEDs placed around the perimeter of the chassis to alert the driver to critical onscreen information. Quite simply, everything else suddenly seems a bit dated.
STACKLTD.COM
RE12 ©2014 Stack Ltd.

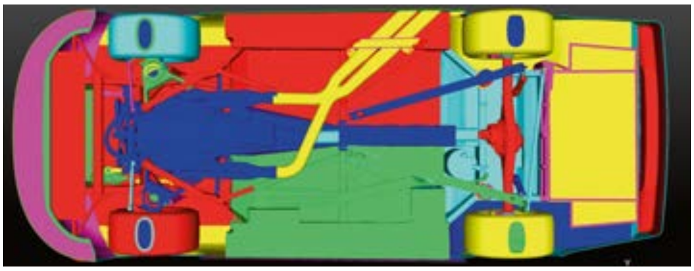


Figure 5: CFD model underbody. The various colours represent the force patches as they are reported

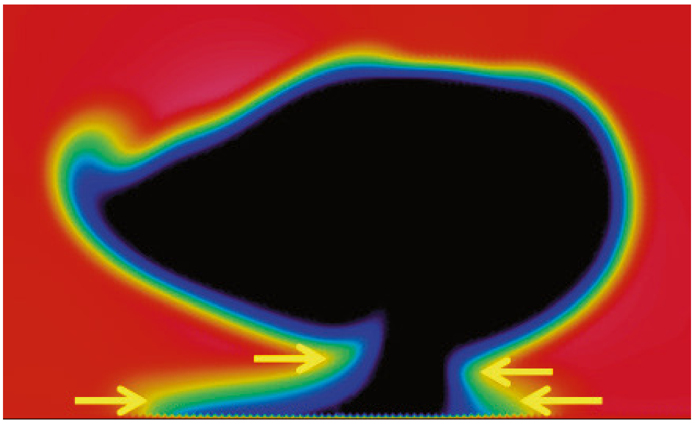


Figure 6: XY plane velocity slice approximately 5ft behind the lead car, with the black region representing airspeeds of less than 50 per cent of the red free stream velocity. The large ground wake region is evident, as well as the 'Snoopy nose' feature at the left, caused by the rear window and decklid fins

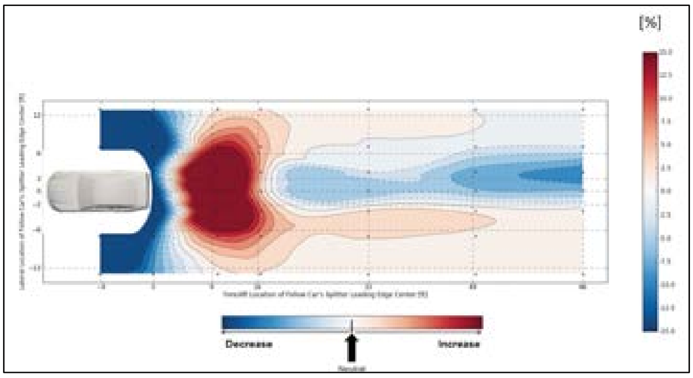


Figure 7: drag percentage delta of trailing car compared to the lead car

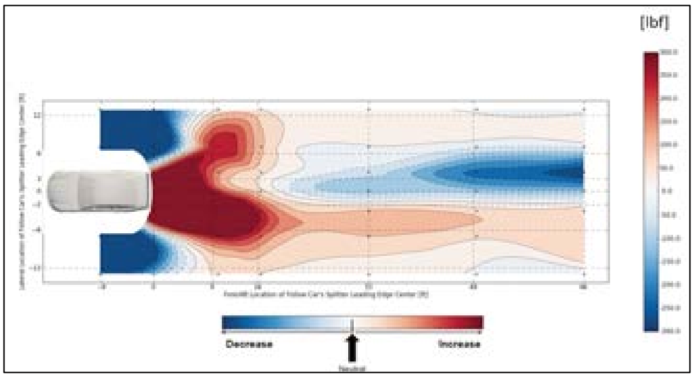


Figure 8: downforce delta in lbf of trail car compared to the lead car

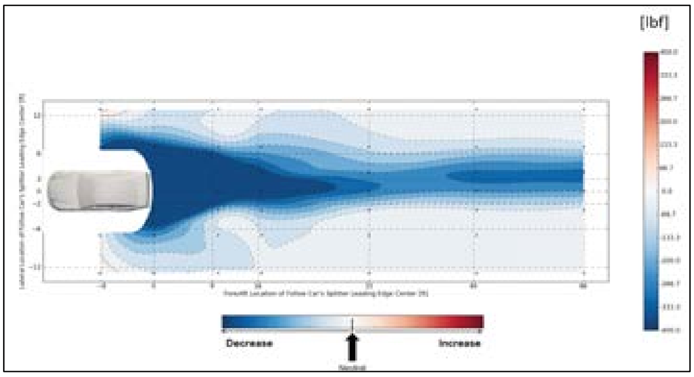


Figure 9: underbody downforce of trailing car compared with itself alone in free air

separate regions that separate the outer and inner components and regions into reporting patches of interest. See **Figure 5.**

The solution is carried out by OpenFOAM, featuring customised wall functions and using the K-Omega SST turbulence model. Typical grid sizes for a single car run are on the order of 50 million polyhedral cells, while two car runs are on the order of 110-120 million depending on proximity. Several transient Detached Eddy Simulation (DES) runs have also been performed to validate certain critical results and wake structures behind the car, but have not yielded any substantial changes that would necessitate running in this condition. For comparison, a 144-core steady state single car run can be completed from ANSA STL to results in 10 hours, while a transient DES run starting from a resolved steady state run can take upwards of four days to run three seconds of flow time on similar hardware. Given this, runs are performed in an incompressible steady-state manner, which yielded a good compromise of run time versus accuracy. See **Figure 6.**

Aero performance mapping

After establishing the baseline model performance and validating at a variety of ride heights and yaw conditions, two car traffic simulations were performed. These consist of a lead car that remains stationary, while a series of 46 simulations are performed with the trailing car in a variety of positions laterally and longitudinally behind the lead car. Both cars are at the same ride height and yaw angle. The 46 CFD runs generate 500Gb of data that includes force patch reporting and automatic pressure and velocity imaging.

The next question is how to best handle the volume of data and visualise the aerodynamic behavior effectively. This is done by plotting the aerodynamic characteristic of interest using a contour plot that interpolates that characteristic spatially between the discrete simulation points. Using a simple two colour common scale creates effective imagery to convey car performance. The black dots indicate where the center of the trail car's splitter was on the run that generated data for that point.

The drag delta plot shows that while the trailing car has a drag advantage of around 5-10 per cent from one car length and further back, at closer range its drag increases markedly. This is a two-fold change: the trailing car is helping the lead car by forming a more aerodynamic two car body, which is at the same time shielding the usually very low pressure A-pillars of the trailing car, increasing its drag. **See Figure 7.**

The downforce delta plot of the trailing car vs. the lead car begins to show regions where cornering performance is compromised, even at substantial lengths behind the lead car. There is a region to the left side of the lead car where the trailing car is at a downforce advantage. Drivers are aware of this region and will work to prevent a trailing car from being in that area. What is the reason for this? Since the body of the car makes lift, when any region of it is in the wake of the lead car, the body makes less lift – and hence downforce. In a sense, the maximum downforce the outer body of the car makes is when it's stationary. The opposite is true of the underbody of the car, particularly the splitter and radiator pan system which require faster moving air to make maximum downforce. Plotting the underbody downforce of the trailing car in traffic compared to in free air reveals the underbody downforce deficit caused by the slow moving air near the track. **See Figure 8.**

The underbody downforce plot of the trailing car compared to itself in clean air paints a clear picture of where downforce losses are coming from. The underside of the trailing car, from the splitter to the very tail of the car is running in the large ground wake formed by the lead car. The majority of the component level loss here is from the splitter-radiator pan system, followed by the underhood

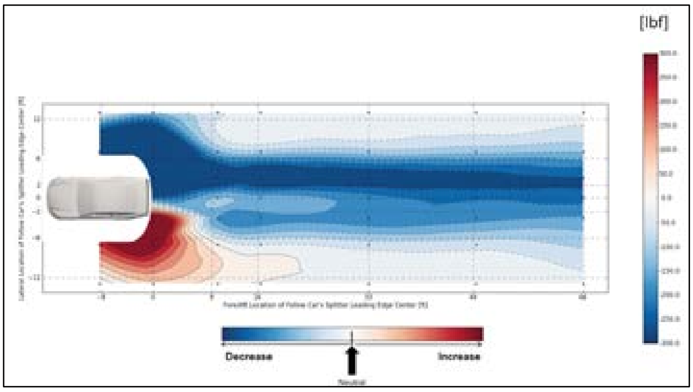


Figure 10: skewing the car (pre-yawing it with the rear axle). This makes the car faster by itself but can make for poor handling in traffic

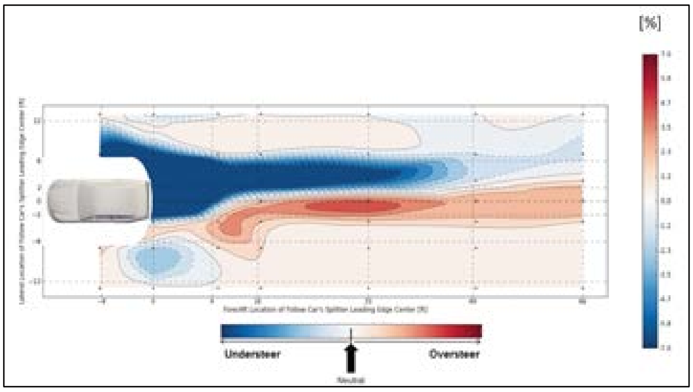


Figure 11: CFD results indicate that the hood and fender region contacting a small part of the slow moving wake causes an increase in front downforce

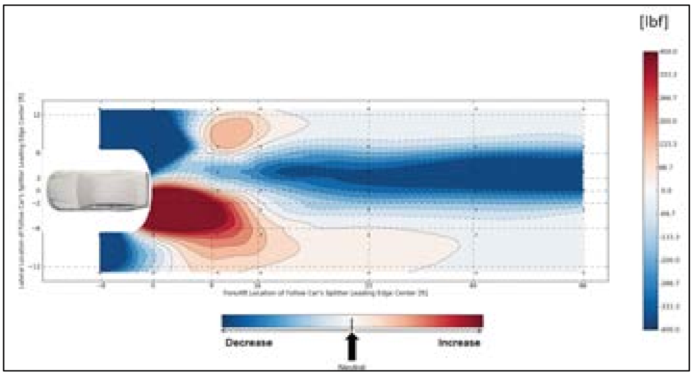


Figure 12: the trailing car is forced to run in the loss region in order to run its optimum line

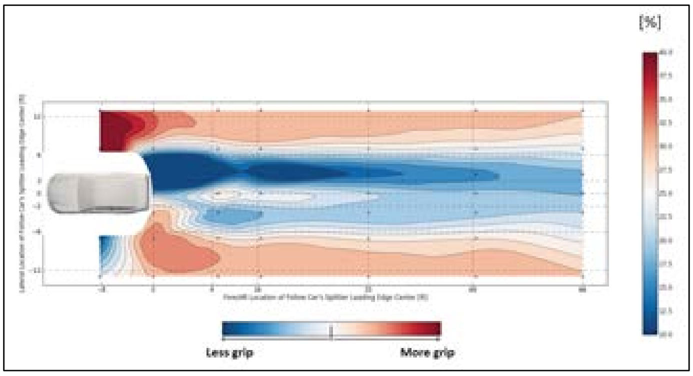


Figure 13: sideforce and traffic-handling issues: the proportion of the total cornering force the sideforce makes up at various positions

and central underbody regions. See **Figure 9.**

The sideforce delta plot reveals a dramatic loss in sideforce of over 300lb, which is well over 50 per cent of the car's total sideforce performance. Interestingly enough, across the various series that NASCAR operates (NASCAR Camping World Truck Series, NASCAR K&N Series and so on), drivers' comments and setup decisions by teams seem to indicate that over-reliance on sideforce is a negative characteristic. This was particularly noticeable in the K&N Series, which featured two separate car bodies: a composite car body based on an older superspeedway car, and a steel bodied car that was built more similarly to a current Sprint Cup car in sideforce levels. The composite car crew chiefs would state that they knew they could generate more sideforce, and hence performance, by 'skewing' the car (pre-yawing the car with the rear axle). This made the car faster by itself, but made the car handle poorly in traffic when sideforce was more highly compromised. See **Figure 10**.

Future steps

NASCAR recently invested in a 128-channel Scanivalve pressure scanning system, with a 128 Kiel probe modular array to begin verifying CFD prediction of the wake structures. Long commonplace in F1, this aerodynamic testing methodology is slowly making its way into the sport. NASCAR will continue to work on improving car aerodynamics, while considering what magnitudes of forces work best at specific tracks and for tyre supplier Goodyear.

Ultimately, bringing solutions from CFD to the wind tunnel can be challenging enough. But bringing solutions that improve racing quality is an even further abstraction, involving simulated races on track with test drivers who may or may not prefer to be on leave between races rather than pounding around the track.

So the answer is not always clear. But continuing on the path of scientific analysis and attacking the problem analytically will ultimately yield the best result for fans, drivers, and the series as a whole.

The change of the trail car illustrated here is dictated entirely by the downforce of the car and excludes sideforce. In the regions where the car tends toward understeer, the splitter and radiator pan (and subsequently the underhood region) take a substantial loss in downforce due to reduced airspeed and mass flow rate. The opposite effect occurs in the oversteer regions; a small portion of the high lift hood and fender areas enter into the car's wake, reducing lift and causing the balance to tend toward oversteer.

Many people attribute the oversteer handling characteristic in traffic to a loss in downforce at the rear of the car – an obvious conclusion to draw. But the data shows that in most situations the spoiler and its effect on the lifting greenhouse of the car vary only by 10-20lb, nowhere near the magnitude required to substantially influence car performance. The CFD results indicate that the hood and fender region contacting a small part of the slow moving wake causes an increase in front downforce (by mitigating lift), leading to the forward balance shift. See **Figure 11.**

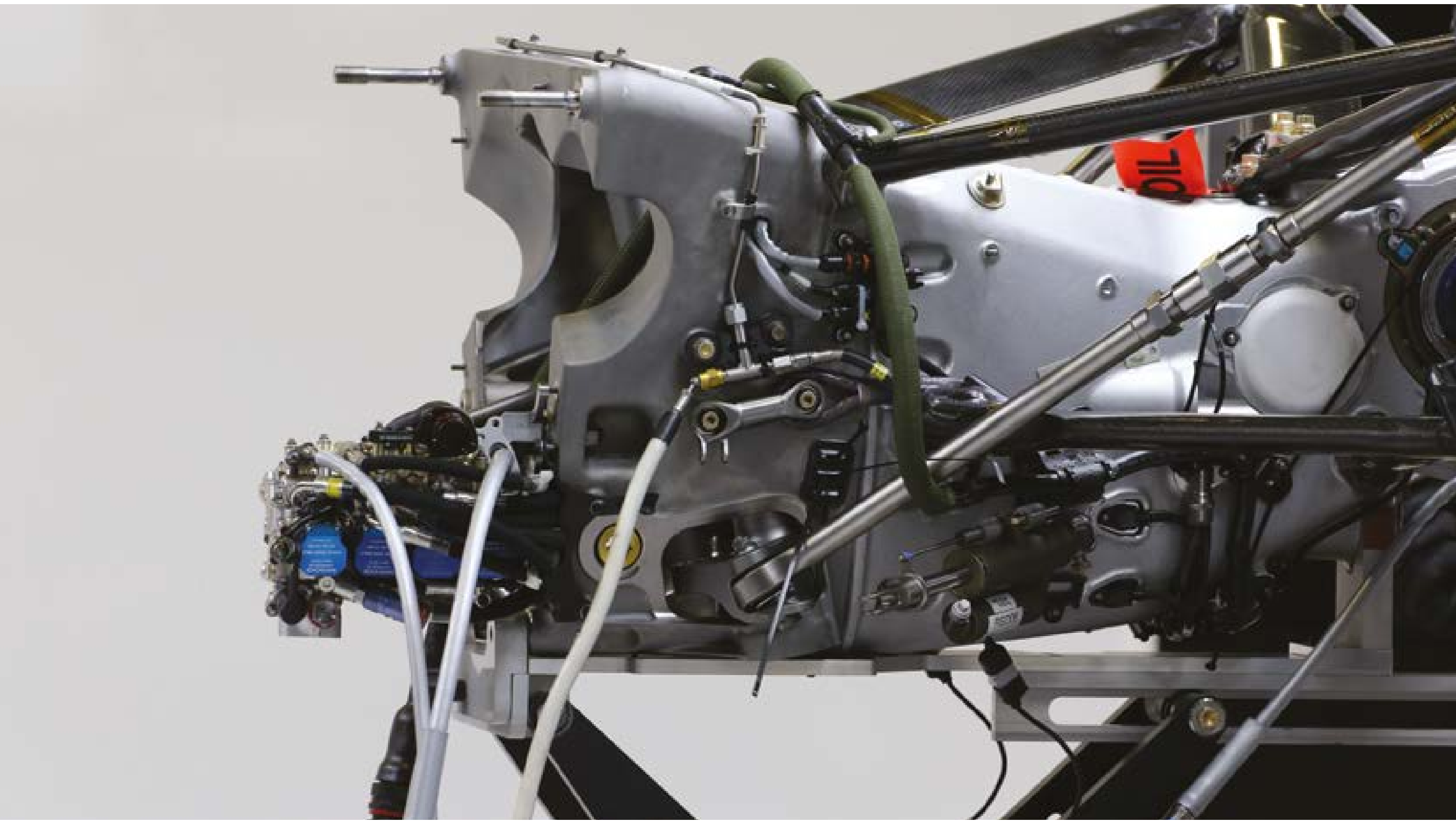
The cornering force plot highlights the difficult situation the trailing finds itself in, and how position dependent that plight is. Cornering force is the combination of both downforce and sideforce (both converted to positive numbers). Behind the lead car and to the right can put the trailing car at a 500lb-force disadvantage to the leading car, while positioning the trailing car toward the left quarter-panel of the lead car can lead to a cornering force advantage.

It should be noted that on many ovals, the trailing car would be forced to run in the loss region to run the optimum line. See **Figure 12.**

A final interesting plot is using the cornering force metric, but adjusting downforce by an average tyre friction coefficient value of 0.8 to reflect how much downforce is converted to lateral force. We then can look at what proportion of the total cornering force the sideforce makes up at various positions. Alone, the sideforce usually accounts for around 40 per cent of the total cornering force, but in the wake region of the lead car, this drops to only 10 per cent or less. This reaffirms more recent thinking that making sideforce with the car body may be a large contributor to traffic handling issues that drivers report. See **Figure 13.**


FUEL SAFE
Racing Cells
Go Fast!
Be Safe!
YOUR CHOICE IN
RACING FUEL CELLS
WEDGE BLADDER
P/N CB400
COMPLETE FUEL
CELL PORSCHE 911/930
CUSTOM TIRE WELL BLADDER
PRO CELL®
IN TRIUMPH OEM CAN
VINTAGE RACER CUSTOM CELL
ASK ABOUT OUR
FLEX FUEL CELL
Race Gas•Alcohol Fuels
Ethanol Blends•Diesel
YOUR ONE FUEL CELL!
International Shipping Available
SHOP ONLINE AT
FUELSAFE.COM
CALL TODAY
800-433-6524
FIA APPROVED
sfi
SFI FOUNDATION INC.
FUEL SAFE
Racing Cells


CD34
THE BEST JUST GOT
BIGGER
RPM 7400
LAP
00:00.0
BEST
00:00.0
KPH 126
4
OILP AIRT COOL BATT
GEMS
CD34
> 8in widescreen LED backlit TFT
> 9 tri-colour shift lights
> 200Mbyte data-logging memory
> Fully configurable layouts
> Up to 100 display pages
GEMS
PERFORMANCE ELECTRONIC SYSTEMS
www.gems.co.uk



Who let the dogs out?

With 3,000 gear shifts asked of an F1 gearbox in a race, sequential transmissions using a dog clutch are the solution

By GEMMA HATTON

Take the regular gearbox found in your everyday car, multiply the number of parts by 1000 and that is approximately how many components it takes to build a 2014 F1 gearbox. Around 3,000 shifts are demanded by the driver in a single race and so have had to be delicately engineered to execute 50 times faster than the human eye can blink. Of course, these impressive statistics are purely the end result of complex gearing technology that aims to accurately control every detail of a gear shift.

Sequential transmissions have become the motorsport standard and the concept can be dated back to 1956 when it was first introduced to single-seater racing on the front engine type 12 Formula Two Lotus. Sequential systems select gears directly in order using a dog clutch which results in a minimal drop in engine torque and no need for a pedal clutch.

The design of sequential selector mechanisms are well suited to semi-automatic systems and the two systems make up the transmissions seen in high performance racing today, with fully automatic transmissions, including launch control still banned by the regulations.

Semi-automatic transmissions offer numerous advantages over manual shifting because it is faster and more precise, but it also generates less wear in the dog clutches, reducing the number of rebuilds required in a season.

'A demonstration of this is the 2014 Ginetta GT4 Supercup championship,' explains Neil Wallace, Owner of Geartronics which specialise in the electronics behind sequential gearbox systems for all degrees of racing from world endurance to rally and hillclimb. 'For the 2014 season, Ginetta introduced the Geartronics paddleshift system as a mandatory fitment for all teams. After a total of 27 races, with some cars covering in excess of 60 hours running, the Ginetta factory have not needed to rebuild any of their Hewland MLG gearboxes. In addition to reduced gearbox wear, over-rev-induced engine failures have also been eliminated.'

Further advantages include reduced torque transients which increase chassis stability during

Sequential transmissions were first introduced to single-seater racing in 1956 on the front engine type 12 Formula 2 Lotus

shifts, and reduced driver workload; minimising driver fatigue and allowing their concentration to focus on other aspects of the race.

There are several approaches to implementing gearbox shift mechanisms into a racecar, although pneumatic is usually the favoured option. 'Pneumatic actuators which utilise compressed air are most suitable,' explains Wallace. 'This is predominantly due to their high power density, ease of control and reduced shock loadings imparted to the shift mechanisms during operation.'

The overall task of the gearbox control system is to simply push or pull the gear lever in the appropriate direction, reverse the torque on the transmission to allow disengagement of the current gear, then engage the next gear.

Of course, in reality unpredictable variables can influence the magnitude and polarity of the torque that the transmission is experiencing at any given time, making it more of a challenge.

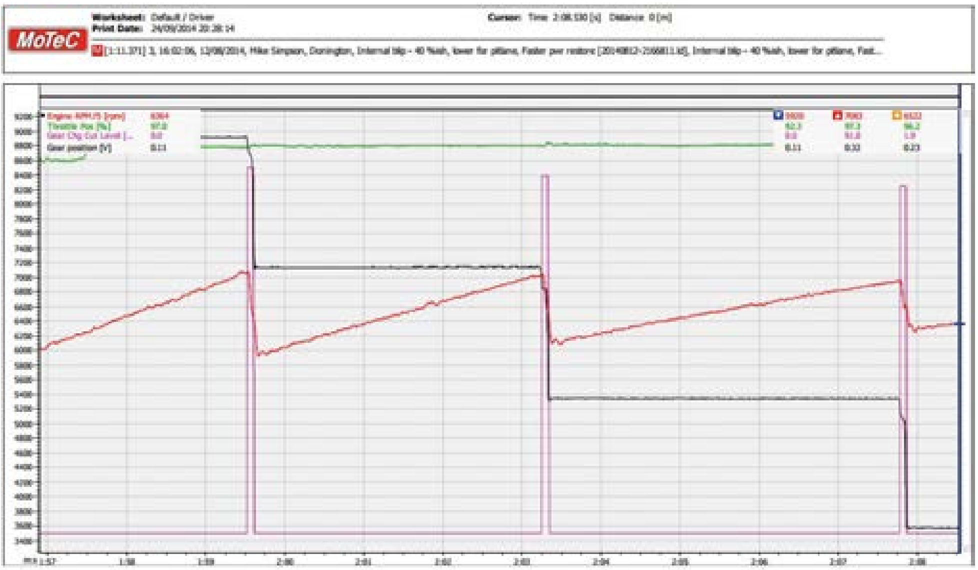
The key part of any transmission control system is the gearbox control unit (GCU), which not only controls the shift actuators, but more importantly, the engine torque output during both the upshift and downshift sequences. 'Pushing and pulling the gear lever is relatively straightforward, but controlling the timing relationship between the actuator movement and the engine torque modulation is critical to the performance of the system, so much so that it could be argued the GCU is more of an engine control system than a transmission controller.'

There are two stages to any gear shift; the disengagement of the current gear and the engagement of the next gear, with the former presenting the biggest engineering challenge due to transmission wind-up. During upshifts this wind-up keeps the dogs locked together even after the engine power has been cut, until the energy in the transmission has dissipated sufficiently. A similar scenario occurs during downshifts but the dogs are locked in the opposite direction until the throttle blip unloads them. The time it takes for the dogs to unlock depends on several complex factors, resulting in gear shift times varying dramatically.

'The results of our datalogging show that in the ideal situation of a clean engagement with no transmission wind up, the shift time is essentially how fast the pneumatic actuator can move the gear lever, which is usually in the order 15-25ms. However, in the real world with the gearbox transmitting torque, upshift times can typically range from 35ms to 150ms,' explains Wallace. To deal with this variability, a control system is required, of which there are two basic types; open-loop and closed-loop. The former does not use feedback to determine if its output has achieved the desired goal of the input, thus there is no feedback route from the engine or transmission and no sensors are monitored. The open-loop control unit consists of little more than a box of timers that apply the same actuator time, engine cut and throttle blip durations regardless of the conditions. 'Essentially, it's a case of programming some 'best-guess' figures based on previous testing, then pulling the paddle and hoping for the best. It is a very hit and miss approach,' says Wallace.

It is therefore unsurprising that this method is rarely used in the world of motorsport, except in low-end club level applications. In addition, the wide ranging possible shift times mentioned above make it almost impossible to estimate one value for parameters such as engine cut duration. The only way to accurately determine this is to constantly monitor the gearbox barrel position sensor and other inputs, which is where closed-loop control systems come in.

Closed-loop control constantly monitors the feedback from a variety of sensors to modify its own operation in response to these inputs. For example, the gearbox barrel position sensor is used to determine how the shift is progressing at every stage, and this information is fed back to the GCU to enable the pneumatic actuator, engine torque reduction or throttle blip to adjust and achieve the fastest and most reliable shift. Some high end systems such as the Geatronics 'Pro' GCU can also measure other variables such as ground speed, wheel slip, gearbox temperature and the ABS status from the CANbus data stream. Therefore, this system



Above: data trace illustrating the upshift sequence of a Ginetta G55 GT4. The selector barrel trace (black) moves smoothly between each gear and the rpm trace (red) is uninterrupted with minimal 'ringing' after each shift has been completed, demonstrating clean and smooth shifting.

Below: The Gearbox Controller Unit – the most important part of any transmission control system and controls the shift actuators and engine output torque during upshifting and downshifting

"Closed-loop control constantly monitors the feedback from a variety of sensors to modify its own operation in response to these inputs"

"It is impossible to be 100 per cent certain that the transmission is experiencing positive torque at the instant the driver requests the shift"


JAKOB EBREY PHOTOGRAPHY

The Geartronics paddle-shift system used in all the G55 GT4 contenders for the 2014 season

can dynamically adjust the shift timings and engine torque depending on how the gear shift is progressing. This results in the fastest and smoothest shifts under all conditions. With the GCU constantly monitoring rpm and making calculations based on gear ratios, detrimental behaviour such as downshift over-revs are eliminated. So if a downshift request would buzz the engine, the shift can either be declined, requiring the driver to make the request again, or it can be placed in a queue where it will be executed once the rpm falls to safe limits.'

Take the example of a full-throttle upshift, which usually involves reversing the positive torque on the transmission by using an engine cut. However, it is impossible to be 100 per cent certain that the transmission is experiencing positive torque at the instant the driver requests the shift – it may be that the driver has just lifted off the throttle, or the wheels are slipping and then regaining traction, resulting in torque reversals. It is essential that the GCU to monitor the gear shift in real-time to ensure normal progression, and if not, dynamically change the behaviour to ensure a successful shift.

The data plot [previous page] illustrates a typical upshift sequence from a Ginetta G55 GT4 race car. As you can see, each shift is completed quickly and cleanly with no unintended torque reversals that could cause chassis instability or shock loadings in the engine and/or transmissions. The selector barrel trace in black is moving smoothly between gears, with no 'baulking' and the red rpm trace is uninterrupted with minimal 'ringing' after each shift.

'It is interesting to note that the current gear does not disengage immediately the engine torque is reduced, as indicted by the initial step in the barrel trace, which is due to this transmission wind-up. Typically this can take anything up to 50-60 milliseconds depending on several factors outside of the control of the shift system. If an upshift is executed under low-load conditions, this 'unlock' time is significantly reduced or even eliminated, which can encourage unrealistic performance claims.'

Torque reversed

Downshifts present a much more complicated problem. Similar to upshifts, the direction of torque needs to be reversed in order to change the current gear. However, the GCU needs to be able to deal with even further unpredictable variables such as wheel lock-up during braking which can, in turn, generate torque reversals, making dog engagement harder. 'The accepted strategy is to blip the throttle as the gear lever is moved in the downshift direction, which theoretically unloads the dogs to allow disengagement and increases the engine rpm to match the next lower gear.' This strategy alone rarely ensures reliable shifting under all conditions, which is why high-end suppliers like Geartronics have developed complex strategies within the GCU software to maximise shift reliability, speed and smoothness.

To provide an effective control system, the GCU and ECU need to be able to communicate efficiently. In the past, this used to be done via hard-wired signals or the vehicle CANbus network. Now, CAN communication not only simplifies the electronic integration, but also allows warnings and notifications to be displayed on the driver's dashboard, it also enables increased data logging capacity. 'The trend is for high-end engine management systems to incorporate transmission control into their software, with varying degrees of sophistication. Usually the addition of transmission control software incurs an additional cost comparable to that of a separate GCU. To illustrate the complexity of transmission control, the Geartronics 'Pro' GCU firmware contains more than 14,000 lines of software code. Currently Geartronics is working with MoTeC to write their advanced shift software into the new M1 'Magnesium' series ECU's. This will provide a 'one-box' engine/transmission control solution in conjunction with a proven pneumatic hardware package.'

Damping ratios applied and tested

After the theory, examples to help confirm damping ratios with on-track running and lap time simulation

By DANNY NOWLAN

Over past *Racecar* articles I have written extensively about using damping ratios and eigenvalues to specify dampers.

I have written a lot about the theory of this and given you some broad brush strokes on how to apply it and how to tie it in to simulation. However one thing I have been a bit remiss on is giving you a specific example on how to tie it all together. This is what we shall be focusing on in this article.

I shall be drawing on actual examples in how this has been applied. This has been applied not only by me – it has been applied by a number of different members of the ChassisSim community.

To keep this article simple I will be focusing on the front end of a monoshock F3 car.

I am doing this for a number of key reasons:

- If I was doing the whole car it would take too long
- Being a monoshock if we make changes to the front we should see large changes
- Also by focusing on one element you should get the idea of how to apply it

The low speed bump and rebound are slightly over-damped – this is to be expected since this is a high downforce racecar

Table 1: monoshock F3 parameters

Paramater	Value
Spring rate	140 N/mm (800 lbf/in)
Front mass	223.5kg
Motion ratio (damper/wheel)	1.082
CLA (peak)	2.45
Total unsprung mass	40kg
Combined tyre spring rate	380N/mm

Table 2: stock damper details

Paramater	Value
Low speed bump rate	9310N/m/s
High speed bump rate	7350N/m/s
Bump bypass	20mm/s
Low speed rebound rate	8820N/m/s
High speed rebound rate	5063N/m/s
Rebound bypass	20mm/s

EQUATIONS

EQUATION 1

$$\omega_0 = \sqrt{\frac{K_B}{m_B}}$$

EQUATION 2

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

Where,
K_B = Spring rate at the tyre.
ω_0 = Natural frequency (rad/s)
m_B = Mass of the body (kg)
ζ = Damping ratio

EQUATION 3

$$\omega_0 = \sqrt{\frac{K_B}{m_B}} = \sqrt{\frac{MR^2 \cdot K_S}{m_B}} = \sqrt{\frac{1.082^2 \cdot 140 \times 1000}{223.5}} = 27.1 rad/s$$

EQUATION 4

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B} = \frac{1.082^2 \times 9310}{2 \times 27.1 \times 223.5} = 0.9$$

EQUATION 5

$$\lambda_i = \alpha_i \pm \beta_i \cdot i$$

$$\omega_i = \sqrt{\alpha_i^2 + \beta_i^2}$$

$$\zeta_i = \frac{\alpha_i}{\omega_i}$$

Table 3: damping ratio numbers

Case	Damping ratio
Low speed bump	0.9
High speed bump	0.71
Low speed rebound	0.852
High speed rebound	0.489

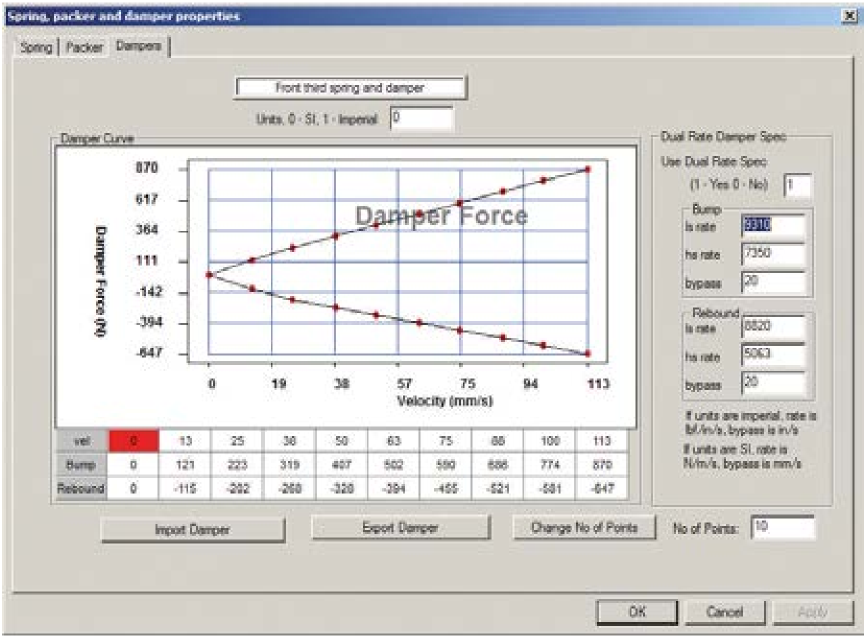


Figure 1: front damper for an F3 car

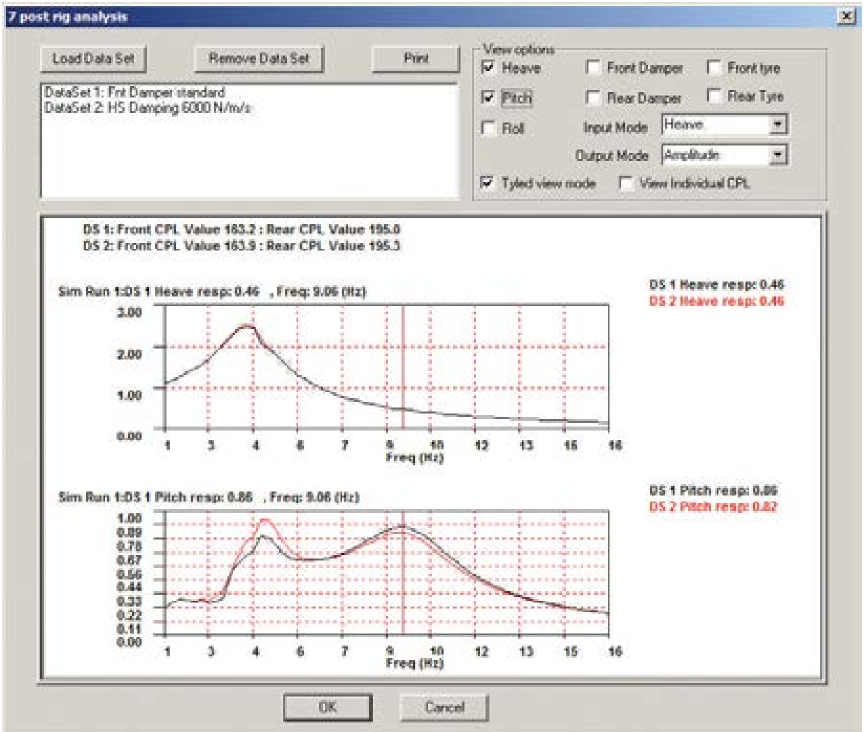


Figure 2: initial damper change

To that end, let's quantify our base setup which we will take from the ChassisSim F3 monoshock template. The numbers we are dealing with are shown in **Table 1.** Also, to complete this discussion, let's show the stock damper. This is illustrated in **Figure1**.

The great thing is, we have specified this damper using the dual rate approximation. This will save us a bit of work. I have summarised the damper details below. We now have everything we need to start our analysis and we'll start by calculating frequencies and damping ratios. Just to remind everyone this – **Equation 1** and **2** – is the formula we'll be using.

Let's now do a worked example for the low speed bump. The natural frequency is as shown in **Equation 3.** The damping ratio will be given by **Equation 4.**

One thing you'll notice is that I converted all spring and damper rates to wheel rates by multiplying by the motion ratio squared. Be very aware of this because that can be a real trap for young players. Anyway the damping ratio numbers are presented in **Table 3**.

This table pesents a very interesting set of numbers. Not surprisingly the low speed bump and rebound are slightly over damped. This is to be expected since this is a high downforce car and we need to control the aero platform. Just from an experience point of view, my personal point of preference is to leave the rebound as is but I might tighten up the front

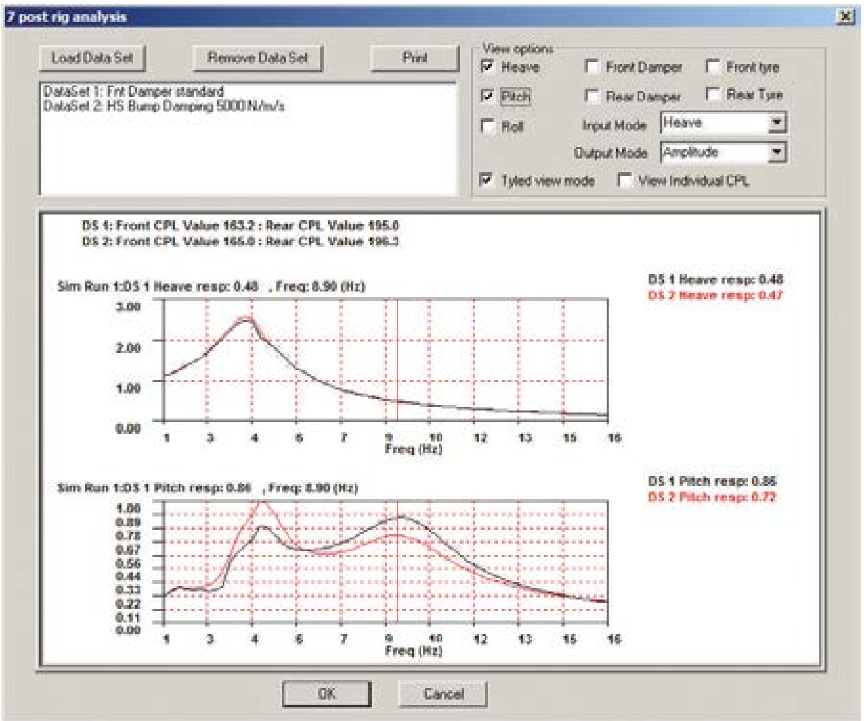


Figure 3: results of high speed damping at 5000N/m/s

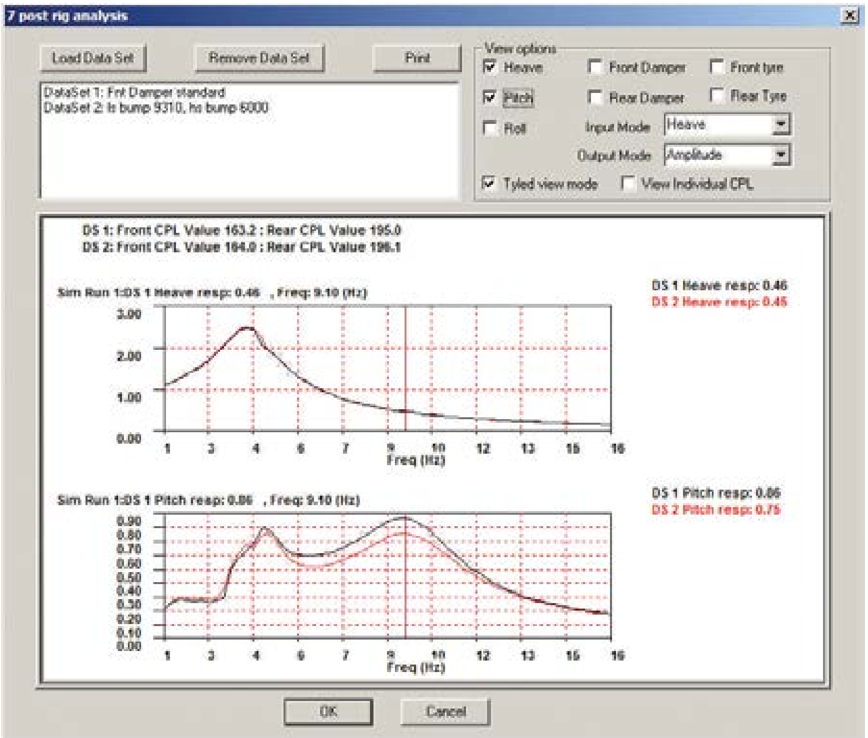


Figure 4: final results with bump damping reset to standard

bump just a little. The high speed damping presents an interesting set of numbers. In terms of rebound I would avoid touching it. As the front of the car unloads over a bump, we want to keep the front in touch with the ground. In terms of the high speed bump I would be tempted to back that off just a bit to give it a bit more compliance. I would be shooting for a damping ratio of, say, 0.6.

Once we have done this we need to run the eigenvalue analysis. For brevity I'm just going to do it for the low speed bump and high speed rebound cases. For everyone's reference I am deriving these numbers via an m-file I created a little while ago. Before we discuss these results, it might be worth reviewing how we evaluate the frequency of a complex mode and calculate it's damping ratio. This is summarised on the facing page in **Equation 4**.

Here αi and βi are the real and complex modes of the eigenvalue and the corresponding frequency (rad/s) and damping ratio of the mode.

The low-speed damping results are shown in **Table 4**. **Table 4** is a really interesting batch of results. Not surprisingly the unsprung mass mode is in the order of -289.9 rad/s, there are no complex components and it acts primarily on the unsprung mass. You can tell this from the eigenvectors of the unsprung mass mode. The largest values are in the xw or tyre velocity entry. The sprung mass mode is primarily dominated by the over damped mode at a frequency of 21.3 rad/s. However there is a complex mode of -10.45 +/- 34.6i right next to it. What this means is it will be an overdamped response with a bit of oscillation. What's interesting about this analysis is, looking at the damping ratios, I was keen to make the front damping stiffer. However looking at this makes me a bit more gun shy about making a change.

The high speed damping results also make for interesting viewing. See **Table 5**.

Again, this table presents an interesting batch of results. Firstly modes 3 and 4 act on the unsprung mass and this has a damping ratio 0.8. This is a bit over the value predicted by the quarter car model, but it will show how the unsprung mass will settle. The sprung mass mode of 1 and 2 shows a very different story.

This has a damping ratio of 0.28. This would indicate to me we might need more high speed rebound damping.

So the next step is to look at the damping ratio and eigenvalue results and from that to make a determination of what you want to do and then run it through the shaker rig toolbox of ChassisSim. Also bear in mind that while we can get some good indications from our damping ratios and eigenvalues, this can change as we do the simulation analysis. So don't be too surprised if you might need to change direction.

The example we are about to present is a good case in point.

The first change I'm going to try is to increase the high speed rebound damping and back of the high speed bump damping. I will choose a damping rate of 6000N/m/s. The

Table 4: eigenvalues and eigenvectors – high speed rebound

Mode	1 & 2	3 & 4
Eigenvalues	-7.82 +/- 26.36	-82.457 +/- 62.1
Eigenvectors		
x_b	0.9236	-0.2565
x_b	-0.01	0
x_w	0.3092	0.9516
x_w	0.0044	-0.0064

Table 5: final damping settings

Paramater	Value
Low speed bump rate	9310N/m/s
High speed bump rate	7350N/m/s
Bump bypass	20mm/s
Low speed rebound rate	8000N/m/s
High speed rebound rate	5000N/m/s
Rebound bypass	20mm/s

The final part of the process is to use the shaker rig simulation to get a final specification of the damper

key thing here is to use your base setting as your standard. The results are shown in **Figure 2**. As we can see we have a very interesting result. On paper you would write this change off as a bad idea.

The CPL has increased from 163.2 at the front to 163.9 and at the rear the CPL went from 195 to 195.3. Also the peak Heave value at resonance increased from 2.45 to 2.5.

However this is not the complete story. Looking at the cross pitch mode at resonance it is worse but as we get to a frequency of 9Hz the cross mode with our change shows an improvement from 0.86 to 0.82.

Based on this, the next change I'm going to make is to set the high speed damping to 5000 N/m/s. The results are shown in **Figure 3**.

Looking at the pitch cross mode on, there is a dramatic improvement at a frequency of 9 Hz. The cross pitch mode response is now down to 0.72. However we have paid for it with another increase in CPL. This is something we need to address because it shows us we are still under-damped at resonance. As a final change we'll reset the bump damping to standard but we'll back off the low speed rebound damping. The results are shown in **Figure 4.**

As we can see we have pulled back the heave response to normal and we have still maintained the advantages with our cross pitch mode response. What this means is we can be more aggressive over the kerbs. The giveaway is the improvement at 9Hz in the pitch response. We have still suffered with the CPL numbers but that's something we can live with. It's at this point I would sanity-check with lap time simulation and prepare for running the car. Just for the record here were the final damper settings, shown in **Table 5**.

It is sensible to reflect on what we have done here. First we have used damping ratios to assess what we have. We then evaluated eigenvalues and eigenvectors to look at it in further detail.

The final bit of the process is to use the shaker rig simulation to get a final specification of the damper. What we had was a good start point so we didn't have that much to do. In fairness I made some wrong calls looking at the eigenvalues and eigenvectors. However that was caught in the simulation. I should also add that this is a natural part of the process and underscores the importance of transient simulation tools such as ChassisSim.

Also the key thing is the process we have discussed here is this is being used in anger right now. This process is:

- Evaluate the damping ratios
- Double check with eigenvalues and eigenvectors
- Cross reference with the shaker rig toolbox.
- Validate with lap time simulation and on track running

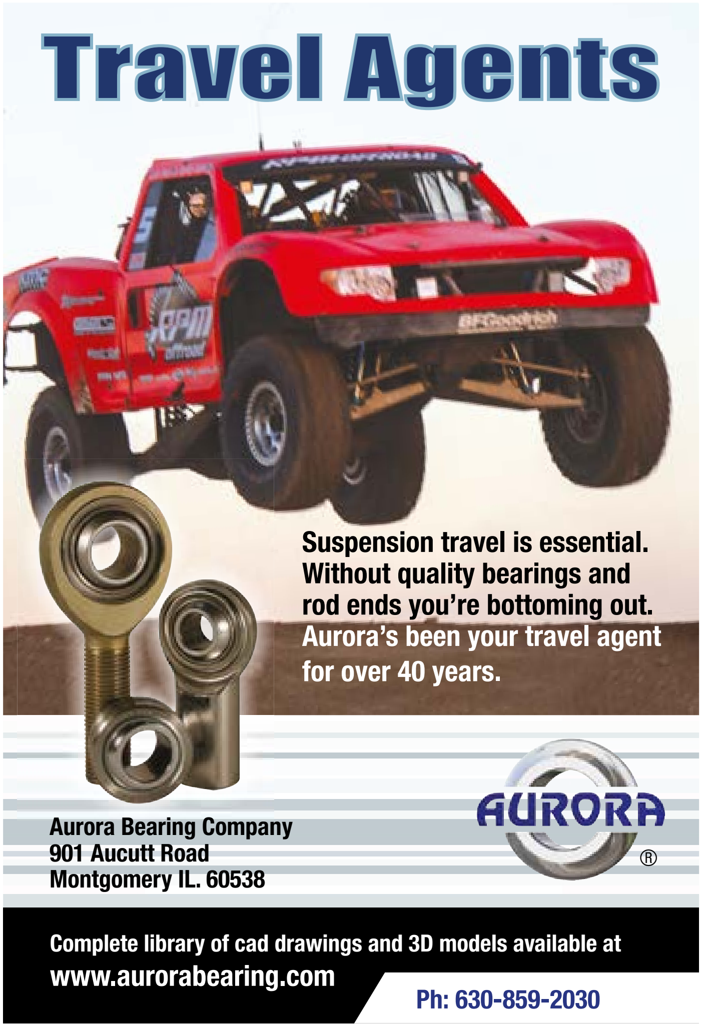
I should also add for the process of illustration that I did not run an in-depth analysis. However the key point is that you now have a road map.

In closing I trust this makes things clearer in tying together damping analysis and simulation tools. The process is to evaluate damping ratios and then confirm this with eigenvalues. We then use the shaker rig simulation to deduce a base specification.

We then confirm this with lap time simulation and track running. The next step I now leave to you the reader. Take your setups and work through the process we have discussed here. You have nothing to lose.


RACING
GST
SEALS
Bespoke design of energy-efficient Oil Seals for all Engine & Driveline applications.
MOTORSPORT INDUSTRY ASSOCIATION
BUSINESS EXCELLENCE AWARD WINNER 2013
Innovative designs & race-proven technologies minimise parasitic power losses & maximise racing advantage
GST Racing Seals
A division of GregSeal Technology UK Ltd
Tel: 077 1753 4027 • Fax: 02380 224104
info@gstracing.co.uk • www.gstracing.co.uk


JLS MOTORSPORT
Air Jacks
• Designed & manufactured by JLS Motorsport, bespoke strokes are available.
• Manufactured with forged alloys & high tensile steels
• Lightweight & compact in design
• Delivering maximum performance & optimum safety
• All Air Jacks are supplied with 3 location rings for positioning & alignment
Air Jack Lance
Air Jack Probe
Made in the UK
European Sales
JLS Motorsport
email : motorsport@lister.co.uk
tel : +44 (0)121 525 5800
fax : +44 (0)121 525 4833
USA Sales
XRP
THE XTREME IN RACECAR PLUMBING
XRP Inc. email : sales@xrp.com
tel : 562 861 4765 fax : 562 861 5503
lister


Travel Agents
Suspension travel is essential. Without quality bearings and rod ends you're bottoming out. Aurora's been your travel agent for over 40 years.
AURORA®
Aurora Bearing Company
901 Aucutt Road
Montgomery IL. 60538
Complete library of cad drawings and 3D models available at
www.aurorabearing.com
Ph: 630-859-2030


PSF
POWER STEERING FLUID
Driven Synthetic Power Steering Fluid utilizes next generation synthetic oil technology to provide lower operating temperatures, reduced parasitic drag and consistent steering feel in high shear racing applications. This competition proven formulation utilizes a proprietary anti-wear and friction reducing additive package that lowers the amount of power required to operate the steering pump.
■ Reduces Operating Temperature
■ Proprietary Anti-Wear Package
■ High Temp High Shear Protection
■ Consistent Steering Response
European Dealer:
Anglo American Oil Company Ltd
WWW.AAOIL.CO.UK
+44 (0)1929 551557
BORN FROM JOE GIBBS RACING
DRIVEN
DRIVEN TO WIN RACING OIL®
DRIVENRACINGOIL.COM
9340j-4

Honda makes F1 return

Honda returns to F1 for 2015 and Silverstone was chosen as the first outing for its power unit

McLaren ran Honda's new Formula 1 power unit on track for the first time during a filming day at Silverstone. The Japanese V6 turbo engine and associated hybrid system, codenamed 1x1, was fitted to a modified 2014 specification McLaren chassis dubbed the MP4-29H.

Attaching the V6 engine to the rear of the monocoque on the car was not a great challenge for the McLaren engineers as all Formula 1 power units share common mounting points by regulation. However the turbo charger installation and cooling system layout are thought to be noticeably different to those of the Mercedes-Benz PU106A that the MP4-29 was originally designed to accommodate. The car completed almost all of the 100km allowed by the sporting regulations, with a single stoppage on track. It is expected that McLaren will now use the Honda power unit for at least part of the post season test in Abu Dhabi.

SEEN: Cadillac announces GT3 car

GM has revealed its long-expected new Cadillac competition car, which is called the ATS-V.R. The car, built to the very loose GT3 rulebook was rolled out at the Circuit of the Americas in mid November. It is fitted with the GM LF4.R, the racing version of the same Twin Turbo 3.6-litre V-6 engine used in the production car. Specific technical upgrades for the GT3-spec race car include larger, twin BorgWarner turbochargers; increased capacity intercoolers; competition engine management and a direct, side-exiting exhaust. The aluminum block and heads are counterbalanced by a rear transaxle unique to the race car, giving the ATS-V.R a weight distribution of 49 per cent front, 51 per cent rear.

The body of the car has been modified to accommodate larger tyres, and features an aero kit with rear wing, front splitter, dive planes and a flat floor with rear diffuser. A second GT3 specification model from GM is under development in Europe, German company Callaway Competition is developing the Corvette C7 Stingray for use in series running to the rules.

Russian billionaire buys the Nürburgring

The Nürburgring again has a new owner after the collapse of the deal which saw German group Capricorn take over the legendary venue back in March of 2014.

The German press has named the Nürburgring's new owner as Viktor Kharitonin, a Russian billionaire who established drugs company Pharmstandard alongside Chelsea football club owner Roman Abramovich. It's believed Capricorn's interest in the Nürburgring ended when boss Robertino Wild failed to make the second instalment of his payment.

The Capricorn deal, which included the two tracks – the legendary 14-mile Nordschleife plus the F1 circuit – and supporting infrastructure, came after an offer from Bernie Ecclestone to buy the circuit for $50m (£32m) was rejected. The Capricorn offer also eclipsed that of HIG Capital, which was previously expected to gain control of the venue.

Capricorn was in a partnership with Getspeed to buy the 'Ring for a deal worth around €77m, with Capricorn the senior partner in the agreement, taking two-thirds of the business. It's this share that Kharitonin is understood to have bought. It's been widely reported that Kharitonin has already made outstanding payments for his majority stake in the venue.

XPB

The mighty Nürburgring is now in Russian hands

Radical reworks range

English constructor Radical has reworked its two most popular models, the SR3 and SR8. First launched in 2002, the SR3 is perhaps the most prolific competition car ever built with over 900 examples sold. The latest, called the SR3 RSX features a new high-performance variant of the RPE 1500 Generation 3 short stroke engine, with more mid-range power and torque as well as longer service intervals and improved efficiency. The four-cylinder engine features a new larger-diameter stainless steel tubular exhaust manifold, bigger 45mm throttle body induction system and redesigned air box, including bespoke inlet trumpets.

The SR3 RSX retains the FIA-approved tubular steel chassis but is clothed in new bodywork. Investment by Radical in its CFD capability have resulted in a reworked front diffuser and revised wheel arches. The new body improves the front aerodynamic efficiency of the car without compromising front-rear balance, and also creates greater stability under braking according to its creators. The company has also reworked its flagship SR8 model, fitting its 3.0-litre RPE V8 engine and updating its chassis.

XPB

Williams launches world talent search

Williams has announced a new talent search project with one of its human resources partners. The Randstad Williams Engineering Academy will begin in 2015 and will see Williams mentor up to 10 students each year in a long term extra-curricular programme that will help guide a new generation of engineers towards a successful career in Formula 1.

To select the best candidates, Williams will be partnering with F1 in Schools, a not-for-profit educational organisation that delivers a world-class STEM competition that engages with millions of students across the globe.

The academy will be open to those aged between 16 and 18 at the time of entry and have successfully made it through to that year's F1 in Schools World Finals.

A selection of nominated F1 in Schools World Finalists will apply to join the academy in autumn each year and following a series of assessments up to 10 candidates will be successful, with the first students joining in November 2015. Over the course of the next seven years each cohort of students will be gradually whittled down in number as they complete a series of vocational placements and mentoring experiences at Williams and undertake e-learning projects. Given the global nature of the academy, with students applying from all over the world, remote e-learning with a motorsport engineering theme will be central. Randstad will be using its global presence and extensive experience of global education systems and vocational training to help Williams in the promotion and the ongoing assessment of the students.

Red Bull Racing sponsorship income eases costs for parent company support

Red Bull Racing's financial results for 2013 show spending of close to £200m, yet the amount of money paid in by the energy drink company itself was significantly reduced thanks to some big new sponsorship deals.

The latest issued accounts for Red Bull Racing and its holding company Red Bull Technology show that the team spent a whopping £196m in 2013, a figure that is likely to add fuel to the raging row that's engulfed F1 recently in the wake of the troubles that have beset backmarker teams Marussia and Caterham.

To put it into perspective, Caterham spent just £42m last year, while the Red Bull figure also eclipses that for the Mercedes GP team in the same period; £191m.

In 2013 Red Bull showed a turnover of £198m and a profit of just £1m – although this is not unusual for an F1 team, which is likely to sink everything into racing operations and R&D. Indeed, in 2013 Red Bull spent £83m on research and development, which is 10 per cent up on 2012 and reflects the extra effort put into the new-for-2014 F1 formula.

XPB

Red Bull's sponsorship deals have led to a lesser reliance on the parent company

Income for the team came from three primary sources: prize money, sponsorship and funds that came directly from the parent company, energy drinks giant Red Bull. But there was a jump in prize money for last year, and a hike in sponsorship – largely through Infiniti's larger presence on the car – both of which meant the parent company could reduce its spend on the F1 team from £66.9m to £12.6m. Red Bull says income has also increased due to a 'new agreement with the commercial rights holder'.

Team principal Christian Horner said: 'These developments have led to increased revenues in 2013 with the company's turnover during the year under review [2013] increasing to £197,599,000.' Turnover in the previous year, 2012, was £176,310,000.

The number employed by the race team also rose in 2013, by 17 to 675, with a total wage bill of £62m.

IN BRIEF

Government training grant

The UK's Department for Business Innovation and Skills (BIS) has announced extra support for training of employees working in the automotive and motorsport supply chain. The minimum grant offered is £40,000 and it goes up to a maximum of £1.5m. It is restricted to those with staff who are employed in England, aged 19 and over. BIS says this investment in skills aims to support projects carried out by companies that will, through additional employee training, improve their ability to grow to meet imminent and longer-term demands. The initiative is a 'co-funded opportunity' where employers and government invest 50 per cent each, unless the training is specific to a particular firm, in which case the government contribution will be 25 per cent.

'Formula 4' is sold out

The brand new MSA Formula, which replaces Formula Ford and is to be the UK's FIA Formula 4 (albeit without the F4 name, which BRDC F4 owns) has got off to a flying start with 32 cars already sold prior to its inaugural season in 2015. Among top level single seater outfits who have ordered cars are Arden Motorsport, Fortec, Carlin and Double R Racing, each of which has committed to buying three of the Ford EcoBoost-powered Mygales.

New GT3 series

The Stephane Ratel Organisation is to launch an all-new GT3 series for amateur drivers which will kick off next year. To be called the GT Sports Club series it will only be open to bronze-rated drivers. SRO boss Ratel has said the reason behind it is growing competition in the Blancpain Endurance Series, and other GT3 championships. The four-event mini-series has been designed with the busy lifestyles of wealthy amateur drivers in mind. Each double-header meeting will include a 25-minute qualifying race and 40-minute main event, both to take place within a 24-hour period. The single-driver races will not include pit-stops.

Marussia almost made finale

The Marussia F1 team almost made it to the Abu Dhabi Grand Prix despite its financial collapse. Team members prepared two cars for the world championship finale after it looked like a last minute rescue package had been put together. The attempt failed as the promised finances failed to materialise.

Lowered 32 truck limit for NASCAR

NASCAR will limit entrants in its Truck Series to 32 trucks in 2015 from 36 in 2014. The Sprint Cup Series will remain at 43 and the Xfinity Series (ex-Nationwide and Busch) at 40. Both the Truck and Xfinity Series will have driver names on the rear window for ID purposes

Dallara IL-15 racecar attracts flood of entries to Indy Lights

Indy Lights is enjoying a surge of interest on the back of the unveiling of its new car earlier this year and grids look healthy for 2015.

The IndyCar feeder series already has 10 teams signed up for next season, with former champions Schmidt Peterson Motorsports the latest to confirm, ordering two new Dallara IL-15 chassis.

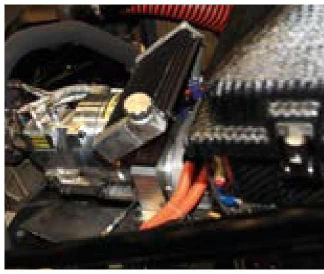
Multiple car orders had already been placed by Belardi Auto Racing, Juncos Racing and McCormack Racing and at the time of writing 10 teams were officially registered for next season, while Indy Lights tells us additional commitments and car orders are in the pipeline.

Dan Andersen, CEO of the company that runs Indy Lights, Andersen Promotions, said: 'The interest level and enthusiasm for next season has been incredible. To have Sam [Schmidt] come on board with a two-car commitment speaks volumes. He is a staunch supporter of the series and we are excited to have the winningest Indy Lights team back in the paddock.

'I couldn't be more thrilled with the calibre of teams that will be campaigning programmes, and I expect to see 15 to 20 cars on the grid next March.' In 2014 Indy Lights saw grids as low as eight cars, with a best entry of 12.

Sam Schmidt, owner of Schmidt Peterson Motorsports, said: 'Schmidt Peterson Motorsports is the only team that has competed in the Indy Lights series since its inception. We believe that the series is a vital step to reach the Verizon IndyCar Series, and the number of current IndyCar drivers who previously participated in Indy Lights is proof that the system works. We are proud to announce our official entry into the series for 2015, and look forward to the incredible competition that will be created by the new chassis and its formula.'

YGK reveals LMP1-H power train concept



Japanese engineers have shown off an innovative new hybrid power train for use in LMP1. The new YGK developed engine has been fitted with an exhaust gas recovery system. What makes the layout different is that the engine is normally aspirated – to date all racing power trains to feature such technology have been turbocharged.

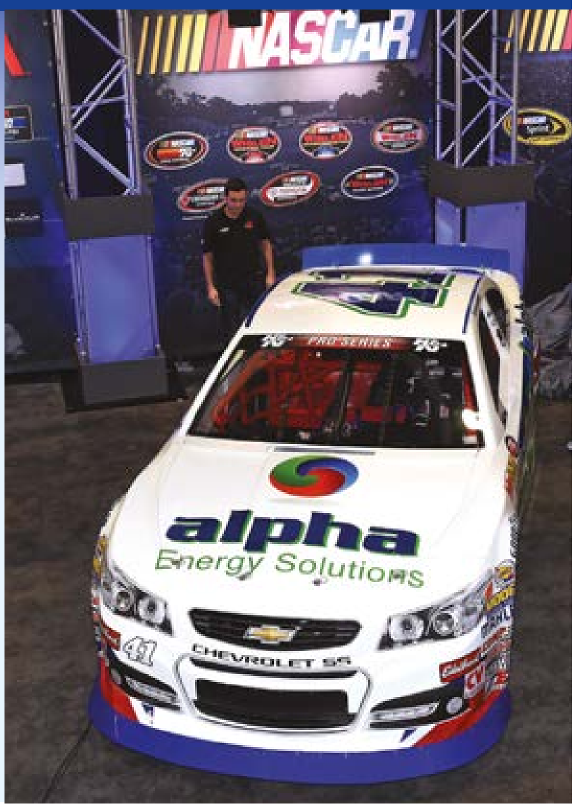
The YGK solution places a turbine generator unit in the exhaust but it only generates electricity, rather like the Porsche 919 solution. Being fitted to a normally aspirated engine gives the turbine a much higher mass flow rate to deal with compared to turbocharged layouts such as that used by the Porsche. The YGK turbine rotates at speeds up to 126,600rpm and is linked to its generator unit via reduction gears as its peak efficiency is at 18,000rpm. Both the motor and reduction gears are liquid cooled and the electricity generated is fed to a small and lightweight capacitor pack, and can be fed on demand to any electrical sub system. The potential output is believed to be quite high, and a prototype had been fitted to YGK's 4.5 litre V8 LMP1 engine. Track testing of the development power unit has been conducted at Fukushima airfield using YGK's Jaguar XJR-15 based test mule. Exact details of the system have not been disclosed as a patent is pending, but the technology could race as early as this season.

SEEN: New NASCAR K&N Pro Series body

A new body for NASCAR's top developmental championship, the K&N Pro Series, was unveiled at the SEMA Show in Las Vegas in November. It's made from a state-of-the-art composite laminate blend and was developed by NASCAR in partnership with Five Star Race Car Bodies. NASCAR says its modular design allows teams to easily instal and repair damaged panels, while it is expected to cut labour costs associated with body maintenance by up to 50 per cent.

The body is eligible for competition at the start of the 2015 season and is mandated as the only approved body in the series from 2017. It will be available in all three manufacturer models: Chevrolet SS, Ford Fusion, and Toyota Camry.

The final season for steel bodies in K&N is 2015, and the current one-piece composite body will be phased out after the 2016 season. The new body will also be eligible for competition in the ARCA Racing Series from 2015 onwards.



CAUGHT

Ryan Newman's fifth placed Richard Childress Racing Chevrolet failed post-race tech inspection at Talladega and the car was taken back to NASCAR R&D center in Concord, North Carolina. After further evaluation of the car race damage was deemed to be the cause the car originally failed rear height inspection. Meanwhile NASCAR fined crew members from the #5 and #24 Hendrick Motorsports Sprint Cup Series teams for their involvement in a post-race brawl at Texas Motor Speedway. In addition, the crew chiefs from those two teams also have been penalised. Jeremy Fuller, a crew member with the #5 team, along with Dwayne Doucette and Jason Ingle, crew members with the #24 team, each have been fined **$25,000** and suspended from NASCAR through the completion of the next six NASCAR Sprint Cup Series championship points races, taking the suspension into 2015. Dean Mozingo, a crew member with the #24 team, has been fined **$10,000** and suspended from NASCAR through the end of 2014. In addition Kenny Francis, crew chief of the #5 team, and Alan Gustafson, crew chief of the #24 team, have each been fined **$50,000** and placed on NASCAR probation.


PRO-SHIFT
electronic gearshift
Championship Winning
Semi-Automatic
Electronic Gearshifters
for Racecars & Superbikes
Now available
This superfast and highly sophisticated
Gearshifting PS3 Paddleshift System suitable
for Racecars and Superbikes with over 170
adjustable parameters
PS3 System
Offering Fully Closed Loop Gearshifting for
both Racecars and Superbikes
Auto-Blip & Downshift Lockout
For clutchless downshifts plus engine over-rev protection
Graduated Ignition Cuts
Individually programmable for all gears
Auto Upshift Facility
Max power upshifting at full throttle..!
For more information:
email: info@proshift.com
telephone: +44 (0)1332 668100
www.proshift.com


EARL'S
PERFORMANCE PRODUCTS
CUSTOM BRAKE LINES | OIL COOLERS | HOSE | FITTINGS
ADAPTERS | FILTERS | NOS | FUEL PUMPS & REGULATORS
Visit www.earls.co.uk for the full range
Online Shop now Available
QUOTE "RCE10" WHEN ORDERING TO RECEIVE 5% DISCOUNT
Earl's Performance Products UK Ltd
Units 15-16 Silverstone Circuit, Northants, United Kingdom NN12 8TL
+44(0)1803 869850 | sales@earls.co.uk


Rottler CNC True Vertical Honing
Linear slideway stroking and precision ball screw mechanisms create precise cross hatch angle & repeatable accuracy
Rottler Software senses interference for Automatic Crash Prevention
NHRA Nitro Methane Funny Car
Rottler Makes Power Fast
"Tim Wilkerson"
• Two Stage Honing System Roughs & Finishes in 1 Automatic Cycle
• Intuitive Rottler Software
• Automatic Load & Force Control
- Fast Cycle Time
- Dual Stage Honing Capability
- Quick Turn Tool Change
So Advanced, It's Simple
www.rottlermfg.com
www.youtube.com/rottlermfg
www.facebook.com/rottlermfg
contact@rottlermfg.com
ROTTLER
THE CUTTING EDGE
8029 South 200th Street
Kent, WA 98032 USA
+1 253 872 7050
1-800-452-0534

INTERVIEW – Malcolm Wilson

New horizons

The WRC team boss talks to Racecar Engineering about his plans for a test track at M-sport's base and also tells us just what it's like for a rally team to go racing

By MIKE BRESLIN

"Drivers aspire to race in IndyCar again; sure, most young guys want to race Formula 1 but getting an F1 seat is nigh-on impossible"

Cumbria's Dovenby Hall has witnessed a great deal of change in its time. First built as a Peel Tower in 1154, it went on to become a manor house – one of its owners gambling the entire estate on the turn of a card once – and it was also a mental institution for a while. So it's packed a lot into its centuries of existence. But the pace of change at the Hall really accelerated in 2000, with the arrival of World Rally operation M-Sport.

M-Sport is headed by Malcolm Wilson, the former British champion rally driver, who comes from nearby Cockermouth and started his company as Malcolm Wilson Motorsport back in 1979. Its presence at Dovenby Hall is impressive. The offices are in the house itself and the old walled gardens have been replaced with a 5575m^2 workshop and final assembly area, while there is also a £1m R&D facility from which technical director Christian Loriaux leads the tech team.

Before 2013 M-Sport was the work's Ford WRC team, but that fell through when the blue oval announced its withdrawal from the sport in 2012. M-Sport still runs WRC Fiestas, though, and Wilson says it gets technical support from Ford, but there has also been a great deal of diversification at the company, which has in part led to a need to develop the Dovenby Hall base.

'We feel it's the next step for us as a company,' says Wilson. 'First of all we've outgrown where we are at the moment, so we need more capacity, even for what we're currently doing with all the rally programmes. So the new building will basically be a [9800m^2] manufacturing facility. We want to take all our existing machine shop, fabrication, things like that into this new facility, and also increase that side of the operation. Plus we want a completely new composites department.'

The road ahead

This is also partly driven by a plan to make more of the M-Sport brand by launching a range of specialist limited edition road car projects, says Wilson. But it's another aspect of the development that is perhaps the most exciting, for M-Sport is planning on emulating Ferrari in completing something even the mighty McLaren has been unable to achieve; building its own test track.

'We feel that there is an opportunity, because we've got the land here, and so we've designed a 2.5km test track,' Wilson says. 'It will be an asphalt track, as we've got our own forest about 20 miles away from the site, so we're okay for gravel.'

The circuit will not just be for M-Sport use so it will be another useful revenue generator for the firm. But tracks are often unwelcome developments these days, particularly in areas of outstanding natural beauty such as Cumbria, because noise concerns. 'We've had acoustic experts working with the circuit designers, so we'll be doing all the relevant things that you need to do to limit the emission of noise from the circuit,' says Wilson. 'For the rally cars in particular we've also designed some specialist silencers, and with these we've managed to bring the decibel levels on a Fiesta R5 rally car to a lower level than a Fiesta ST road car.'

The new development, which will also include a hotel, is set to create 180 jobs – on top of the close to 200 already employed at M-Sport – and because of the employment creation aspect of this 'multi-million pound' project Wilson is hopeful of some government support. There are planning hurdles still to clear, but Wilson says he has been working alongside local planners on this for over three years and he is 'reasonably confident' it will be given the go ahead.

Yet despite all the talk of diversification rallying is still meat and drink for M-Sport, and beyond running cars it has also become probably the biggest producer of rally cars in the world – it's just rolled out its 88th R5 Fiesta, for example, and it sells other rally-bred versions of Ford's hatchback.

Volkswagen ascendancy

While this sales success is obviously welcome, things have not been so good on the WRC stages this year in the face of Volkswagen's continued ascendancy, and this comes on the back of years of dominance by Sebastien Loeb and Citroen.

In fact, without Loeb, Ford and M-Sport would surely have scored more than its two Manufacturers' titles during the last ten years. Yet Wilson's take on the Frenchman's time in the WRC, which ended last year, shows no hint of bitterness or regret, quite the opposite in fact. 'I have loved being involved through Loeb's time, and admire what he achieved. 'I think he's very special. There's no question he's the best driver that's been in the WRC.'

So far as the current state of the WRC is concerned, Wilson is

M-Sport receives essential technical support from Ford also positive. 'I think there's not a big issue anymore. There has been, but I think I'm seeing a ray of light at the end of the tunnel. We've had difficulties with promoters in the last few years, but now that we've got support from Red Bull [Media House, the promoter], and of course Hyundai and Volkswagen have been making big commitments, I think it's in reasonable shape.'

But with big manufacturers like VW and Hyundai coming in, so do big budgets – Wilson estimates that the heaviest investment in WRC, presumably VW's, is now €70m a year – so an essentially privateer team such as M-Sport is sure to suffer, isn't it? 'I think that's where the FIA has been very good with the technical regulations,' Wilson says. 'There was a big step made a few years ago to control the costs.

'There's no question, if there was the sort of technology that's involved in Formula 1, then we would be out of WRC at the highest level. But because of the way the technical regs are we can remain reasonably competitive, purely and simply because they are so well controlled.'

Talk of Formula 1 is a reminder that M-Sport has now taken to the race track, teaming up with Bentley to run its Continental GT3 in the Blancpain Endurance Series. It's been a successful venture, with the team taking second in the standings, but just how easy was the switch from stage to track? 'We haven't brought in any racing specialists from outside. We've basically used staff involved in the rally side,' Wilson says. 'But a lot of it's the same philosophy, certainly with the engineering and design.'

Wilson's happy with the GT3 commitment at the moment, and he says he might consider other racing opportunities if they came up in the future. And with the future in mind it's interesting to note his favourite memory of M-Sport's debut full season of racing. 'I must admit the most enjoyable part for me this year was the Spa 24 Hours. There were a lot of similarities in Spa to an old classic Safari Rally, where every team member plays a vital role. If a mechanic slips taking a wheel out of the workshop then it's time lost. There are so many similarities to what rallying used to be like in the old days.'

Just maybe the next chapter in Dovenby Hall's long history will be as a home for a Le Mans 24 Hours team then? Pure speculation, of course, but one thing's for sure: while it's obvious the Hall's had a storied past, it now seems clear it also has a bright future.

RACE MOVES

XPB

Sam Michael left Formula 1 and his post as sporting director at McLaren at the end of the F1 season. Michael handed in his notice in March and his resignation is said to be part of a long-term plan to move back to his native Australia with his family. Michael joined McLaren from Williams, where he was technical director, at the end of 2011.

Former F1 team principals **Ross Brawn** and **Stefano Domenicali** were on the FIA Accident Panel that was set up to investigate **Jules Bianchi**'s crash in the Japanese Grand Prix. The panel is led by **Peter Wright**, who is president of the FIA Safety Commission, and also includes **Gerd Ennser; Emerson Fittipaldi; Eduardo de Freitas; Roger Peart; Antonio Rigozzi; Gerard Saillant** and **Alex Wurz**.

Hulman & Co president and CFO **Jeff Belskus** is to retire from the Indianapolis Motor Speedway-owning company early in 2015. He has held many positions during his 27-year career with Hulman and its affiliates, but is best known for his four years as president and chief executive officer of the Indianapolis Motor Speedway. He has also been the CEO of IndyCar.

McLaren has begun to streamline its F1 technical structure, with a number of its staff being told they are no longer needed at the team. Among these is head of aerodynamics **Doug McKiernan**, who has now been put on gardening leave.

Adam Jacobs is now chief marketing officer for Haas F1 Team, the US outfit set to join Formula 1 in 2016. Jacobs comes to Haas from brewing company Anheuser-Busch, where he oversaw its NASCAR and other sports sponsorship tie-ups in his role as sports marketing manager.

American **Jeff Swartwout** is to be the team manager at Australian V8 Supercar outfit DJR Team Penske from the beginning of next year. US racing legend **Roger Penske** will formally take control of Dick Johnson Racing (DJR) on January 1.

Famed US racing driver and racecar constructor **Dan Gurney** (83) has received the Edison-Ford Medal at a ceremony conducted in the Henry Ford Museum in Dearborn, Michigan. The award is said to recognise people who 'fully leverage the creative, innovative and entrepreneurial spirit that resides in every one of us'.

Raymond Beadle, the NHRA drag racer who went on to be a successful NASCAR team owner, has died at the age of 70. Beadle was involved in NASCAR's top level from 1983 until 1990, his team claiming 20 wins and 73 top-five finishes in that time.

Simon Fuller's XIX Management company will cease to represent Formula 1 driver **Lewis Hamilton** at the end of this year. When asked why, Hamilton said the contract with Fuller had come to an end and he was looking for a change.

Former Ferrari team principal **Stefano Domenicali** has now joined Audi. The German company insists he will have nothing to do with its motorsport programme but will instead work in the service and mobility area of the organisation, utilising his experience of working in an international environment. The news was greeted in Germany with a fresh flurry of rumours linking Audi with an F1 campaign.

Andretti Autosport's long-time director of operations **Kyle Moyer** has left the team to take up an as yet unknown position at Penske. Moyer has been connected with the **Michael Andretti**-headed team for over 20 years.

Tube specialist expands

SS Tube Technology Ltd, the engineering led precision fabrication company based in Oxford, UK is continuing to expand, developing new technologies and growing into new premises. The business designs and manufactures exhaust systems and thermal management solutions for high performance industries, including the motorsport and performance automotive sectors.

To accommodate this growth, the business is renovating its recently acquired 60,000 sq/ft facilities to deliver a world class headquarters and customer reception, and standard setting manufacturing business units.

These facilities will also house the sister companies of SS Tube Technology within the Polar Technology Group, these are Lentus Composites offering advanced composite products, and Horizon Engineering, a precision 5-axis machining business. All of these Polar Technology Group businesses are in an exciting phase of rapid growth serving the resurgence in Advanced British Manufacturing.

SPONSORSHIP

Wilson Security and **Payce Consolidated** will no longer appear on the **Dick Johnson Racing V8 Supercars** after the end of the 2014 season. Both companies teamed up with DJR in 2013 and went on to extend their contracts into 2014. DJR is to be known as **Penske DJR** next year, following **Roger Penske**'s purchase of a controlling share of the team.

Silverstone suspends executives and restructures

The managing director of British Grand Prix venue Silverstone and two other executives have been suspended while an internal investigation into an unknown matter takes place.

Managing director Richard Phillips, financial director Ed Brookes and legal director David Thompson will receive full pay during the investigation.

Meanwhile, there has also been a management restructure at Silverstone Circuits Limited (SCL) – the British Racing Drivers' Club-owned company that runs the track – which the BRDC insists is wholly unrelated to the suspensions.

The restructure sees BRDC chairman John Grant and director Lawrence Tomlinson – boss of Ginetta, who was elected to the BRDC's board in August – taking up a shared position as joint-acting chief executive at SCL.

A BRDC statement said: 'Whilst we cannot comment on the suspension of senior executives at SCL, it should be noted this is only coincidental to the restructure.'

Grant and Tomlinson will now concentrate on reinvigorating the business, says the BRDC: 'Having reviewed the Silverstone business, [Grant and Tomlinson] have embarked on an exciting programme of restructuring to make the business more streamlined, concentrating on the core competencies as a circuit operator and the home of the British Grand Prix.'

Grant, who became the president of the BRDC in 2013, has said that Silverstone's future as the home of the British Grand Prix – a deal which was renewed for 17 years in 2010 – was safe despite a failure in recent negotiations to sell SCL. Any future plans to sell the circuit would now have to be voted on by the 800 members of the BRDC.

RACE MOVES – continued

XPB

Gerhard Berger is to stand down from his position as president of the FIA Single Seater Commission. Berger has filled the post since 2011 – he originally planned on just one year in the role – and during his tenure he has played a key part in the launch of the hugely successful FIA Euro F3 Championship, plus the FIA's new entry level Formula 4 category.

WC Vision, the company that manages US GT and touring car series the Pirelli World Challenge, has taken on **Julie Bentley** as its director of public relations. It has also promoted **Greg Gill** to vice president general manager. Bentley has experience working for racing teams as well as at the California Speedway, while she has spent the last 13 years with the American Le Mans Series and IMSA.

NASCAR Sprint Cup outfit Roush Fenway Racing has signed up **Mark McArdle** as its engineering director. McArdle has spent the past 15 years in NASCAR, most recently working as the director of racing operations at Richard Childress Racing.

Roush Fenway Racing has also signed up **Kevin Kidd** to its NASCAR Sprint Cup operation. Kidd has worked as the crew chief for Joe Gibbs Racing's No. 20 NASCAR Nationwide Series car since 2010, overseeing three victories in the second tier category.

Auto Club Speedway president **Gillian Zucker** is switching sports to take up the post of president of operations at NBA basketball team the Los Angeles Clippers. Zucker has headed up the Fontana speedway since 2005, and was once named as one of the five most powerful women in motorsport.

Mike Talbott, formerly of Wirth Research, has joined the Rahal Letterman Lanigan IndyCar squad and will lead its vehicle dynamics programme. He is set to be joined at RLL by **Martin Pare**, whose brief is to oversee the team's damper development. Pare come to RLL from Multimatic.

Jimmy Prock has resigned as crew chief on the John Force Racing-run Castrol GTX High Mileage NHRA dragster. He has moved on to take up an as yet unspecified position with rival team Don Schumacher Racing, which fields seven cars in the top level NHRA championships.

Christophe de Margerie, the chairman and CEO of oil company Total, was killed in an air crash in Moscow in October. De Margerie was well-known in the Formula 1 paddock as a result of the French firm's sponsorship tie ups in the sport. His plane struck a snow plough.

Terry Ozment is to resign from her post as vice president of club racing at the Sports Car Club of America (SCCA) at the end of this year. She joined the staff at the organisation's national office in 2004.

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

Switch panels
Custom designed

Cartek now produces bespoke Power Control Panels for all motorsport applications. These products are custom designed switch panels with integrated solid-state electronics offering high current switching, adjustable circuit protection and custom functionality in a single 'plug-n-play' unit replacing individual switches, relays, circuit breakers and complex, interconnecting wiring.
www.cartekmotorsport.com

Spacers
Adjustable for bearings

Our patented, adjustable wheel bearing spacers allow for precise hub set-up while reducing rotating drag by up to 1200 per cent. Bearing spacers eliminate excessive preload which leads to bearing drag, heat build-up and bearing failure. Bearings are locked into pace regardless of spindle nut torque. Standard and custom available.
store.drpperformance.com

All parts
Components

Fast Forward Automotive offers the supply of engine components either as individual items for the manufacture of prototypes or in small batches through its carefully selected partner network and works for engine developers, car, truck and motorbike manufacturers, racing teams and engine rebuilders.
www.fastforward-automotive.com

Display
Good data

Life Racing's new D5 full colour sunlight readable WVGA display allows custom layouts, easy page navigation, programmable driver aids, warnings and alarms. It can receive streamed data from LR ECUs and record to USB sticks if required allowing it to be used as a fully featured central hub for a single connection point
http://www.liferacing.com

Pedals
Underfoot assembly

Tilton's new 600-Series underfoot pedal assembly is perfect for racers who need additional space in the cockpit. Unlike traditional floor-mount pedal assemblies with forward-facing master cylinders, the underfoot pedal assembly features rear-facing master cylinders, enabling the pedals to be mounted further forward, providing a greater range of driver seating positions.
www.tiltonracing.com

Strike pins
Rugged off-road solution

AeroCatch Xtreme is the fifth variant in the AeroCatch range and offers steel strike pins which provide a rugged solution, ideal for extreme off-road and rally events. Safer and easier to use than the traditional sliding pin catch, AeroCatch Xtreme retails at the same cost as the standard AeroCatch.
www.aerocatch.com/aerocatch-xtreme

Simulators
Firm seeks simulator agents

WHR Devices is an Australian company delivering world class high fidelity six axes racing simulators. Their MP6 Motion Platform delivers the most immersive simulation experience available on the market today – all for a five-figure price tag.
The company is currently looking for distributors/agents. Interested parties should contact the General Manager, Keith Morling
keith.morling@whrdevices.com
www.whrdevices.com

Track replication
Dynamometer services on offer

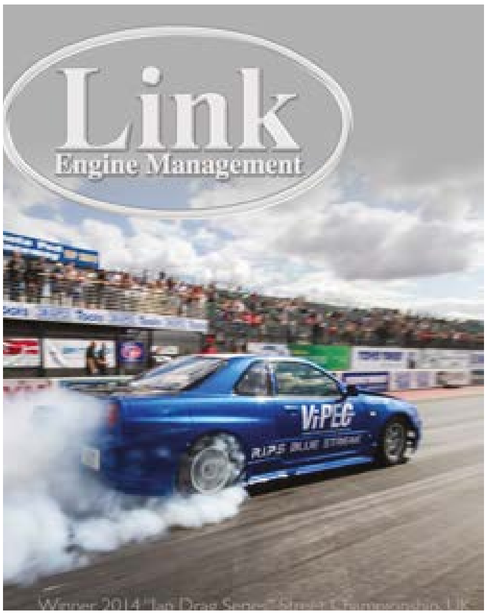
Essex Parts Services is a company that offers brake system dynamometer services including track replication.

This dynamometer is capable of testing iron or carbon/carbon discs and pads up to 420mm in diameter at temperatures up to 1,100degC. Air flow can be separately regulated to the disc, caliper, and test section.
www.essexparts.com

Engineering services
Low friction surface finishing

The Sandwell Superfinishing process is designed to refine and polish surfaces to enhance component performance. This is an engineered finish with the benefit of producing a low friction surface that will reduce rolling resistance and hence contact stresses. Of benefit on transmission parts as well as sliding and rotating surfaces.
www.sandwell-uk.co.uk

Engineering services
Flexible engine management



Link Engine Management offers the flexibility and control demanded by leading tuners. Vi-PEC Premium ECUs give the tuner the ability to compete at the highest level. Designed on the basis of excellence, assembled with medical precision delivering rock solid, repeatable engine performance. Reliable profit from reliable product.
http://www.electronz.co.nz

Sponsorship
Motorsport sponsorship

Are you looking for Motorsport Sponsorship for 2015? We can help. Simply fill in a profile on our website at www.powermaxedracing.com and we will put your details in front of other brands looking to advertise in Motorsport. We will also send you free Power Maxed products, clothing and maybe more!
www.powermaxedracing.com

Timekeeping
Bespoke track stopwatch

The brand new Tag Heuer Circuit Pocket Pro gives users access to timekeeping functions dedicated to motor sport circuit racing. The innovative and bespoke electronic stopwatch makes it possible to time training sessions for circuit events with individual starts and finishes (qualifying), lap time with best lap and gap, and 5 individual count down.
www. tagheuer.com

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

25 years and motoring

This month again sees the greatest motor show open its doors at the NEC

The global motorsport community will converge on Birmingham in January, as Europe's largest dedicated motorsport trade show, Autosport International, celebrates its 25th anniversary.

Since it was first held in 1991, the event has brought together international guests and leaders from the United Kingdom's renowned high-performance engineering sector together to network and view the latest technology on the eve of the new motorsport season.

That tradition continues at Birmingham's NEC on 8-11 January, with the opening two days dedicated to industry and including Autosport Engineering, and the ongoing evolution of motorsport reflected in the new Low Carbon Racing and Automotive Show.

In 2012, Britain's Motorsport Valley generated £9 billion in sales, up from £4.6 billion in 2000, in figures compiled by the Motorsport Industry Association. The community goes well beyond being home to eight of the 11 teams in Formula 1, comprising 4,300 companies and employing 41,000 people.

Autosport International's role as the industry's principal showcase is evident through its growing audience; almost 28,000 motorsport professionals attended Autosport International 2014, while 600 companies from more than 20 different countries were present as exhibitors. With 150 firms having exhibited at the maiden show in 1991, it highlights not only the growth of the event, but also the industry as a whole.

Among the countless launches held at the show during its history, recent years have seen several emerging UK manufacturers reveal new projects. In 2014, the Zenos E10 sports car was unveiled, while a year earlier Anglo-German venture Sin Cars introduced its new R1 concept.

Other highlights have included Lola Group and Drayson Racing Technologies' ground-breaking Lola-Drayson B12/69EV all-electric prototype racing car in 2012 and Quaife's R40 racer as it celebrated its 40th anniversary in 2005.

'Motorsport has changed massively since the very first Autosport International in 1991, namely with the move towards greener solutions and an increase in simulation technology, but what hasn't changed is that the UK is at the forefront of the industry,' said Autosport International Show Director, Ian France.

'The show has also grown considerably in that time, to now bring approximately 600 companies and almost 28,000 engineers, buyers and decision makers from around the world together under one roof. The networking and business conducted at the show each year influences what happens on the racetracks, and flows into other high-performance engineering sectors such as automotive, aerospace, defence and marine.

'As we prepare to celebrate the 25th anniversary of Autosport International, we're proud to have played our part in the ongoing growth and success of the robust local industry and are excited about what's in store for the next 25 years.'

As the big event opening approached, 300 companies from 16 different countries had signed up as Autosport International 2015 exhibitors. Among them are industry leaders such as ATL Fuel Cells, Brembo S.p.A., DC Electronics, M-Sport, Ohlins Racing AB, Quaife Engineering, Wirth Research and Zircotec. AP Racing has been a regular at the show since first exhibiting in 1991.

'AP Racing has been an Autosport International exhibitor since the very beginning and while motorsport has changed a lot in that time, the show remains an important part of it here in the UK,' Joe Bennett, AP Racing marketing engineer, said. 'Every January it really brings the industry together. For exhibitors, it provides a valuable platform to keep everyone aware of our brand, who we are and what we do, showcasing out latest developments and meeting potential customers.'

Commencing with two days dedicated to industry visitors, Autosport Engineering in association with *Racecar Engineering* on 8-9 January, Autosport International trade registration is available from £27, with discounts for group bookings. To register call +44 (0)845 218 6012, or visit www.autosportinternational.com.

HALL 9, 8-9 JANUARY – WHERE THE INDUSTRY MEETS

Throughout Autosport International's 25-year history, suppliers, engineers and decision makers from around the world have come together to network and view the latest technology on the eve of the new season, and Autosport Engineering, held in association with Racecar Engineering, was introduced in 1996 as a dedicated 'show within a show' for the global motorsport community.

The UK's high-performance engineering sector is joined by companies and professionals from around the world. Highlighting the local sector's status, industry guests from 63 different nations were among Autosport Engineering's 2014 trade audience of 28,000. The scope of Europe's largest dedicated motorsport trade show goes beyond the track, with the transfer of technology into arenas such as aerospace, automotive, defence and marine also on the agenda.

LOW CARBON RACING AND AUTOMOTIVE SHOW

HALL 9, 8-9 JANUARY

GREEN IS GOOD

Formula 1's new power units, hybrid technology at Le Mans and the all-new FIA Formula E Championship all highlight motorsport's ongoing shift towards greener solutions, which will be in the spotlight with the new Low Carbon Racing and Automotive Show (LCRA).

Taking place alongside Autosport Engineering, LCRA will showcase innovations, provide networking opportunities and cement the UK's position as a global hub for motorsport and automotive low carbon technologies.

Sales of hybrid and electric vehicles are increasing by 17.4 per cent year-on-year, and expected to hold a 60 per cent market share by the year 2030. Motorsport is fuelling the development of technology, and the inaugural LCRA is hosting a number the sector's key players.

HOLINGER ENGINEERING

HALL 9, STAND E680

FROM A LAND DOWN UNDER

Holinger Engineering has released its first in-line, six-speed sequential transaxle, an extension of its OEM 'kits' for the likes of Aston Martin, Lamborghini and Porsche.

The Australian firm has applied its decades of experience producing world-leading in-line gearboxes and transverse transaxles to the versatile MFT, which can accept input from either end, and be orientated with the differential above or below the input shaft. As a result, the MFT is suitable for a diverse range of applications, from mid or rear-engined GT cars to off-road buggies. Two versions are available, high torque and extremely high torque, both featuring internal direct pneumatic actuation at the camshaft and delivering fast, positive and consistent gear shifts.

ZIRCOTEC

HALL 9, STAND E962

HIGH-TEC FROM ZIRCOTEC

An award-winning, plasma-sprayed coating that enables the use of lighter and more efficient materials in electronic applications features on Zircotec's Autosport Engineering stand. Offering protection from electro-magnetic interference (EMI), the EMC coating won Composites UK's 2014 Innovation Award and has been proven in Formula 1. Composites in electrical and electronic insulations are a considerably lighter solution than the metal shields traditionally used to prevent EMI interrupting or degrading transmitted data signals.

Driven by a surge in electric hybrid powertrains, Zircotec's EMC coating is already in use within motorsport and set for applications in defence, aerospace and marine applications.

PFC BRAKES

HALL 9, STAND E662

PFC BRAKES CHOSEN TO SUPPLY ANOTHER RENAULT SERIES

Reinforcing its position as a leader in the design and manufacture of competition brake systems, PFC Brakes has been chosen as brake supplier to Renault Sport Technologies for its new V6 3.8L twin-turbo 500bhp Renault R.S. 01. The braking system on the R.S. 01 combines 380mm carbon discs, carbon pads and six-piston PFC calipers. This choice is an excellent compromise between efficiency and endurance. PFC Brakes also supplies Porsche Motorsport with a full brake package for the 991 championship along with Ginetta, Opel, Toyota, BMW and Mercedes.

TOTAL SIM

HALL 9, STAND E892

THE CATESBY TUNNEL

The Catesby Tunnel is set to become the world's premier full scale vehicle testing facility. Located in the Northamptonshire countryside, this disused railway tunnel is in the planning phase to restore and convert into a test facility. In addition to the Tunnel, the accompanying Science Park will see the Catesby project becoming a worldwide centre for aerodynamics and vehicle development.

The project is being developed by Aero Research Partners of which TotalSim Ltd are one of the two partners involved. The tunnel will be suitable for both automotive and motorsports applications and capable of testing:

- Vehicle performance
- Vehicle aerodynamics, drag and downforce/lift
- Noise
- Soiling
- Cooling performance

For full details of this extraordinary and exciting project, please see Racecar Engineering RE V24N11 for Peter Wright's analysis.

FINE CUT GRAPHIC IMAGING LTD

HALL 9, STAND: E1049

Fine Cut Graphic Imaging Ltd has recently been awarded a significant Business Growth Grant, from the Coast to Capital Regional growth fund, to support investment in developing their advanced engineering division. Fine Cut are specialists within the industrial graphics, laser engraving and advanced engineering sectors. Continually investing in the latest production equipment, the grant which is in excess of £95,000, contributes towards Fine Cut's development of their Advanced Engineering division and plans to create seven highly skilled employment opportunities. The project kicks off with a new 5 axis-machining centre that has a large 3.6m x 2.6m bed which was specifically built for specialist composite engineering including carbon fibre trimming.

The new CMS Ares and Faro arm will allow for the supply of an even greater range of high quality engineered parts to the industry.

The Government's Regional Growth Fund is a £3.2 billion fund designed to help companies in England to grow. So far £2.9 billion of funding has been allocated to support projects and programmes committed to deliver sustainable jobs and economic growth. The sixth round is now closed and received 174 applications, allocations will be announced in early 2015.

OBP MOTORSPORT

HALL 8, STAND 8711

New pedal boxes and a new hydraulic handbrake headline obp Motorsport's display of its latest developments. UK designed and manufactured, the Pro-Race V3 Full Billet Aluminium Bias Brake Pedal Box is made of aircraft-grade billet that provides an ergonomic fit, responsive throttle return and a range of adjustability options. Its predecessor features in the new-for-2015 Mini Challenge racecars. A line of drifting and Time Attack pedal boxes have been developed specifically for Japanese performance cars. Meanwhile, the lightweight Premium Aluminium Billet V2 Hydraulic Handbrake has been produced for drifting, rallying, rallycross and autocross and features adjustable lever length.

ELECTROX LASER

HALL 9, STAND E1046

Electrox's EMS Workstation range of laser marking, etching and engraving systems offer a versatile and practical solution for a number of manufacturing industries. With three models to meet all ergonomic working environments and budgets, the line-up spans compact, bench-mounted units to larger, free-standing systems.

The entry-level EMS 100 features a lift-up door, laser-safe viewing window and fume extraction port, and is compatible with Microsoft Windows for programming through a computer.

Show celebrations

The Autosport International Show and its show partner, Racecar Engineering, are both celebrating reaching significant milestones

Following one of the warmest years on record in the UK, forecasters are predicting a cold snap that will see a devastatingly cold winter. I am not sure they really know what they are talking about – the window is usually the best way to work out what the weather is doing, but I do know that the drop in ambient temperature signals the new year, and that in turn leads to the Autosport Engineering Show, held in conjuction with *Racecar Engineering*.

Regardless of the weather outside, inside the show will be its usual hive of activity. It is the place to start the year, with new products and services launched in its dedicated hall, people catching up after Christmas and, as is always the case in motor racing, taking the chance to do business.

The Racecar Engineering stand at the show

This is a special year for the show as it marks its 25th anniversary, and *Racecar Engineering* also kicks off its 25th year. There will be a series of events throughout the year to celebrate our silver anniversary, but there is no better place than the Birmingham NEC to begin the celebrations. We hope that you will join us at the show!

Trade passes for the show are available from £27, with discounts for group bookings. To register call +44 (0)845 218 6012, or visit www.autosportinternational.com..

Graham Jones award

During his time as editor of *Racecar Engineering*, one of the tasks that Graham Jones most looked forward to was picking the most innovative product on display in the Autosport Engineering Show.

Every year Graham, who passed away in September 2011, took great pride in presenting the winner with the award. In 2013, British company Versarien won the inaugural impressive trophy. It wasn't awarded in 2014 but there are already a wealth of candidates lined up for the 2015 show and the team is looking forward to the often spirited debate over the respective products.

For those attending the Autosport Engineering show, watch out for the *Racecar Engineering* team around the show and feel free to point out any new products that we may have missed, and get yourselves into contention for this prestigious award.

Students warm up for an engineering future

Earlier this year, EngineeringUK revealed the extent of the industry's skills shortage, with an additional 1.48 million qualified engineers required to fill roles before 2020. Motorsport isn't immune, and Autosport International will focus on the topic with its Careers in Motorsport area, where the University of Bolton will highlight its growing partnership with Ginetta and entry to LMP3 competition in 2015.

Earlier this year, EngineeringUK revealed the extent of the industry's skills shortage, with an additional 1.48 million qualified engineers required to fill roles before 2020. Motorsport isn't immune to the shortage, and Autosport International will focus on the topic with its dedicated Careers in Motorsport area, where the University of Bolton will highlight its growing partnership with Ginetta and entry to LMP3 competition in 2015.

Beyond giving the next crop of innovators the chance to network with high-performance engineering firms and view the latest developments, education and training providers will attend the show to provide information and advice about pathways into the field.

Britain's world-leading Motorsport Valley alone accounts for 41,000 jobs and 4,300 companies, including eight of the 11 teams contesting the 2014 Formula 1 World Championship.

On 8-11 January, the University of Bolton will showcase its Centre for Advanced Performance Engineering (CAPE) and expanding partnership with Ginetta Cars. Managed by students, CAPE had its own entry in the Ginetta Racing Drivers Club in 2014, but that will step up another level in 2015. The University of Bolton and CAPE are the world's first customers of the new Ginetta-Juno LMP3 racer, which will make its debut as part of the European Le Mans Series and Asian Le Mans Series'.

The University of Bolton will launch its new LMP3 racer on its Autosport International stand, 7120 within Hall 7. 'Only our advanced performance engineering students have access to work on a Le Mans race team and as a result of our partnership with Ginetta they will now be working on the brand new LMP3 car,' Professor George Holmes, Vice-Chancellor of the University of Bolton, said. Oxford Brookes University, Tresham College of Further and Higher Education and University of Dundee are among the other education providers set to have a presence at Autosport International.

WHERE THE INDUSTRY MEETS – continued

Self-contained with an integrated laser and programmable Z-axis, the EMS 200 lets customers begin marking with minimal set-up requirements. A wrap-around door offers flexible access. The EMS 300 Workstation is ideal for more complex applications or larger components. Featuring a welded construction, an automatic, pneumatically-controlled door and removable side panels mean it's easily integrated into production lines.

REVERIE
HALL 8, STAND 8610

Carbon fibre composite specialist Reverie is showcasing its new-for-2015 Supersports FIA-approved seat, which features an optional bolt-on head restraint for enhanced side impact protection. It's joined on the stand by a pair of new, 310mm chord, autoclaved carbon fibre wing sections, one a low drag version, the other offering high downforce. The low drag variant is also available as a dual-element, with a 110mm or 150mm flap, while universal alloy case chassis and boot mountings will be on show from a line-up that spans multiple manufacturers and components.

DEVELOPMENT ENGINEERING & ENTERPRISE
HALL 9, STAND E480

DEE-Ltd is showcasing its range of Toyota-derived powertrain products, led by its adaptation of the award-winning, three-cylinder D-1KR-FE engine. The low-carbon D-1KR-FE weighs just 70kg and is ideal in a power-to-weight critical application, either as a primary power unit or range extender in a hybrid drivetrain solution. A 120bhp turbo version of the engine is set to power cars in Formula Genesis, an entry-level single-seat series.

It's among a long line of solutions developed as part of DEE-Ltd's exclusive relationship with Toyota, which gives the Coventry firm unique access to the Japanese manufacturer's current range of engines and transmissions.

TE CONNECTIVITY
HALL 9, STAND E440

TE Connectivity has expanded its DEUTSCH ASDD range of connectors, developed to meet motorsport's ongoing push for more compact packaging options for the sensors and connectors powering complex electronic systems. Utilising technology proven across the ASDD connector line-up, the addition allows 118 ASDD size-24 contacts to fit within a regular, size 18 Autosport shell. The 118-way ASDD interconnect will be available in all of the keyway options across TE Connectivity's Autosport range, with PCB, inline, flanged, clinchnut and flangeless variants.

TRELLBORG SEALING UK
HALL 9, STAND E746

First-time Autosport Engineering exhibitor Trellborg Sealing Solutions is launching its unique Turcon® Roto L seal. With a patented design, it only seals around the axle of central inflation systems when required; when the tyre is pressurised for inflation or deflation. Engineered for central tyre inflation systems commonly used in off-highway vehicles and trucks, it provides total life sealing and reduced operating costs through fuel and energy savings. Trellborg Sealing Solutions is also providing advanced seals to Protean Electric for its innovative, in-wheel electric drive system, which enhances performance and improves efficiency.

Pole position starts here

Autosport Engineering has attracted the World's leading suppliers of Motorsport Technology, components and materials used in all formulas of motor racing.

I have the pleasure of once again providing a unique forum for motorsport professionals to meet each other to discuss the latest leading edge products available. Manufacturers from all over the world will exhibit their latest products to be used for the coming season.

A new area within Autosport Engineering for 2015 will be dedicated to Low Carbon and will be located by the popular TT Bar.

The unique Bloodhound, together with some of its specialised suppliers will for the first time be located within Engineering.

BLOODHOUND SSC is a jet and rocket powered car designed to go at 1,000mph (just over 1,600 km/h). It has a slender body of approximately 14m length with two front wheels within the body and two rear wheels mounted externally within wheel fairings. It weighs over 7 tonnes and the engines produce more than 135,000 horsepower – more than six times the power of all the Formula 1 cars on a starting grid put together!

The car is a mix of car and aircraft technology, with the front half being a carbon fibre monocoque like a racing car and the back half being a metallic framework and panels like an aircraft.

Finally, with my unique position working with the world's leading motorsport industry magazine, *Racecar Engineering,* I am proud that the show has assembled a comprehensive array of specialist engineering suppliers.

I am looking forward to welcoming both visitors and exhibitors in the TT Bar. I really feel that this show may prove to be the best event ever.

Tony Tobias

IN BRIEF

Quality all the way
"We come to Autosport International every year but in 2014 we displayed our new dual intelligent battery system. The show really helped build the momentum around the product, as it also featured in the Autosport magazine supplement the week before the show. All in all it is really helpful to us and the actual leads and enquiries are of a very good quality." – Martin Dewey, DC Electronics

We can work it out
MIA Business Workshops will again return to Birmingham's NEC alongside Autosport Engineering on 8-9 January. A diverse range of free seminars will be held by the likes of Base Performance Simulators, Claytex, King Engine Bearings and MarchantCain Design.
Click here [http://bit.ly/1qoZPJt] for listings and to pre-register.

Only connect
TE Connectivity (TE) will feature the latest, more compact addition to its DEUTSCH ASDD Range of Connectors at Autosport Engineering. Using technology proven throughout the ASDD connector range, the 118-way ASDD interconnect will enables 24 contacts in the size of an 18 Autosport shell and will be available in all the keyway options with PCS, inline, flanged, clinchnut and flangless variants. For more information, visit www.deutsch.net or Stand E440 in Hall 9 at Autosport Engineering.

Racecar Engineering
The International Journal of Motorsport Technology

PIT CREW

Editor
Andrew Cotton
@RacecarEd

Deputy editor
Sam Collins
@RacecarEngineer

News editor
Mike Breslin

Design
Dave Oswald

Chief sub editor
Henry Giles

Technical consultant
Peter Wright

Contributors
George Bolt jr, Ricardo Divila, Chris Eyre, Gemma Hatton, Simon McBeath, Danny Nowlan, Mark Ortiz, Don Taylor, Rudoplh van Veen, Peter Wright

Photography
James Moy

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

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

Advertisement manager Lauren Mills
Tel +44 (0) 20 7349 3740
Email lauren.mills@chelseamagazines.com

Advertisement sales executive
Stewart Mitchell **Tel** +44 (0) 20 7349 3745
Email stewart.mitchell@chelseamagazines.com

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

Publisher Simon Temlett

Managing director Paul Dobson

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

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

Subscriptions
Subscriptions Department
800 Guillat Avenue, Kent Science Park
Sittingbourne, Kent ME9 8GU
Tel +44 (0) 1795 419837
Email racecar@servicehelpline.co.uk
http://racecar.subscribeonline.co.uk

Subscription rates
UK £66 (12 issues)
USA $162 (12 issues)
ROW £84 (12 issues)

News distribution
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
Tel +44 (0) 20 7429 4000
Fax +44 (0) 20 7429 4001
Email info@seymour.co.uk

Printed by Wyndeham Heron
Printed in England

ISSN No 0961-1096
USPS No 007-969

recycle

www.racecar-engineering.com

Expense account

The 2014 season was one of the most interesting that motor racing audiences have seen for four decades. New technical regulations in Formula 1, the World Endurance Championship and the World Touring Car Championship. Never before have all the headline acts changed their regulations at the same time, and never before have they been so ambitious. And let's not forget that F1 and the WEC started 2014 with a brand new fuel flow sensor that was far from perfect.

The move from conventional engines to powerful hybrid systems in Formula 1 and the WEC led to an explosion of costs compared with 2013. In both, the manufacturers have swallowed the costs. The WEC has promised to keep an eye on them in the future through a commission, while in Formula 1 some of the development costs have been met by selling customer engines.

It's an interesting point to note that in both, the customer teams have struggled to match the big spenders – look at our news pages to see the disparity between Red Bull and Caterham – and that's hardly a surprise. The engine bills for Formula 1 have risen from an estimated $10m to an estimated $40m this year for the customer teams and that, coupled with the other technical developments such as mastering brake by wire, has led the likes of Caterham and Marussia into financial difficulty. And not only them – Lotus has been outspoken in its criticism of the relative cost compared to difference in lap time between Formula 1 and GP2, while Sauber has hinted at a subtle destabilisation of the ground making it difficult for the customer teams to establish a firm footing.

Privateer teams could find more rewarding homes

Some say that Bernie and the FIA are playing a game and have a clear ulterior motive, others say that Bernie is not the powerhouse that he once was and that, at the age of 84, he is beginning to show his age in these meetings. Regardless, the financial structure of Formula 1 is coming out in the public eye. Will it stay there? It will if the teams fail to show up in 2015 and the grid falls below the magic number of 16 for the Australian Grand Prix in March. If the customer teams continue, the problem will disappear for now, but the spectre of such a drop in grid numbers could affect everyone, from the front of the grid to the back.

The bottom line is that top class motorsport is expensive, and the new regulations stretch the budgets that much further. However, there is always a reliance on a customer team, or a privateer, if not to balance the books as a manufacturer (through engine sale) then to maintain grid numbers and spectators love the idea of the underdog claiming an unlikely win. The problem is that manufacturers need to score overall wins to justify their high spends. They don't want to have the customer teams around threatening them, and the customer teams don't want to be there unless they can challenge.

As Formula 1's finances enjoyed their day in the sunshine, it was interesting to note how the others model themselves. In the WEC, the manufacturers say that the power units are too complicated to hand to a customer team. With a class structure and different rules for manufacturers and privateers, there is wriggle room. The cost of competing in the LMP1 category for a privateer remains high, so the LMP2 class is aimed (for now) primarily at the privateers, and the GTE-Am category is just that.

In the World Touring Car Championship, Citroën has enjoyed Mercedes-esque type superiority this season. The French marque has won 17 out of 23 races this season, and its driver Jose Maria Lopez has scored ten of those wins, more than any other driver in a single season. Honda has pledged to step up to the plate next year, Lada will step up its programme in 2015 and might be joined by Volvo, SEAT or Alfa Romeo if rumours are to be believed, but that makes it even more difficult for the privateers to glimpse the front of the grid. So, next year the WTCC will have a prize fund per race, and will have an overall fund for the champion, enough to pay for the upgrades from one season to the next. The budgets are by far the lowest for a World Championship – €1.2 million per car for a WTCC season for a privateer.

Interestingly, the rise of domestic championships, such as the British Touring Car Championship in the UK, the VLN series in Germany and the International GT open are all gaining entries. Privateers are finding other areas that deliver higher returns, although the lure of a world or an international programme is hard to resist. One of these is the Blancpain Endurance and Sprint series. With more than half of the drivers paid to drive, and with significant prize money for all races, and a last round grab for cash in Baku in November, teams have a genuine Grand Prize to aim for.

Bernie says that there is no place at the table for those who come begging for scraps, but in reality, these teams have a genuine role to play. It is not all about the elite, and it never has been, although I also don't agree with the GP2-style category in F1.

Top level racing does need to take care of the costs, and provide a genuine incentive to high-quality private teams before they all find a more rewarding home.

ANDREW COTTON Editor


What's the
secret
about the new 911 GT3 Cup's
new brakes?
It's Quicker.™
OFFICIAL PARTNER
PORSCHE
MOTORSPORT
PFC
BREMSE
www.pfcbrakes.com
*44(0) 1295 221 020