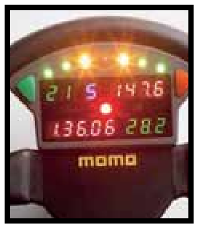
INSIDE: HOW TO START A FORMULA 1 TEAM

The International Journal

Racecar engineering



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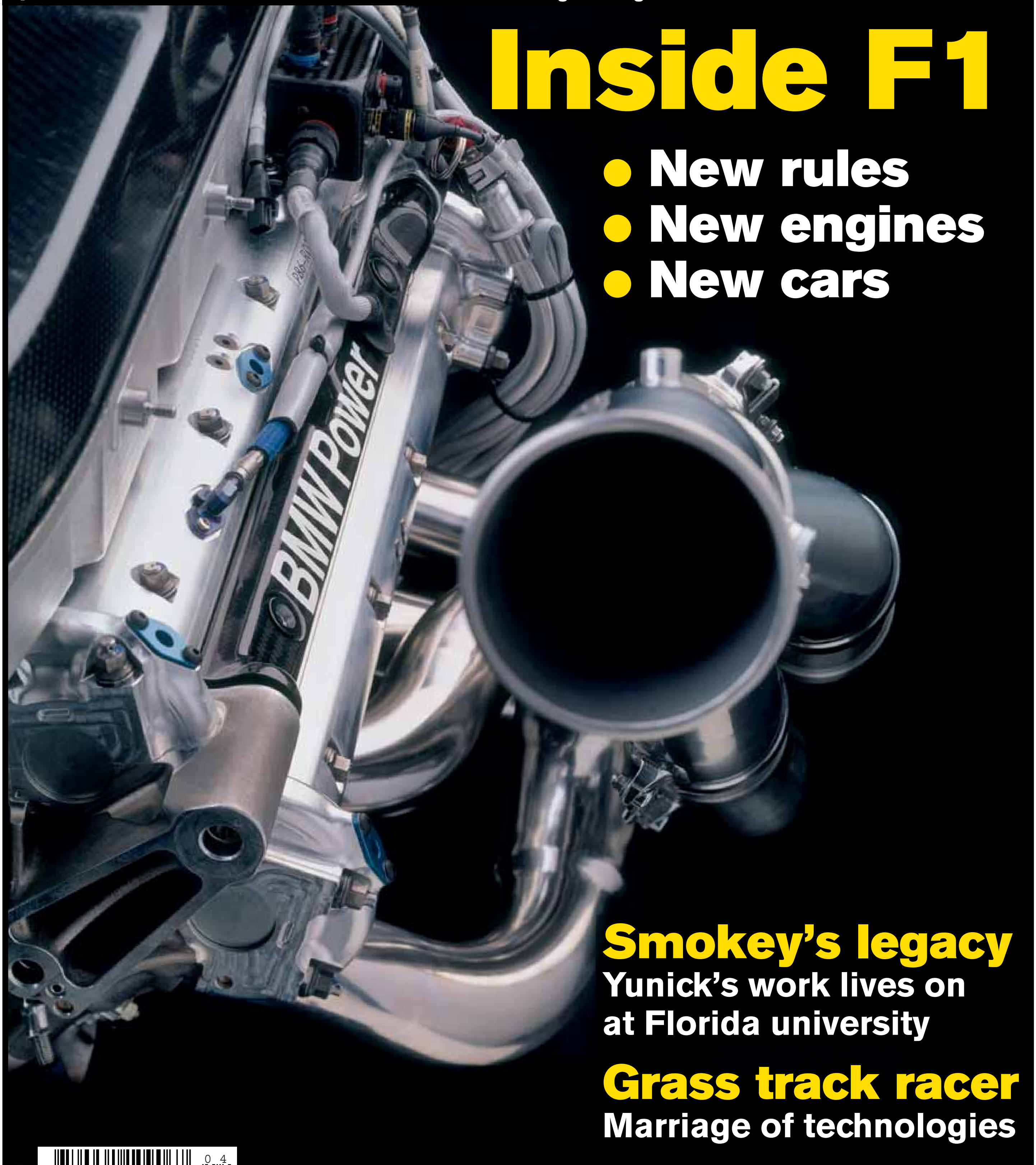

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- New rules
- New engines
- New cars

Smokey's legacy
Yunick's work lives on at Florida university

Grass track racer
Marriage of technologies

BMW

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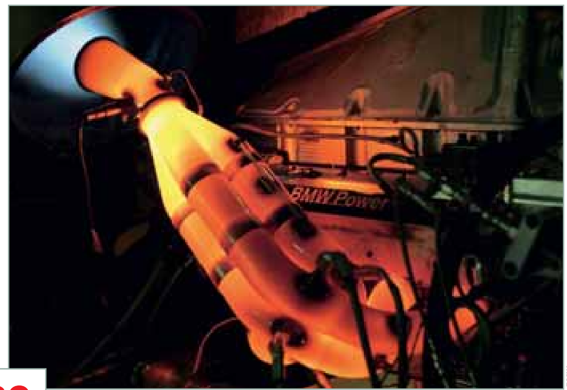

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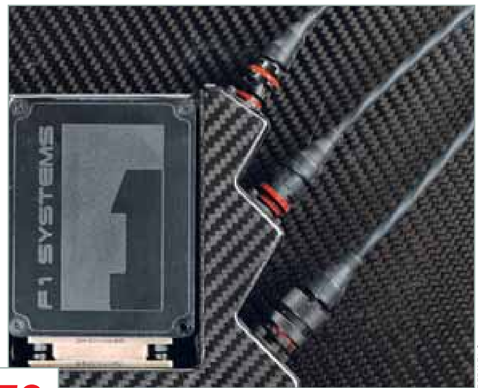

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Write Line

Formula 1 is no longer a technical sport. You don't believe me? Then you should have attended some of the new car launches this season. I'm sorry, that is a misleading description. Campaign launch is perhaps a more apt term. Yes the new cars were present at each event, but they did little more than prevent the sponsors' liveries collapsing in a heap of paint chips on the stage. Actual technical information was all but nil. Granted the teams wheeled out a technical representative but they would probably have been more comfortable discussing their parents' sex lives than anything about their new challenger. To some extent one can sympathise. These people are under enormous pressure to bring home points and live in fear of giving the opposition the slightest whiff of information, however unlikely it is that it might prove useful. Instead, they spent the entire launch fending off questions with generalities that could be applied to any car on the grid.

But although it may not be in the public domain, you might argue that there is a massive amount of technology being exploited to bring the new car to the grid in a competitive state. I agree, and it all plays a huge part in determining the outcome, but if it's done behind closed doors, is it part of the sport? Or, is it like playing the soccer world cup in the dark so nobody can see the teams' tactics and copy them at the next match?

> **"WOULDN'T IT BE EASIER TO PUT EVERYBODY IN GP2 CARS?"**

I've said this before and excuse me if I bore you but if it's not part of the show then what is the technology for? Wouldn't it be easier to put everybody in GP2 cars and paint them different colours?

Alternatively, perhaps it does have a purpose, one that has nothing to do with the show. Could it be that motorsport makes better road cars? Not directly because, in so many ways, a road car is more sophisticated than a racecar. In less direct ways though, perhaps there is a chance that racing has a technical benefit. Exposing engineers to the motorsport environment can make them more versatile and effective. Also, short lead times and rapidly repeating iterations can accelerate development of new materials or design technologies, particularly for aerospace. Are these things happening? The jury is still out, but one thing is known. Unless motorsport can justify its conspicuous consumption in pursuit of technical development then either the technology will disappear into a world of spec racers or the sport will disappear altogether in the form we have come to know it.

This is a problem that has taxed the mind of Herb Fischel who, as ex-head of GM Motorsport, is not without some influence. As you may have read in the magazine [V16 N1], he is campaigning to make motorsport more relevant to car manufacturers by looking at ways the relationship between the two disciplines can be more productive. Where he feels this can be most productive is in sports and GT racing and this month he brings together representatives of manufacturers and organising bodies to discuss the problem at an event hosted by the SAE [see news story].

I urge everyone in professional motorsport to take note. It may be your future they are discussing.

Editor
Charles Armstrong-Wilson

The International Journal
Racecar engineering

Pit Crew

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Editor
Charles Armstrong-Wilson
Deputy Editor
Sam Collins
Art Editor
Barbara Stanley Borras
Chief Sub Editor
Mike Pye
Editorial Assistant
Katie Power
Contributing Editors
Paul Van Valkenburgh, Allan Staniforth
Technical Consultant
Peter Wright
Group Art Editor
Patrick Morrissey
Contributors
Brett Becker, George Bolt Jr, Pete Knivett, Simon McBeath, Mark Ortiz, Ian Wagstaff, Paul Weighell, Tim Whittington
Photography
Ian Harris, LAT, Tony Tobias
Business Development Manager
Tony Tobias +44 (0) 20 8726 8328
Mobile 07768 244880 Fax +44 (0) 20 8726 8399
tony_tobias@ipcmedia.com
Advertisement Sales Executive
Andy King +44 (0) 20 8726 8329
andy_king@ipcmedia.com
Group Advertisement Manager
Nick Lee
Publisher
Gavin de Carle
General Manager
Niall Clarkson
Managing Director
Paul Williams
Editorial & Advertising
Racecar Engineering, Focus Network, Leon House, 233 High Street, Croydon, Surrey CR9 1HZ, UK
Tel +44 (0)20 8726 8364
Fax +44 (0)20 8726 8399
E-mail racecar@ipcmedia.com
Back Numbers Back issues department, PO Box 772, Peterborough PE2 6WJ, UK
Tel +44 (0)1733 385170
Website mags-uk.com/ipc
Worldwide News Trade Distribution
Marketforce (UK) 5th Floor, Low Rise, Kings Reach Tower, Stamford Street, London SE1 9LS, UK
Tel +44 (0)20 7633 3300
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Formula 1 new challengers

Over the winter a number of new Formula 1 cars have been unveiled, though some of them may not be as new as first appears. Rumours of 'chassis plate swapping' are rife, so it is questionable just how new some of these new cars actually are. BMW-Sauber admits that its F1.06 is a re-work of the Sauber C24; Scuderia Toro Rosso's challenger is last year's Red Bull (which in turn can trace its roots back to the Jaguar team) and Super Aguri is using a modified Arrows chassis.

For a full feature on the new F1 entries see page 30

Honda

Honda RA106 (top right)
BAR has morphed into the Honda Racing F1 team, and hopes that it has cured some of the aerodynamic problems encountered on the BAR007

Ferrari 248 (middle right)
Few details about Ferrari's latest challenger had been released as *Racecar* closed for press

Red Bull RB2 (right)
Red Bull's first racecar (the RB1 was Jaguar derived) looks competent, and an influx of new staff could see this Ferrari-engined team be a surprise front runner

All pics LAT unless stated

BMW-Sauber F1.06 (above)
Not an entirely new car as it is a Sauber C24, albeit extensively re-worked, not least to accept the BMW V8 instead of a Ferrari V10

Williams FW28 (left)
Williams will use Cosworth's CA-2006 V8 this season, and has switched from Bridgestone to Michelin tyres

unveiled for 2006

Midland M16 (above)
Midland was initially planning to work with Dallara on the Toyota-powered M16's design but the car that was eventually built is solely the work of the team formerly known as Jordan

Toyota TF106 (above)
Toyota has been experimenting with a variety of aero tweeks in winter testing, and a new kit is expected to be on the car for Bahrain

Renault R26 (left)
Last year's championship winner has had to make the biggest change to accommodate the new rules, having had to change from a 72-degree 3.0-litre V10 to a 90-degree 2.4-litre V8

McLaren MP4/21 (left)
In testing, the new McLaren has been blighted by engine problems, forcing Mercedes to consider revising the units' design. And in recent weeks a spate of senior figures have left McLaren for rival teams

Red Bull RB2

In winter testing the Ferrari-engined RB2 has been experiencing over-heating problems, forcing the team to make hasty alterations to the cars' sidepods. Red Bull claimed there had been an error in 'heat rejection' figures from the Ferrari V8 engine.

STOP PRESS

Sportscar racing, and its benefits to car manufacturers, are to be discussed in an open seminar at the SAE's 2006 World Congress. The event will take place on 3 April 2006 at the FEV Powertrain Innovation Forum at the Cobo Convention Center in Detroit, USA. Participating in two panels will be:

Sanctioning Organisations

- Scott Atherton, president and CEO, American Le Mans Series (ALMS)
- Roger Edmondson, president, Grand American Road Racing (Grand-Am)
- Harry Turner, technical director, Sports Car Club of America (SCCA)
- Stephane Ratel, chairman of SRO Motorsports Group, Federation Internationale de l'Automobile (FIA GT)

Manufacturers

- Steve Wesoloski, group manager road racing, General Motors
- Giorgio Ascanelli, technical director, Maserati Corse
- Robert Davis, vice president marketing and product development, Mazda
- Dr.-Ing. Walliser, general manager motorsports strategy, Porsche

David and Goliath battle ahead for new prototypes

Two new LMP-class prototypes broke cover shortly after Christmas. Lola's new LMP1, the B06/10, ran for the first time at Sebring's 'wheels down' test week in January. The all-new chassis could be seen as an evolution of the already successful B05/40 LMP2 chassis, with a number of the lessons learnt from the second category Le Mans winner being applied to the LMP1. Dyson racing is the customer for the first two chassis, which will replace its aged LMP900-rules B01/60. It was one of Dyson's new cars fitted with a 3.6-litre AER V8 that ran at Sebring – 'Gorgeous, a beautiful piece of engineering,' enthused James Weaver, the first driver to try the car out. 'Lola has done us proud and so has AER. It is a quality piece of equipment – very impressive.' It was also Weaver's first experience of a drive-by-wire car. Dyson's former cars, the B01/60s, are now in the hands of Autocon and Highcroft Racing.

Features on the B06/10 car include a quick-release nosebox, dual high-pressure fuel pumps, back-up batteries and starter motors. Whilst Lola's own HT (high torque) gearbox has already been race proven and has a maximum input torque in excess of 800Nm, Dyson Racing will use a semi-automatic, six-speed, sequential system developed by AER on its cars. The first car has also been fitted with new Penske dampers that are a derivative of those used by McLaren and Renault in Formula 1.

The first European customer for the Lola will be Chamberlain-Synergy who placed an order for one of the new cars, which will be powered by the AER V8. 'We anticipate selling at least three more chassis during the season in readiness for Petit Le Mans and also a full campaign in 2007, when the LMP1 market should really take off,' revealed Lola's Sam Smith.

There is also the David vs Goliath philosophy where this season we will be up against the works Porsche Spyders and Audi R10s. Apart from ourselves and Courage, there is no one else offering a sustained challenge to these manufacturers,' he continued. 'However, don't forget that Lola have worked with manufacturers in the 1980s, with Corvette and Nissan, and also with MG in this decade, so we know how they operate and how they can be beaten.'

Lola's two LMPs will indeed race against stiff competition this year, with Audi's 'whispering diesel' R10 setting the pace in LMP1, and in LMP2 the Porsche RS Spyder the one to beat.

But in Le Mans, Courage Competition is plotting to beat Lola and the works teams with two new cars, the LC70 for LMP1 and the LC75 for LMP2. As *Racecar* closed for press the LC70 was reaching completion, but the LC75 had already tested extensively. Both chassis aim to achieve Courage's main design objectives: reliability, security, modularity and performance. As the cars were developed it became clear that the bar had raised and the Le Mans constructor had to make the largest investments in tooling, people and money it had done since its inception 24 years ago. A joint venture between SLC for assistance in the design and production of the car saw Paolo Catone become chief designer of the project and Ben Wood the chief aerodynamicist. Wood is notable as the man who undertook much of the research that brought about the new ACO aero rules.

Courage's new LC75, already tested with a derivative of Mechachrome's 3.4-litre V8 GP2 engine, is out to beat Lola and Porsche in LMP2

Sebring testing best times

Car	Category	Time
Audi R10	LMP1	1:47.308 *
Porsche RS Spyder	LMP2	1:49.477
Lola B05/40	LMP2	1:50.231
Lola B06/10	LMP1	1:50.359
Lola B01/60	LMP900	1:50.640
Courage C65-H	LMP2	1:55.960 **

*diesel; **rotary engine

LAT

Lola's new 06/10 LMP1 contender on its first time out testing at Sebring

Car of tomorrow 'not successful'

LAT

Rear, boot-mounted wing seen at Daytona looks to be a sign the COT did not perform as expected, aerodynamically

NASCAR's car of tomorrow has been in action for the first time, but has already received a negative initial response from a number of teams. Following a test at the Atlanta Motor Speedway with five cars from different teams, plus NASCAR's own Car of Tomorrow, the governing body followed up with a solo car test at Daytona. At the Florida track there was said to be a noticeable difference over previous tests due to the addition of a rear, boot-mounted wing. An invitation was sent to teams in an effort to have more cars on track, but Petty Enterprises was the only team that showed up with its car.

It seems as though teams have put their own COT plans on hold until NASCAR decides which direction to take with the cars. Plus, due to the new testing and tyre leasing rules, teams are hoarding their 2005 and older tyres for their own use, not to help NASCAR.

In its current guise it seems like no one outside of the governing body cares for the look of the car, much less some of the ideas that have gone into it. It is also widely known that the major car manufacturers are not happy as it has become even more difficult to tell the marques apart from each other, save for headlights and grille.

To allow the exhaust to be mounted higher under the car, avoiding bottoming out on some tracks, sections of the right side chassis rail have been channelled out to allow the exhaust pipes to pass through on the right side instead of the left. This will also have the effect of aiding driver cooling, but will create two major issues: one, it weakens the chassis in a hard impact and two, the hollow frame rails are used to place lead ballast to bring the cars up to the minimum 3400lb weight. Having the exhaust pass through them severely cuts down storage space and could conduct additional heat transfer within the chassis, weakening it further.

The front nose section or 'clip' from the centerline of the front wheel forward is much shorter than the current car and resembles a NASCAR truck. However, it's actually so short that the thicker radiator used for restrictor-plate racing will not fit between the engine and steering box and the front nose section. There are also some concerns that a shorter nose may not absorb as much energy as the older, longer nose, though this does depends on its construction.

Just like F1, NASCAR is looking at ways to make the 'show' more competitive and cost effective for the teams. Currently the most exciting racing in NASCAR's three 'elite' divisions can be seen in the Truck Series, so it's understandable that the COT shows some resemblance to the pick-ups. The more upright front windscreen also adds to that look and, of course, adds drag.

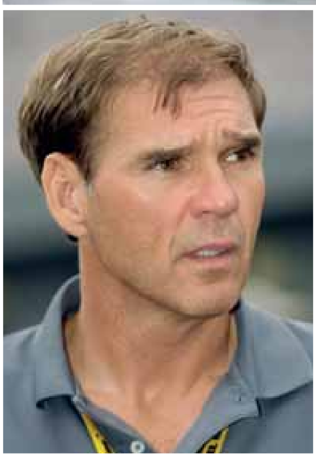
Safety is the other priority, with the left side frame rail offset an additional two inches from the centreline of the car, allowing the seat to be closer to the centre of the vehicle. In reality though, with the much larger seats of recent years – especially the carbon fibre versions – this measurement will rarely be achieved. However, the larger and visibly squarer 'greenhouse' area, as NASCAR refers to it, does add to the safety factor, with the car now two inches taller and four inches wider in the upper cage area. The body will also be symmetrical to the centreline of the chassis in an effort to curb aerodynamic costs and, instead of more than 30 body templates for each make of car, the idea is to have one common three-dimensional template that can simply be lifted on and off the car. Also, the front and rear bumper height will be the same, with the front bumper now three inches higher than current models, and will feature a horizontal opening for cooling, unlike the current vertical grilles on the lower front spoiler.

Some of the other modifications include impact absorbing left-side door bars with the addition of steel plate for protection. The rollcage has been moved

LAT

A short front overhang and a taller, wider 'greenhouse' are obvious changes, but manufacturers dislike the generic shape

in testing



> **WHY IS THERE A WING ON THE BACK OF A STOCK CAR? IF I WANTED A WING I'D GO RACE SPRINT CARS**
>
> **Ray Evernham**

rearward three inches, the propshaft will be enclosed in a full steel tunnel and the floor, which has always been an OEM stamped style, will now be a re-configured bespoke part.

NASCAR announced the schedule for teams to start using the car beginning with the fifth race of the 2007 season at Bristol and then at 13 other events that year. In 2008 the car will compete in 26 of the 36 races, moving onto the full schedule in 2009.

Currently teams have an inventory of around 10-15 cars per driver, depending on budgets, and certain cars designed for different tracks. With the COT the proposal is for one chassis to work at all tracks, including circuits and restrictor-plate tracks, so teams could effectively halve their fleets of cars. This could potentially have a knock-on effect for employees too, particularly high-end fabricators and aerodynamic engineers.

Team owner Ray Evernham *(above left)* summed up the thoughts of many car owners at a post-season media briefing: 'Right now the car has not completed a successful test. Aerodynamically the car did not accomplish what they [NASCAR] were looking for, otherwise you wouldn't have to put a wing on it. Why is there a wing on the back of a stock car? If I wanted a wing I'd go race sprint cars.'

Meanwhile, NASCAR is to switch all three of its top divisions to unleaded fuel by the 2008 season. 'We have tested a current engine with unleaded fuel and all the indications are good,' said Gary Nelson, NASCAR's vice president for research and development. 'We still have more testing to do though because we want to be careful there are no unintended consequences.'

Even with the fuel switch in the works though, it seems NASCAR still has no intention in the immediate future of changing from obsolete carburettors to fuel injection.

Bolt

Impact absorbing left-side door bars and a bespoke floor are new for COT

Toyota: entry into NASCAR in 2007

Toyota has finally announced that it is to enter America's best-selling car, the Toyota Camry, in the Nextel Cup and Busch Series in 2007, following three successful seasons in NASCAR Truck. Three teams have been announced so far: Bill Davis Racing – an existing Toyota operation that fields three trucks; Michael Waltrip Racing – who will enter two Cup and two Busch teams; plus an organisation new to NASCAR, Team Red Bull, owned by the Red Bull company who will operate two Cup teams run by Marty Gaunt, a British-born Canadian.

It is also very possible Penske Racing will enter the 'rising sun gang.' Roger Penske owns more than 30 Toyota dealerships worldwide, as well as the largest US Toyota dealership in California.

Word within Penske, after shuttering one team over the winter, is that its 400,000sq.ft facility will house three Cup teams again in 2007, so maybe a switch to Toyota is also on the cards.

One thing is for certain, Toyota will surely want to align itself with at least one existing top-flight Cup team and Davis has not been that in many years, while Waltrip's once successful self-owned Busch programme has faltered to the point where it failed to even qualify for several races in 2005. With this in mind, Toyota has to be looking at a Ganassi, Penske or a Joe Gibbs-type organisation.

Currently Toyota builds engines itself just outside Los Angeles and in North Carolina for its truck programme, leasing them to the teams. The same applies to the majority of the trucks, which are supplied by Toyota in almost turnkey specification, less shocks, springs and brakes. When a truck suffers damage the majority go back to Toyota's North Carolina chassis and fabrication facility to be repaired.

However, the Cup programme will apparently not be run in the same manner. Some teams will build their own engines and cars while some will be built by Toyota. The Japanese manufacturer's involvement in the Truck Series seems to have spiced up competition and hopefully the same will happen in Cup. The only downside being that Toyota may be willing to plough more money into the programme than the 'big three' marques currently in the sport.

Bolt

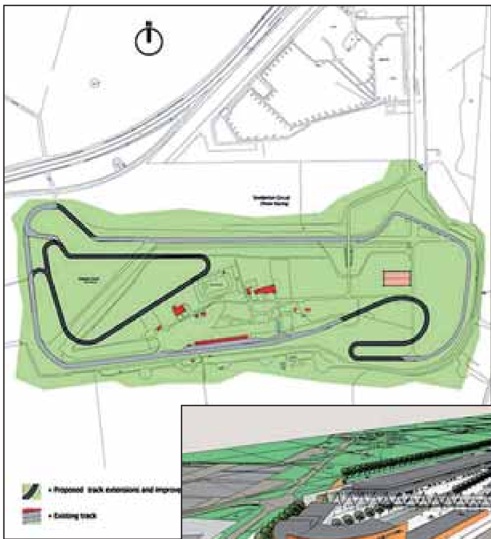
All new for NASCAR's 2007 season will be Team Red Bull, with two teams of Toyota Camrys being run under Marty Gaunt

UK tracks reveal future plans

Britain's only super speedway, Rockingham, has closed temporarily for an extensive construction programme to turn the venue into Rockingham Performance Park. The new complex will feature the existing Speedway and infield road course, along with a new skid pad and quarter mile short track to attract the ever-growing NHRPA series. Associated with the track is an all-new exhibition, conference and hotel complex. The £10 million construction plan is a sign the circuit may have a longer future than some had speculated.

Rockingham was purchased by Corby Developments Ltd last summer as part of a plan to integrate the circuit into the new Priors Hall housing estate. Currently the circuit hosts the SCSA stock car series (old ASA cars) and smaller events like the Shell Eco Marathon. In the past Rockingham has struggled to make money after losing its premier series, Champ Car, to Brands Hatch.

Meanwhile, 75 miles to the east, Motor Sport Vision's Snetterton circuit is also set for a major re-work. The former Second World War USAF airbase is one of the most heavily used race circuits in Britain, and is often used by major teams for testing in the run up to Le Mans.



Motor Sport Vision's plans for Snetterton include lengthening the track and developing a new motorsport business park

Now MSV plans to make the circuit a major venue with a business and engineering park aimed at smaller racing teams and chassis manufacturers. It will allow teams to recapture the 'Brooklands village' convenience of being able to drive the racecar straight out of the garage and onto the circuit. A hotel and retail village will also be constructed on the site, which will be served by its own railway station.

The track is situated in the heart of the East Anglian motorsport cluster that is already home to Van Dieman, RTN and Lotus. Such a facility could bring the region up to rival areas such as the A43 corridor between Oxford and Northampton, sometimes referred to as Motorsport Valley, that is host to Silverstone, Rockingham and a large number of grand prix teams.

Changes to the track itself will lengthen it to 3.3 miles and bring it up to the standards required to host international motorsport.

It is hoped that once the plan receives the necessary permissions the re-worked venue will be completed by 2010.

BMW launches homologation special to contest WTCC title

BMW has signalled its intent to retain its WTCC titles by producing a 'homologation special' 3 Series model for the 2006 season. Designed to comply with FIA rules, just 2600 of the new model will be produced, with 500 in right-hand-drive format.

Badged the 320Si, the new model uses a four-cylinder engine with a 1mm larger bore and 2mm shorter stroke compared with the standard 320i, while overall weight and centre of gravity have been improved with aluminium alloy liners. A further 10kg has been saved by using a carbon cam cover.

Larger inlet and exhaust valves are fitted in a cylinder head that breathes through a conventional throttle body, rather than BMW's usual 'Valvetronic' system. The result is an engine producing 23bhp more than the production 320i, peaking at 173bhp at 7000rpm, allied to 200Nm of torque at 4250rpm and should provide an excellent basis for the WTCC unit.

In addition, BMW has also announced that a racing version of its 120D turbo diesel model will be available from BMW Racing Parts, priced at 95,000 Euros (£65,000). Producing 245bhp and 450Nm of torque, the 1135kg car comes fully prepared with Sachs suspension and AP Racing brakes.

Team Schubert Motors has entered a 120D in the Dubai 24-Hours and an FIA Group N version is expected later in 2006.

New 173bhp 320Si shows BMW's intent to attempt to retain its WTCC crown

NEWS IN BRIEF

- A British kart racer caught running an illegal crankshaft pin used to adjust ignition timing has recently been fined a record £30,000 ($53,000). He would have been fined £6,000 more if he had not admitted guilt at the last minute.
- Germany may lose one of its two grands prix due to financial problems. A race alternating between the Nürburgring and Hockenhiemring has been mooted.
- Britain's ASA-based SCSA stock car series has abandoned plans to run on road courses this year leaving just the Rockingham oval on the calendar.
- Racecar manufacturer Ginetta has been bought out by Team LNT. The Le Mans and GT racing team is also the UK distributor for the Panoz Esperante GTLM and wants to set up a motorsport centre of excellence in Yorkshire.

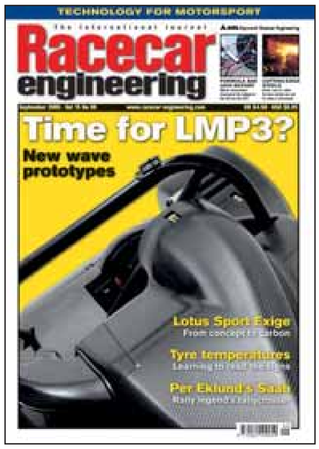
LMP3 becomes a reality with the dawn of IMSA Lites

In the wake of V15N9's cover feature 'Time for LMP3' US sanctioning body IMSA has announced a new series for small prototypes, IMSA Lites.

Initially, the five-round series will only be open to chassis from three manufacturers – Radical, Elan VanDieman and West Race Cars. 'The reason for limiting the chassis types initially is to keep costs under control,' explained series manager Jon Baytos. 'The three manufacturers are locked in for five years, and any changes to cars must be approved by us and come from the works only. Individual teams cannot modify their cars beyond factory spec.'

Two classes of prototype will be able to race, Lites One and Lites Two, with Elan VanDieman supplying a re-worked version of its Formula X chassis for Lites One. The DP02 now features a carbon fibre tub and is powered by a sealed 2.3-litre, four-cylinder Mazda MPZ engine. Up against the re-worked VanDieman


IMSA



West Race Cars, Radical and Elan VanDieman will provide Lites chassis
Right: V15N9 suggests LMP3

will be Radical's proven 1500cc SR3.

In Lites Two West Race Cars, who already announced a four-car works effort, will field its WR1000 chassis, which originated in SCCA C and D sport racing against offerings from Radical and Elan VanDieman. 'This series will work well as it offers club racers a step up to the ALMS. You can take your C-sports racer and race in IMSA Lites and the other way round,' enthused Baytos.

Baytos also hinted that once the series had settled down and established itself, more chassis may be allowed in. Certainly companies like Stohr, ADR, Chiron, Ligier, Lola and Lynx would welcome a new market.

Of course, the announcement of a 'baby prototype' series supporting the ALMS raises the question of whether a similar series will be announced in Europe. Radical's Mick Hyde believes the new Radical World Series fits the bill: 'whilst it is single marque, it's multi chassis and multi class. There will be five classes to cater from the smaller Prosports up to the big SR8s and an invitation class for modified Radicals.' Radical will dip its toe in the LMS support package water at the Donington Park 1000kms meeting in August.

However, there are those that see the French CN category as the foundation of an LMS Lights series, with multi chassis and multi-marque competition.

IMSA Lites calendar 2006

13 May	Road Atlanta*
21 May	Mid Ohio
1 Jul	Lime Rock
20 Aug	Elkhart Lake
30 Sept	Road Atlanta

*All but the first round are also ALMS rounds

Don't Panic!


Panic

Panic Motorsport's new Howard Drake-designed Sports 2000 chassis was nearing completion as *Racecar* closed for press. The English constructor is hoping that the car will be 'the cheapest prototype on the market.'

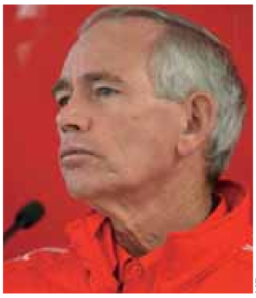
Engineers exchange knowledge in Oxford

Oxford Brookes is leading a group of British universities in a scheme called the Motorsport Knowledge Exchange, its aim being to see 'the UK motorsport industry better served by academia.' Brunel University, University of Hertfordshire, the Open University, Brooklands College, Cranfield University, National College for Motorsport and Oxford and Cherwell Valley College form the MKE consortium, along with Brookes.

Short courses will be run for all sectors of the industry, providing training and skills development opportunities. Work-based learning and online courses are also being investigated so small motorsport businesses can benefit without losing too much 'shop' time.

When the MKE comes on stream it will utilise the new Motorsport and High Performance Engineering Centre at Oxford Brookes' Wheatley campus. This 4500sq.m building is being built with a £1.3 million grant from SEEDA (a regional government agency), along with a further £1.6 million worth of support from local motorsport firms including Prodrive, Xtrac and Menard, as well as F1 teams Renault and Williams. MIRA will also supply and install a wind tunnel in the facility that will house a number of laboratories including ones for thermodynamics, engine dynamics and chassis dynamics.

Future courses being investigated by the MKE include business for motorsport and effective workplace communication.


LAT
Rory Byrne


LAT
Patrick Faure


LAT
Max Mosley


LAT
Slim Borgudd

● Red Bull Racing continues its enthusiastic employment drive. McLaren chief aerodynamicist, **Peter Prodromou**, will join the energy drink-fuelled team in the same role. This follows in the wake of **Adrian Newey's** shock departure from the Woking team to join Red Bull.

● Former Honda Racing F1 chief aerodynamicist, **Willem Toet**, has signed for rival team BMW Sauber in the same role.

● **Dickie Stamford**, long-time Williams F1 team manager, has taken a step back for this season, allowing test team manager, **Tim Newton**, to move up to the race team.

● **Rory Byrne** is set to stay with Scuderia Ferrari as design and development consultant. He had previously been thought to have been planning on full retirement. **Aldo Costa** will take over responsibility for the design and development department.

● Ferrari has signed former McLaren man **Nicholas Tombazis** to fill the role of chief designer.

● Honda engine specialists, **Tenji Sakai** and **Akihiko Koiki**, along with chassis designer **Kazuhiko Shimada**, have joined the new Super Aguri F1 team, which had its entry into the world championship accepted in January.

● **Jacky Eeckelaert**, the former Sauber technical director is now with the Honda Racing F1 team.

● **Patrick Faure**, current chairman of Renault Sport, will step down this summer.

● **Max Mosley** has been acknowledged by being awarded the prestigious French award, 'the Chevalier dans l'Ordre de la Legion d'Honneur' for his contribution to motorsport and road safety.

● **Jackie Stewart** has announced that he will not serve another term as president of the British Racing Drivers' Club.

● New GP2 outfit, FMS, has signed former F1 engineers **Humphrey Corbett** and **Vincenzo Castorino** as technical director and data engineer respectively.

● **Marcus Haselgrove** has been named technical director and team manager of the BK Motorsports – Mazda LMP team. Hasgrove had previously filled engineering roles at Le Mans-winning team Champion Audi.

● **Slim Borgudd**, the former racing driver and pop star, has joined Radical to look after its global distribution.

● Former Prodrive employee **David Ewles** will head up **Tom Walkinshaw's** latest motorsport project, which involves Mitsubishi rally cars.

● **Jaques Regis**, the president of the World Rally Championship Commission, has stepped down from his position after coming to a mutual agreement with the FIA.

● **Colin Malkin**, a significant player in the Mitsubishi WRC campaign until he retired in the 1990s has died aged 63.

● **Nick Mead**, the sales director of Comma Oil and Chemicals, died suddenly at the Autosport International Show in January.

● There have been a number of staff changes within the Sports Car Club of America (SCCA). Most significantly **Jim Julow**, the former vice president of motorsports at DaimlerChrysler, has been announced as the body's new president.

● Meanwhile, three new members were appointed to the SCCA board of directors – **RJ Gordy**, **KP Jones** and **Larry Dent**.

Further to that, **Bob Introne** will replace **Gary Pitts** as chairman of the club. Pitts had served the maximum two terms allowed.

● SCCA vice president of marketing, **Garret Mudd**, has departed the organisation to join Champ Car, meaning a number of new positions have been created and filled – **Eric Prill** is now director of marketing communications, **Lynda Randall** is director of operations and **Harry Turner**, senior technical and race operations director.

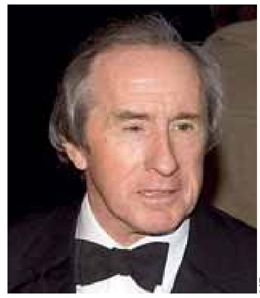
● The British governing body, the MSA, has also made a number of personnel changes over the winter – **Cheryl Lynch** has been promoted from her role as licensing manager and is now race, kart and speed executive. **Steve Redhead** will fill her old position.

● **Gary Putnam** has been named competition director for the Cal Wells-owned PPI Motorsports, following former positions as crew chief for Petty Enterprises, MBV Motorsports and Nemco Motorsports.

● **Craig Dawson** has been awarded the 750 Motor Club's prestigious Stock Memorial Trophy for his work on the Oxford Brookes Formula Student car, the Isis FS04. Previous winners include Colin Chapman.

● The boss of V8 Supercar team WPS Racing, **Craig Gore**, has taken a step back from day-to-day operations of the team after a merger with Larkham Motorsport. **Mark Larkham** has now become the managing director of the new operation.

● Champ Car World Series Race director **Tony Cotman** has been forced to stand down after disagreements with series co-owner Gerald Forsythe.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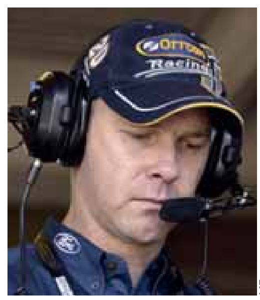
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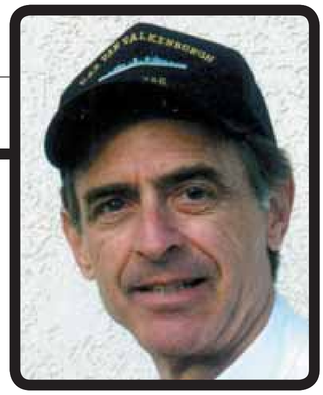
By Paul Van Valkenburgh



New year's revolutions

For any innovator there is a need to visualise ideas. Could rapid prototyping provide the key?

As I sit here writing this on New Year's Day, I'm expecting some big changes in the coming year – in my life, at least, if not in racing, where I expect more regression. And I have some more oddball stuff, which may be more interesting than racecar engineering is today.

At PRI, as I went searching, like Diogenes, for an honest innovation, I was reminded that racing technology has become very 'mature', meaning components are now sold as commodities, on price and quality, and less on feature differentiation, with few to no revolutionary products. It's just evolution.

The only exciting thing to me was a new twist on a 20-year old fabrication technology, called rapid prototyping, which we did a feature on in November 1999. But I'm amazed how little most people still know about it – even engineers. As a one-sentence review, it's a way of producing parts from computer design files, by generating solid objects one miniscule plane at a time. It's sort of the opposite of CAM, which *removes* material one pass at a time. 3DSystems Corp. originated the idea in 1986, with its patented Stereolithography process, which creates laser-solidified layers on the surface of a vat of liquid resin, as a support table lowers the object below the surface in small increments (less than 0.1mm). They distinguish Stereo Lithography Apparatus (SLA) that solidifies a resin, from Selective Laser Sintering (SLS) that sinters powders, using different power lasers. Many variations have been developed since then, with different resins, such as epoxy, nylon, polycarbonate and polystyrene, different powders in plastics and metallics, and laminated paper layers. And even, at a much larger scale, concrete wall building. And →

"COMPLICATED MECHANISMS WITH MOVING PARTS CAN BE GENERATED ALREADY ASSEMBLED" more durable new materials for production parts are coming out all the time.

As I sprinted past over 1000 vendors at PRI, the only one that really caught my attention was 3DSystems, a company displaying transparent and flexible plastic components that it can produce now. This might not mean much to the end user, because it is used more for prototype fabrication than production, and because the finished parts are of limited strength and durability, and because the equipment is expensive (although it is available for individuals at small service agencies). As the previous story explained, the most common racing application has been wind tunnel

> **“WHAT OTHER APPLICATIONS IN RACING CAN YOU THINK OF FOR THIS AMAZING TECHNOLOGY?”**

models. However, the new flexible and transparent materials should stimulate new applications. The first one that came to my mind was transparent prototype cylinder heads, for improved port flow visualisation on a flow bench – much like a real-world verification of the vivid computer visualisations of CFD. And likewise, the transparency might improve internal flow visualisation in the engine rooms of complete sedan models in the wind tunnel.

Maybe the rubber-like prototypes are less important to racing, compared to production vehicle applications, but remember that these generated objects can also be used as moulds or dissolvable cores for casting complex end-use items. However, the designer has to keep in mind that a flexible object may need temporary reinforcements to maintain its shape during generation.

The really trick, 'almost like magic' aspect is that complicated mechanisms with moving parts, like latches, hinges and ball bearings, or maybe even a complete plastic engine, can be generated already assembled. You just have to design in the necessary clearances between the parts, and clean out the excess material. What other applications in racing can you think of for this amazing technology?

Considering trade-offs between different techniques and materials, depending on the shape and end use, I ought to mention two other rapid prototyping technologies: laminated paper and 3D printing. The former uses a laser to cut paper sheet as it is laid down, and the crosshatched waste is chipped out at the end. The latter solidifies one layer at a time in a bin of powder by using an inkjet printer head and is the only technique that generates multi-coloured prototypes. Both may be faster and less expensive than laser sintering and solidified resin, but are generally less durable and have a less finished surface.

My enthusiasm was not just because of new racing applications, but medical as well. I went to 3DSystems headquarters, near Los Angeles, and saw rooms full of demo examples, such as the merged skulls of conjoined (Siamese) twins, and their network of blood vessels (in a contrasting colour resin) that also had to be separated for surgeons to study. My own interest, the cerebral cortex, is not just in generating it as a solid object, but showing activated areas from fMRI, in contrast (via multi-pass darkened resin), for the first time in medical applications. I've already received the first model.

When I showed my kids the model of my cortex, they started 'brain storming' about future applications, like form fitting realistic flexible masks (á la *Mission Impossible*). Or like emailing solid objects around the world, as fast as they can be printed out. Wider public use would drive the market for cheaper and faster 3D printers – an inevitability, following Moore's law for electronic devices. Especially if you consider the theoretical possibility of these machines eventually being used to reproduce themselves.

Now let's see, what else will be revolving in the coming year?

I just started on a revolutionary new vehicle prototype – a unicycle with a training wheel – so it is actually a two-wheeled unicycle. A contradiction? No, because both wheels are parallel, and they function as one wide wheel on the same axle, to prevent it from tipping laterally. I got the idea from my Segway column two months ago. In fact, maybe I should call it a 'pedal-powered Segway.' See http://members.aol.com/pvanvalken/unicycle.jpg

As I get older every year, the less interested I am in driving high-performance cars on the street. So I sold my 1963 Stingray coupé, after 38 years as my daily driver. I auctioned it on ebay, with some reservations and a reserve, but I preceded that with magazine classifieds announcing the auction, and used my own email network to raise awareness, which generated over 4000 viewings in 10 days. You ought to try that. So this year maybe I can get back into my hybrid EV project, using racecar materials and fabrication technology to keep total weight below 1000lbs (half in batteries). See http://members.aol.com/pvanvalken/SmallHybrid.jpg

Oh, incidentally, I also just applied for a PhD research fellowship in cognitive neuroscience in the coming year. It's a long shot, but if I make it, there won't be much time for me to be doing this column any more. I got the inspiration at a medical conference after a presentation of my brainmapping data. While sitting around at dinner listening to PhDs talking about cars. I said, 'That's ironic, you know what we auto engineers talk about? Neuroscience.' Well, at least one, my friend Casey Annis, a former neuro researcher who is now the publisher of *Vintage Racecar Magazine*. Which makes me think – hey, maybe rapid prototyping would be good for reproducing unobtainable vintage racecar parts. So there's one more revolution example – thinking around in a full circle. RE

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By Charles Armstrong-Wilson

The numbers game

Has data acquisition become so sophisticated that engineers are now missing simple patterns that could be identified by far less complex means?

Race engineers call it the lie detector, but these days data acquisition can do so much more than test the honesty of the driver. Virtually everything on a racecar can have a sensor stuck on it and be made to generate a stream of numbers. A grand prix car will have as many as 200 separate parameters monitored. The speed and capacity of modern data loggers is awesome and they can generate enough information to make the Encyclopaedia Britannica look like a pamphlet. But what's it all for?

Ask a data engineer and they will always give you a good reason why each and every parameter is recorded. At least, a slightly more convincing reason than 'because we can'. But do they really make good use of all that information?

Every team, whether it competes in Formula Ford, Formula 1 or anything in between is time limited. There just are never enough hours in the day at the track, back at base or during a race weekend and the last thing anyone has time to do is comb through gigabytes of unnecessary data. Yes, the essential traces will get a good going over; anything that might show the driver how to go quicker over a lap. Also anything that might help the basics of set-up. But often the things engineers could do with knowing are buried in several parallel streams of data and are not easily teased out.

I had this rammed home at the Performance Racing Industry Show in Orlando last year when among the stands I stumbled on CatchIt. This company has a remarkable take on data acquisition that many engineers may deride but makes a very important point. For as little as $399 (£225), the company will sell you a lipstick camera, a mounting clamp, a cable and a padded bag. Simply connect your domestic digital camera to the cable, pack it into the bag strapped to the rollcage and mount the camera looking at the thing you want to monitor.

On its stand, the company was showing a video of a

CatchIt Cam

A simple camera trained on an appropriate part of a racecar under load can offer a valuable insight into engineering issues that may not be so apparent from multiple streams of grey data

dirt oval racer's rear suspension while the car was in action that made very revealing viewing. It provided no measurable output or data that could be displayed as graphic traces, but the picture of exactly how the rear suspension was behaving was clear and easily accessed. Viewers could easily recognise the rear wheel was spending a significant amount of time off the ground. However the spring was being compressed at the same time due to the inertia of the high unsprung weight lifting the wheel clear of the ground as it skipped over humps in the track. Load sensors on the suspension normally used for logging tyre loadings

> **"YOU CAN SEE THE NUMBERS, BUT CAN YOU GET THE WHOLE PICTURE?"**

would present a completely erroneous picture.

To try and create a picture as complete as this using conventional data acquisition would take an impractical number of sensors. Then, with the outputs saved, interrogating that data to really understand what was going on would tax the best race engineers. This was when it struck me that the objective is no longer how to acquire data, we have that pretty →

Pi Research

PiVids, from UK firm Pi Research, has been around for some time and now, with a microphone and audio stream, offers full video capability linked directly to a data logger

well sussed. The real challenge for the future is finding ways of digesting that information and learning something from it.

At this point, seasoned race and data engineers are probably throwing the magazine down in disgust. I know you all pride yourselves on your ability to read multiple traces in parallel to understand what is going on. Also you have analysis tools that will give statistical analysis of revs, throttle position, temperatures and the like. But do they really give you the whole picture?

Going back to the digital camera in a bag, if an experienced race engineer was given the digital signal from the camera on its own, they would have to be pretty clever to deduce the behaviour of the suspension from it. Unless the picture is reconstructed, the task of interpreting the signal usefully is impossible. Likewise, to somebody unfamiliar with studying data, the many traces from a sophisticated data acquisition system can be equally impenetrable. Even for the experienced race engineer, is the stream from the car as penetrable as it could be or may it be concealing secrets that go unnoticed? 'Surely not,' I hear our expert cry, 'if it's in the numbers then I can see it'. Are you sure? Yes, you can see the numbers, but can you get the whole picture?

I accept the video record of the car's suspension could be argued to be of little or no use in a modern formula car where suspension travel and deflections are too small to be seen. Yet this market had access to video technology long before our friends at CatchIt came up with the idea. Pi Research unveiled its Pi Vids function for its data loggers a few years ago. This links an on-car camera to the logger to record pictures. Originally it was a picture-only system, until the company incorporated a microphone and an audio stream in the first iteration for no reason more compelling than it could be done.

The results were a revelation to everyone concerned. I remember them crowding round the screen with enthusiasm replaying the driver's missed gearchange over and over again. This was more than a cruel revenge on the driver, it was like a veil being lifted as the engineers came one step closer to experiencing the car first hand. It was now possible to monitor progress with more than one sense. The sound pattern that betrays wheel spin or clutch slip could be detected first hand rather that trying to diagnose it from a wavy line while simultaneously trying to relate it to suspension travel, pedal position or steering input.

When sensing the world, we seek out patterns we recognise and use them to revise our virtual impression of reality. Absolute figures don't necessarily allow us to see those patterns and if we don't see them we don't register their existence. From what I have seen in the world of racecars, developing methods of displaying data that show patterns in ways we can recognise is key to moving data acquisition forward. And this is as true of simulations as it is of real world recorded data. The biggest challenge will be how to do this.

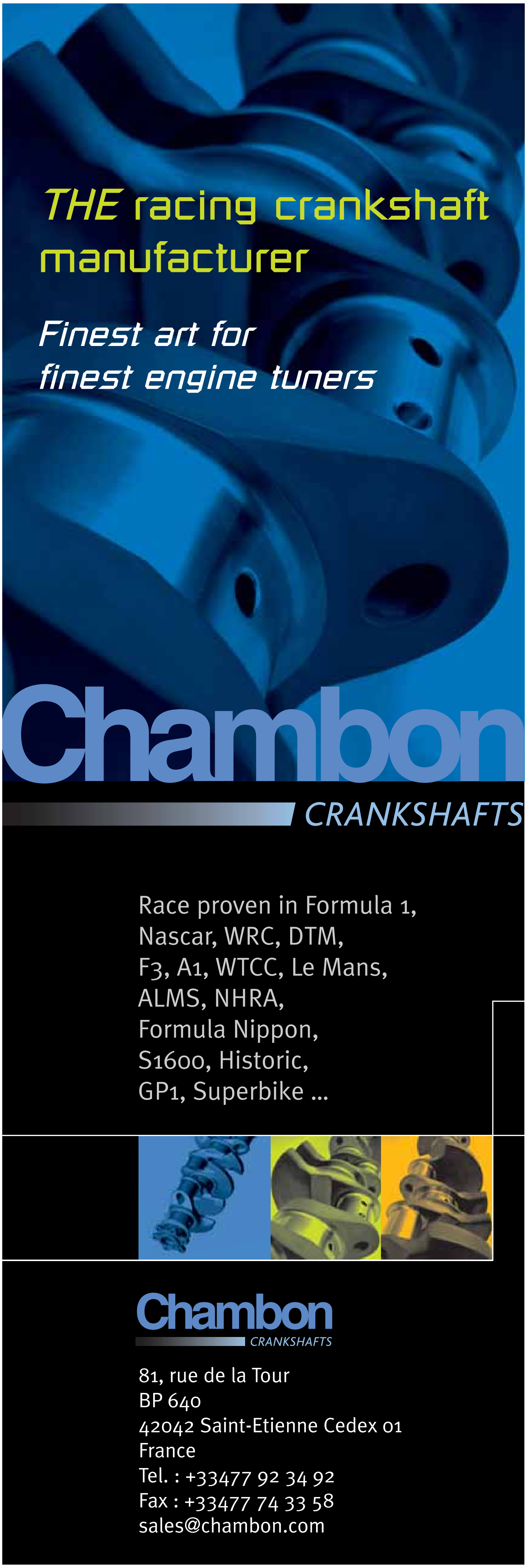
My first thought is that some audible version of the engine revs is essential. If a recorded soundtrack is not possible then a synthesised version is a must. There are no great challenges in this, all computers have MIDI sound, the frequency just needs to be pegged to engine revs. The important thing is it allows another sense to be employed. Also how about an electro-mechanical steering wheel to simulate steering forces and feel the loads at the contact patch as they change? Some of the kickback loads might give some engineers a shock, to the amusement of drivers.

'DISPLAYING DATA IN WAYS WE CAN RECOGNISE IS KEY TO MOVING DATA ACQUISITION FORWARD'

Next we could tap into some of the better video game technology to give a graphic rendition of the car in action. Perhaps a gain control could be used to amplify movements to make them visible.

Beyond that, some brighter engineers may find more abstract displays of data useful. These may have no visual similarity to a real car but could be a good way of interacting different data streams to coax out the patterns. It may take users a while to learn to recognise different phenomena but it could become a powerful tool with practice.

Who knows what we may find hiding in all those grey numbers.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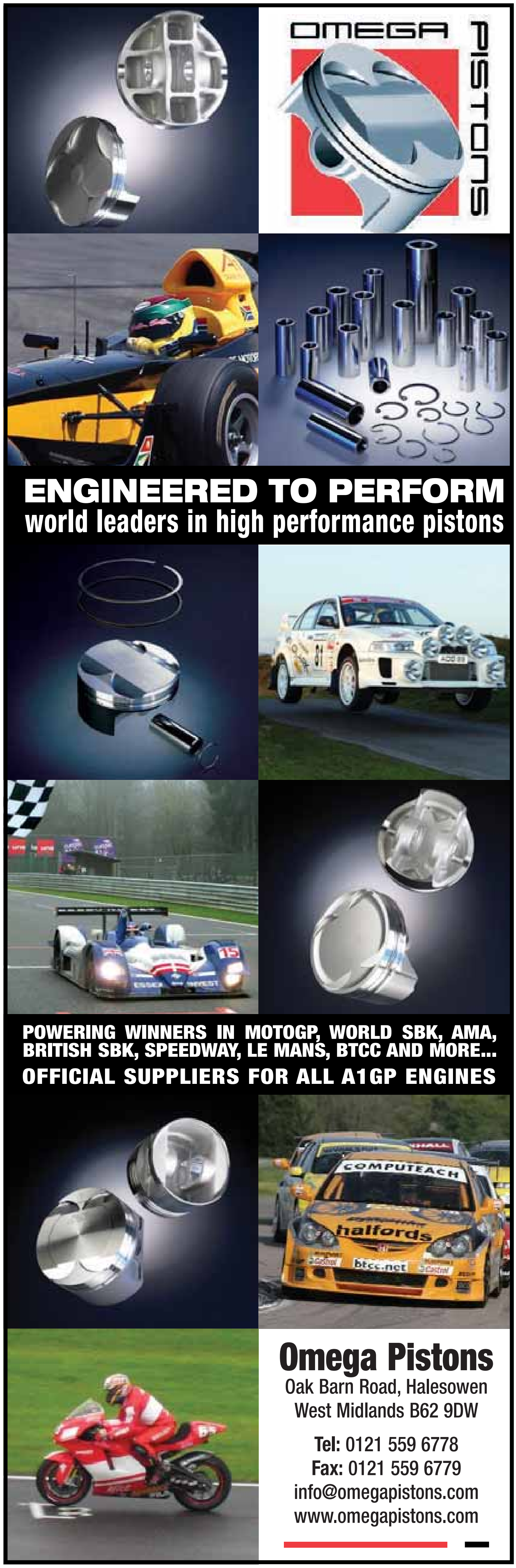
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Formula bland

The blandness of the new tracks, and the modified 'old' tracks, are mere symptoms of a larger ailment. Nearly all of motorsports, especially at the professional level, is becoming homogeneous.

Time was that motor racing had true character and spirit across the board. I can remember turning the calendar page with anticipation from the past racing season to the next, to see what innovations and changes happened over the dark, cold winter. Who was driving for whom? In what livery? What was the technical innovation for that season? Six-wheeled Tyrrells, ground-effects Lotuses (Loti?), or a slimline early-'80's Brabham? Turbo or atmo engines? Six, eight, or 12 cylinders? In America, who had the winning chassis design? Jim Hall or Penske? Or a factory car from March or Lola? Drivers were true ironmen, racing in a number of vehicle types – open wheel, sports cars, tin tops and stockers. For example, possibly the greatest period in American racing was the few short weeks in 1967 covering Dan Gurney's F1 victory at Spa in his homemade Eagle chassis, AJ's third Indy win in his Coyote, and the two of them won the 24 Hours in a Ford (that was commissioned to beat Ferrari) at LeMans. When have we had a moment like that since?

Even the names from that era instantly recall memories of classic times. A generation later, in the US, it's AJ, Mario, Donahue, and the Unsers. In F1, it's Mario (again), Stewart, Emmo and Lauda and later Prost, Senna, Mansell and Piquet. Except for Mikey, what racer has that kind of power in today's F1? And forget about American open-wheel racing, it is merely a 'who's not' of names. Tracks also had their own character, with challenging dips, twists, flats and straights that tested every nerve and muscle of driver and car alike. The old European tracks are virtually all classics, as are some in the US, like Road America, Road Atlanta and Mid-Ohio, to name only a few. While some of the rough edges had to be smoothed over in the name of safety, that has been taken much too far, as Mike Breslin points out in his column (V15N11). So, it's more than the tracks, it's a top-to-bottom flushing from the sport of what made the sport great, at least in the opinion of this race fan. Today we have sterile drivers in sterile cars on sterile tracks, all for the sake of fleeting spectacle, cult of personality, and the bottom line. What's my answer? For the time being, I will look for the excitement in my local sports car club chapter, and hope against hope that one day the sport will come to its senses.

Richard G Docken Jr
Beavercreek, Ohio, USA

LAT

UCLAN's 'sidewinder' entry is still controversial

Best of British

Regarding Ian Allen's letter in V15N11. The Formula Student event takes place in the UK, and is made up primarily of UK teams, therefore shouldn't the rules conform to UK motorsport rules, and not to the rules of American cone chargers? Wouldn't it encourage more universities to take part if they thought it more financially responsible? As it stands now, universities spend thousands of pounds so the car can compete in two events – class 1 and class 1-200 the following year, and then they can spend more so they can fly the team and the car to America to worry road furniture if they wish to race the car again. Surely there would be greater interest if the thousands spent could be used more efficiently, if after the formula student event the car could be used in local or national events or even sold on to be used in the UK.

As a former UCLAN student I feel I also have to congratulate the guys who built the 2005 car, as it showed more freedom of thought than most of the other entries. All of the other entries seem to stick to the same format: legs-wheels-drivers' body-engine-wheels. But not UCLAN, they endeavour to show that things can be done differently. You may think it's a tank but it won't snap your legs when you hit a badger on a hillclimb. The other cars won't even get a shot at the badger because they will be turned away from any British event. I think it is inappropriate to have American rules for a UK event because they are so restrictive to future events and therefore are not an attractive proposition to economically-aware universities.

Will Parry
by email

Future technology

I appreciate your commentary in the V15N12 Write Line column. I too feel that motorsports has outlived its usefulness as an automotive technology tool and today serves principally as a medium for entertainment and, more so today, as a medium for very expensive entertainment. That is a marked difference from a generation ago. Up through the 1980s, motorsports served to move the auto industry forward – in terms of safety (seat belts and crash protection), performance development (wide tyres, increased horsepower, and turbocharging) and aerodynamics (streamlining, downforce) and even alternative fuels (methanol for Indy cars). What major innovations can be touted since then, and for what cost were they obtained? Racing needs to become the crucible for relevant automotive technology if it is to be saved from the public trash can. As the price of gas shot quickly through $3.00 per gallon after Hurricane Katrina, the talk in the States turned to alternative fuel technology. That means that there is some social support that could be tapped for racing, if racing were to tout a viable alternative fuel. An alternative fuel with green potential would be even better, especially in socially conscious US and Western Europe!

The solution? Sportscar racing, with its class structure, is a good place to start. Establish a bio-green prototype class. Start with the high-profile race – Le Mans – and build it into the respective European and American series in the following years. Use this period of development to wean the sport off fossil fuels. Another solution is to take either US open-wheel racing series (they already mandate methanol and mandate conversion to a spec bio-green fuel). There is bound to be noise made over the burden to convert, but won't that issue exist in 'real life?' I'm sure there is mileage to be made in that category, too. Forget costs, because costs are all relative. After all, how much money have organisers, manufacturers, and sponsors thrown down the toilet in the last five years alone? And for what? In this day and age, bio-green fuels for racing should be seen by all industry and public alike – as an investment in a sound motoring future. How long before racing is legislated out, like cigarettes? As I write this, the Belgian government is having difficulty recruiting a partner to promote the most classic of all European F1 races, and the town of Monza; *Monza!* The so-called cauldron of speed has passed an anti-noise ordinance. I think the attack has begun. Maybe bio-green fuels are the life-sustaining force racing needs, and soon!

Richard G Docken Jr
Beavercreek
Ohio, USA

Line astern in WRC?

I write regarding the rally car safety feature in V16N2. As most World Rally Cars are based on 4-5 seat passenger saloons, why is it that the occupants need to sit next to each other? Communication between them is normally made by means or intercom, due to the use of helmets and in-car noise etc.

So if a car is being constructed from a front-wheel-drive chassis the transmission tunnel will need to be engineered into the floorpan and I can see no reason why this cannot be offset from centre. If it was it would allow the crew to sit in tandem on the centre line thus gaining at least 12-15in of deformable structure. Weight distribution on the centre line may well have handling benefits also. I understand this may be a simplistic view but are not the simplest solutions normally the best, not to mention the cheapest?

Ian Pinney
by email

Deputy editor (and rally co-driver) Collins replies: Ian, whilst from a pure motorsport engineering point of view this may seem a logical solution, in practice if the crew are sat line astern like the pilot and navigator of a fighter aircraft the co-drivers' forward vision would be severely obscured. Rally navigators need a similar frontal view to the driver to judge exactly when the pace notes need to be called, which is often not as easy as it may appear.

However, in the 1980s a crew did turn up for a rally with the co-driver's seat mounted in the rear passenger seat position of the car, but they were not allowed to run. It would have been interesting to see the result had they been able to take part.

LAT

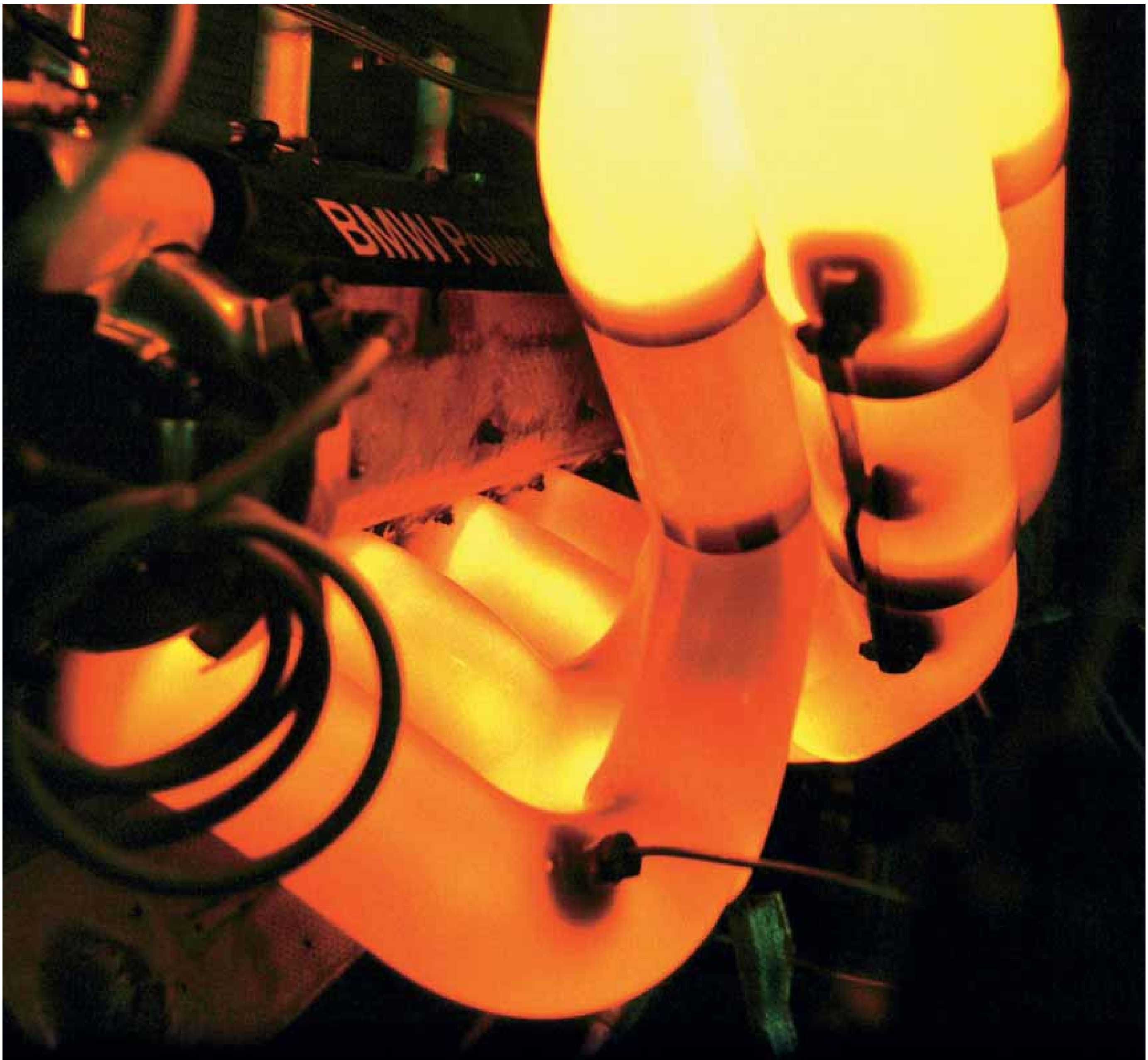
Zipp's latest bicycle wheel has a concave bulge to re-capture and control airflow coming off tyres of various widths. Dimple size and density varies by location around the disc relative to air velocity

Cute dimples

I was terribly excited to see the dimpled wing in your coverage of PRI (V16N2). Five years ago our company developed a dimpled bicycle disc wheel and have since designed numerous other bicycle wheel and rim shapes employing dimpled carbon fibre composite to maximise aero efficiency. We have learned some pretty fascinating things about surface roughness as it relates to the very low-speed flow (30mph/50kph) seen in bicycle racing, and had even discussed using this on underfloors or wings with some of our neighbours (we're on Main Street in Speedway, IN) but with little interest from anybody in motorsport. I'm not sure what they have seen with their wings but at our very low Reynold's number flows we see an improvement in drag of roughly 1-2 per cent at a fixed yaw angle, as well as an increase in stall angle of as much as two degrees. This translates to 4-6watts of efficiency improvement in the most common yaw angles, which is a major gain in a sport where peak sustainable power output is in the range of 400watts.

I would love to see Simon McBeath look at this in a future issue. I imagine if there was even half of the benefit that we have seen at our flow regimes, this could be valuable for motorsport.

Josh Poertner
Zipp Speed
Indianapolis, USA



Planet of the eights

The FIA has rolled the dice again for this season, so what are the challenges facing Formula 1 teams and how have they tackled them?

Words	Charles Armstrong-Wilson
Photos	BMW; Ian Harris, LAT

By introducing 2.4-litre V8s in an attempt to reduce performance, the FIA has thrown another wild card into the teams' design briefs and once again they are faced with trying to re-establish a base line to work from. The ones that can do it most quickly will be the ones who get the results. Inevitably, they will be the best-funded teams, but money does not guarantee success, and making the right call is just as important. With the new cars appearing, the challenges teams have had to tackle are becoming apparent and their solutions will prove to be crucial in the battle for the 2006 Formula 1 World Championship.

Drivetrain

The biggest challenge sent to tax the talents of Formula 1 teams this season is undoubtedly changes in the engine rules. This not only impacts on the engine departments but also affects almost every other part of the car to a greater or lesser degree.

As widely reported, the new regulations have in effect called for two cylinders to be lopped off last season's V10s, creating 2.4-litre V8s. However, new regs are much more complex and far reaching than this. The V angle is now mandated at 90 degrees, perfect for a V8, unlike a V10 that has an ideal V angle of 72 degrees. As luck would have it though, for reasons of packaging and a lower c of g, almost all the F1 engines were already 90 degrees.

> **"INDUCTION-RESTRICTED, REV-LIMITED V10S WOULD HAVE BEEN A MUCH MORE AFFORDABLE OPTION"**

The exception was Renault that, after experimenting with an ultra-wide V10, has been running an optimum 72-degree V10 for the last two seasons. It would be easy to assume the Viry Chantillion team has been unexpectedly presented with a much bigger task than its rivals. But in reality, all the teams have found the task of building a fully optimised V8 an extremely expensive exercise, and any intentions by the FIA to create a cost-effective transition to a less-powerful engine seems to have been lost in the details. On reflection, many of the teams that put their signatures to the new engine rules feel, with hindsight, that induction-restricted, rev-limited V10s would have been a much more affordable option.

Capacity and configuration aside, there was much more in the new engine regs to challenge the drivetrain teams. The engines now have a defined minimum weight of 95kg and, to make matters more complicated, the centre of gravity has to be at least 165mm above the bottom of the sump – so expect to see some creative use of cooling fins under the engines. Also the c of g has to lie within 50mm of the centre of the engine, both longitudinally and laterally. The bore spacings are also defined at no less than 106.5mm apart and the maximum cylinder bore allowed is 98mm. The crank axis is also dictated as no less than 58mm above the reference plane.

Other engine rule changes include the prohibition of metal matrix composites (MMCs), commonly used in pistons and conrods. This has inevitably led to heavier reciprocating masses stifling attempts to replace lost swept volume with more revolutions per minute.

Toyota first ran its V8 engine on a dyno in March 2005 before all these regulations were finalised. While the team still felt it was a productive, if expensive, exercise it revealed that without the restrictions, its engine would have been 10kg lighter.

After the reduction in capacity, the rule that has perhaps hit the pursuit of power hardest is the ban on variable length induction systems. Without these, the ability to develop a wide spread of torque is seriously hampered, and is mentioned by engineers as one of the more painful losses inflicted →

Renault switched to a 90-degree V8 (above) from a 72-degree V10 (below)

BMW's new P86 V8 engine will power its Sauber-based cars for this season on them by the 2006 regulation changes. The only mitigating effect of this change is that with lower power, the drivers will be on full throttle more of the time and will be spending less time in higher gears in an attempt to tame the power and find traction. What it also means is the teams are playing with different induction designs. Tuned for different circuits, each one has to optimised, no doubt bringing with it a sizeable slice of research and development expenditure.

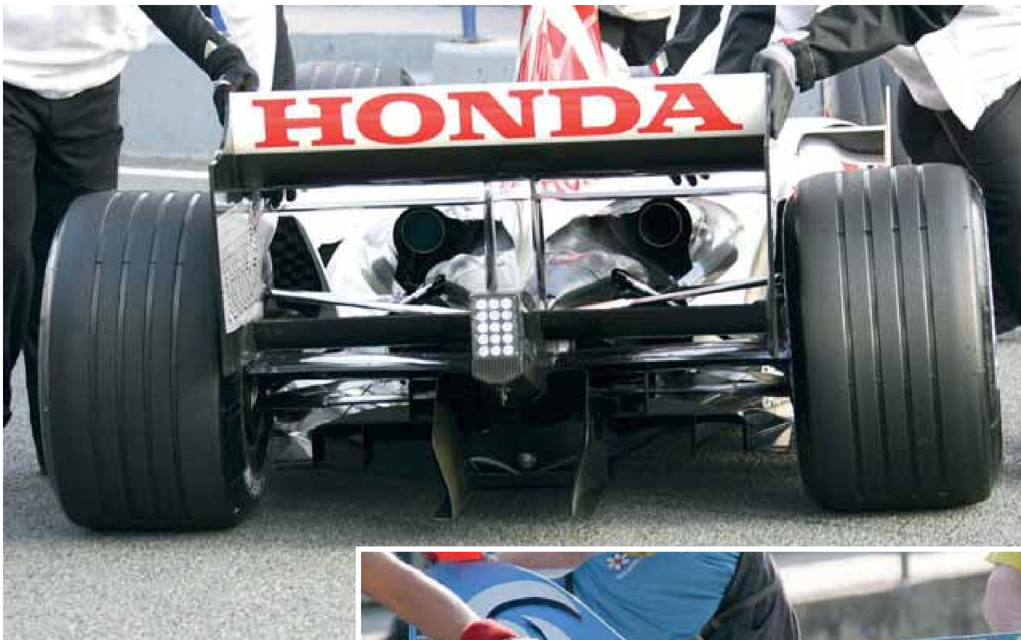
When the move to the new rules was announced, some of the industry's past masters were predicting an instant jump in revs. They reasoned that, with a shorter crank and camshafts, harmonic limitations would be raised and revs would soar. One old hand even predicted 23,000rpm straight away. In reality, there seems to be no evidence of any such hike in engine speeds. Cosworth was showing an engine in a dyno cell running at 20,001rpm in a bit of showmanship on its website and, in the event, that seems to be typical of all the engines at this point in their development. This is about where the V10s were expected to be by now and, even allowing for the effects of banning MMCs, it seems to be no more than the product of linear development.

"INTERNAL VIBRATIONS THAT HAVE TO BE RECONCILED"

A fundamental difference between the V8 and the outgoing V10 is the vibration signature. A hallmark of the 90-degree V8 engine, with a flat-plane crank all the teams will inevitably all be using, is a very distinctive vibration pattern. It acts transversely at twice the frequency of the engine revs. This is different from the V10 vibration signature that rotates about the crank axis at the frequency of the engine revs. While most of the teams have played down the severity of the vibration, they have all designed the rest of the car with it in mind. Efforts have been made to beef up or isolate ancillaries against its effect, and components like ECUs are being mounted further away from the engine.

These, however, are the net vibrations experienced outside the engine. The designers talk of internal vibrations that have to be reconciled. These are much greater but, although they cancel each other out to some degree, they are still experienced directly by the internal components of the engine.

With 20 per cent less capacity, the amount of fuel burned each revolution is reduced by the same proportion. So one would expect an initial 20 per cent reduction in fuel consumption and heat rejection, the latter to be capitalised on in the form of smaller radiators and lower drag. However, two factors upset this rule of thumb – to a small degree the increase in revs and, more significantly, the duty cycle of the lower-powered engine. By revving harder for longer, as the driver is able to use more full throttle, the gains in lower cooling requirement and fuel consumption are significantly less. Typically, fuel consumption is emerging at around 15 per cent less than the V10s and we can assume heat rejection is reduced by the same amount.



Central rear wing supports are catching on this year as a way of taking loads out of the end plates and freeing up their design. Toyota was one of the pioneers last year with BAR [left] who, as Honda, is retaining the design on its cars

World Champion Renault adopted the central rear wing support before the end of last season and has continued with it for 2006

McLaren has employed some cunning structural engineering to get its 2006 spec nose (left) through the FIA crash test. Compare it to the 2005 spec nose (above)

Honda Racing F1 has opted to use a shallow cord front wing this year (left) after the BAR-Honda of 2005 (right) suffered from aerodynamic problems

Being smaller, the new engines have given teams more space to play with, easing packaging issues. However, everyone has chosen to keep number one cylinder in the same place and retain the same wheelbase. This allows them to run the body tighter around the transmission, clearing more space for improved aero. Carbon fibre is moving in as the material of choice for transmission casings, with the Honda 'box entering its second season and the Ferrari casing now almost entirely carbon. Both Honda and McLaren are believed to be running seamless-shift technology, while Williams has a working system ready to use as soon as its reliability has been proved. All the teams are now running seven ratios, the only exception last year being Renault. Bob Bell admits it was a bit marginal then so, with the reduced torque and power spread of the new engines, seven speeds were essential.

The rotary rear damper revolution that threatened to sweep the grid has stalled slightly. Midland F1 has adopted them on its M16 but Toyota has dropped them with concerns over the effectiveness of the ZF Sachs units.

Aerodynamics

Aerodynamically, the biggest influence on the cars for 2006 has, remarkably, been the engines. By cutting the power available, the FIA has forced designers to favour improved lift-to-drag ratios over increased downforce. Just how far the balance has shifted in favour of the former over the latter is impossible to pinpoint, but has been reached by all the teams through simulation. Using existing data from the tracks and predicted power delivery from the new engines, scenarios will have been run again and again to achieve an optimum achievable level of drag and downforce for each circuit visited during the season. Work then began in earnest to try and achieve those targets.

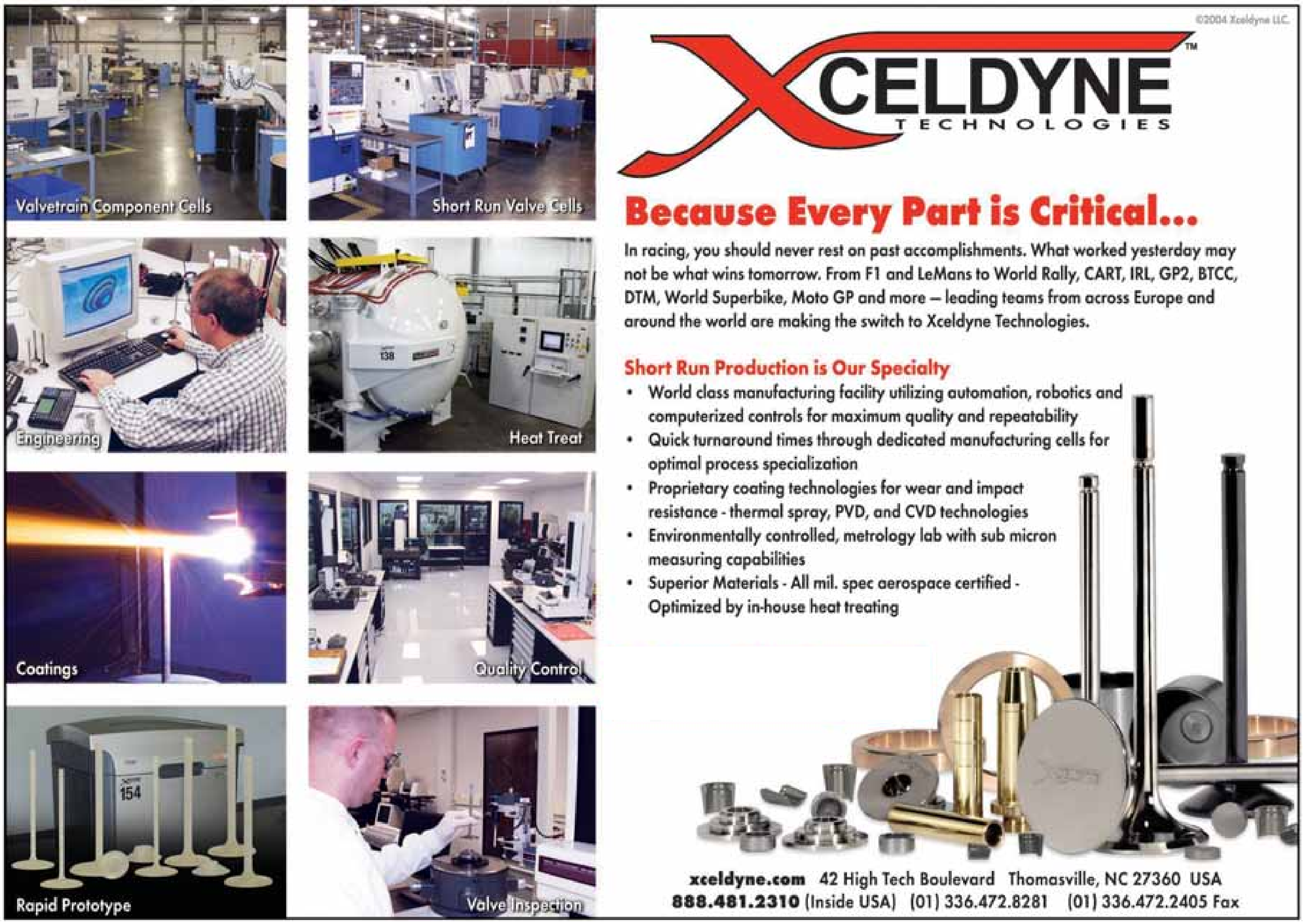
The teams have been handed one trump card in that the engines cannot physically pump as much air as the V10s so, with less combustion taking place, less heat is produced. With less cooling requirement, oil and water radiators have been made smaller. Otherwise, the odds are stacked against them and the teams talk optimistically of perhaps matching last year's level of downforce, rather than exceeding them by the usual annual increment.

Looking closely at the new crop of cars it becomes clear where these objectives are being sought. 'You are seeing far more three dimensionality in both the front and rear wings,' observes Angus Lock, chief engineer at MIRA's aerodynamics facility. 'More teams are following McLaren and Renault's lead from last year on the front wing, using the complete plan area available to you. Most teams were going for a more aggressive profile on the front wing which gives better peak downforce figures but the efficiency is not as good as you get with a longer chord profile.

> **"FUEL CONSUMPTION IS EMERGING AT AROUND 15 PER CENT LESS THAN THE V10S"**

'You can also see that a number of cars are still struggling to come to terms with last year's increase in height of the front wing. A few of the vehicles are copying Renault with its biplane front wing. Williams has got a variation on that. You are also seeing more people either going to a version of Renault's 'V'-keel, like Ferrari, or a zero keel arrangement at the front, like Toyota, McLaren, Williams and BMW, to allow more air underneath. The flow onto the front splitter is cleaned up. You haven't got the single or twin keel that used to exist.'

Renault's V-keel is an attempt to achieve the same aerodynamic →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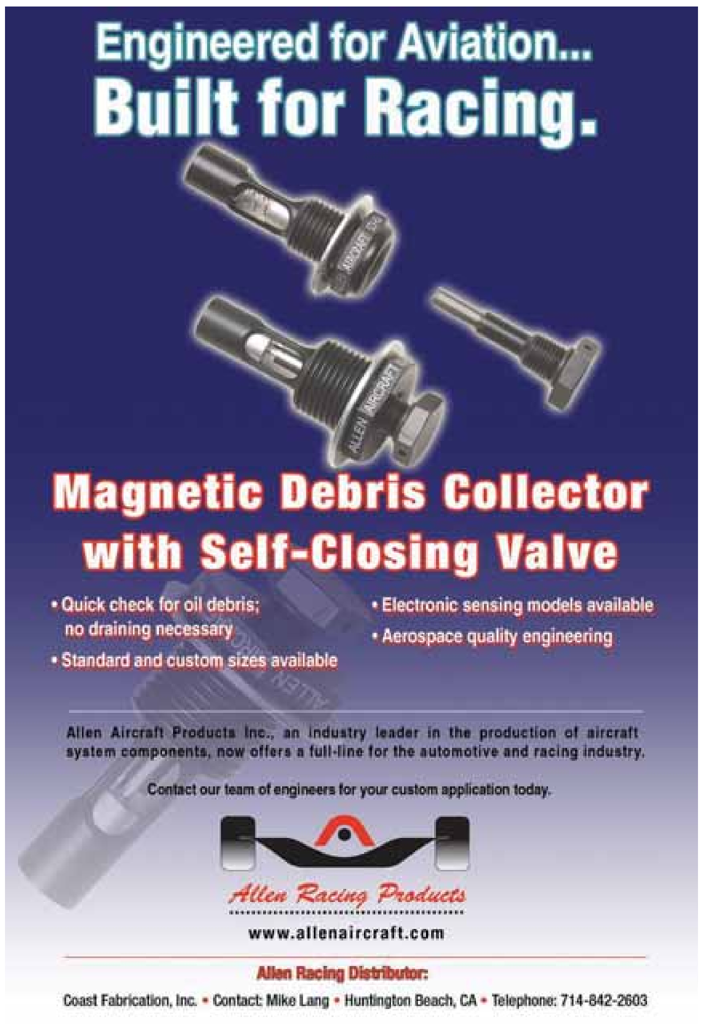
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Renault's side pods are roughly aerofoil shaped, with a complex array of winglets and chimneys. Smaller radiator inlet shape is similar to that used by McLaren

Williams' aerodynamic development is already proceeding at a rapid rate, as alterations to the radiator duct show – left, at the launch, and right, just days later

benefits as other systems, but without their structural or geometric disadvantages. Both twin and, to a lesser extent, single keel designs are structurally inefficient. The twin keel is a structural engineer's nightmare as the blade-type lower wishbone mounts have to resist bending in cornering and braking, and consequently either end up being too heavy or flex under load. The single keel is slightly better as under braking loads the forces from each side balance each other out, but it still lacks integrity in cornering when the forces from each side act in the same direction.

The Renault-style zero keel, on the other hand, feeds the suspension loads into the monocoque at much more structurally efficient locations. However, the suspension members can assume severe angles of droop in the static position that has an effect on suspension geometry. Over bumps the resulting lateral shift of the contact patch puts sudden lateral loads into the contact patch and under braking, the dive induces track variation that can cause instability. However, the size of these effects depends on the amount of front suspension movement allowed for in the car. The triangular structure of the V-keel offers better structural efficiency without the unwelcome geometric effects of the zero keel.

Despite the attempts to clean up the flow to the splitter, all the teams are running a lowered centre section on their front wings to make the most of the regulations. Introduced last year, they mandated the higher portion from a given distance either side of the centreline. Within those points, the element can be low enough to still generate useful levels of ground effect.

Lock is intrigued by this. 'If you look at the Renault and McLaren and the size of their noses, they've really trimmed them back to allow for the reduced ride height of the front wing centre section that also allows as much air through as possible, especially the McLaren. I struggle to see how they managed to get through the crash test. They've obviously got some fairly gifted structural engineers there.'

"THE FIA HAS FORCED DESIGNERS TO FAVOUR IMPROVED LIFT-TO-DRAG RATIOS"

Rear wings, too, are being influenced by last year's front runners. 'The rear wing is not in an optimal situation,' says Lock, 'it's behind a vehicle so the onset flow to the rear wing is going to be highly three dimensional. In order to extract the maximum from that, you need to align the wing to the local flow direction. It is about working different parts of the wing harder and other sections of the wing less hard in order to improve efficiency.

'Things like the Renault floating rear flap allow you to run a steeper rear flap angle by allowing the air to bleed from the pressure side – in other words, the upper surface of the rear wing out through the end plate. You get a larger wing tip vortex that normally you are trying to get rid of, again for efficiency and drag reasons. But creating a vortex allows the air to stay attached at steeper angles of attack. The flow around the corner of the rear flap produces an up-wash that reduces separation of the flow in that area.'

Looking at the cars for the coming season, Lock notes, 'Of all the new cars I have seen the two that look to have had the most aerodynamic development are the McLaren and the Renault, which is perhaps not a surprise given the performance last year. The McLaren rear wing is a case in point. If you look at the main wing section at the top of the end plates and the lower section above the rear diffuser, they are both highly profiled sections. There's a lot of effort gone into the shape of those.' →

This level of profiling has driven the move toward central pillar mountings for the rear wings. These appeared on the BAR and Toyota last year, with Renault following suit before the end of the season. Now Ferrari is following suit, too. The strut is aerodynamically inferior but better structurally, allowing more freedom in the design of the lower wing element and the end plates that would otherwise be carrying all the rear aerodynamic loads.

'You've seen quite a big change to the sidepod design,' notes Lock, 'primarily because of the reduction of the cooling requirements of the V8. On a lot of the teams the sidepod inlet looks like an inverted L. They've chopped that back significantly. The sidepod itself is sculpted in order to get as much flow through to the top of the rear diffuser and so allow the rear diffuser and rear wing to work efficiently. It's to do with shaping the sidepod to accelerate the airflow through the gap between the top of the rear diffuser and the lower rear wing profile, drawing air from under the car.

“TURNING VANES TRY AND KEEP AIR AWAY FROM THE REAR WHEELS”

'If you look at the Renault from side view, the side pods look very aerofoil shaped – as though they're trying to encourage as much air through that gap as possible, pinching off the lower part of the radiator intake. Because they have gone to a V8, most teams have kept the same wheelbase as last year's car so you can have an even more pronounced Coke bottle profile.

'The other interesting thing is some teams are running 'fake' cooling towers, Ferrari in particular. They seem to have chosen to exit their cooling air out the back of the vehicle over the rear diffuser, but they've still got the cooling tower shape as part of their package of upper body aerodynamic devices. A lot of those parts on the top edge of the sidepod are looking at controlling the flow over the rear wheels. The wheels on a Formula 1 car contribute hugely to the aerodynamic force because they are exposed. At the rear of the car a lot of work has been done on flip-ups and turning vanes and a lot of the teams are now running turning vanes to try and keep air away from the rear wheels.

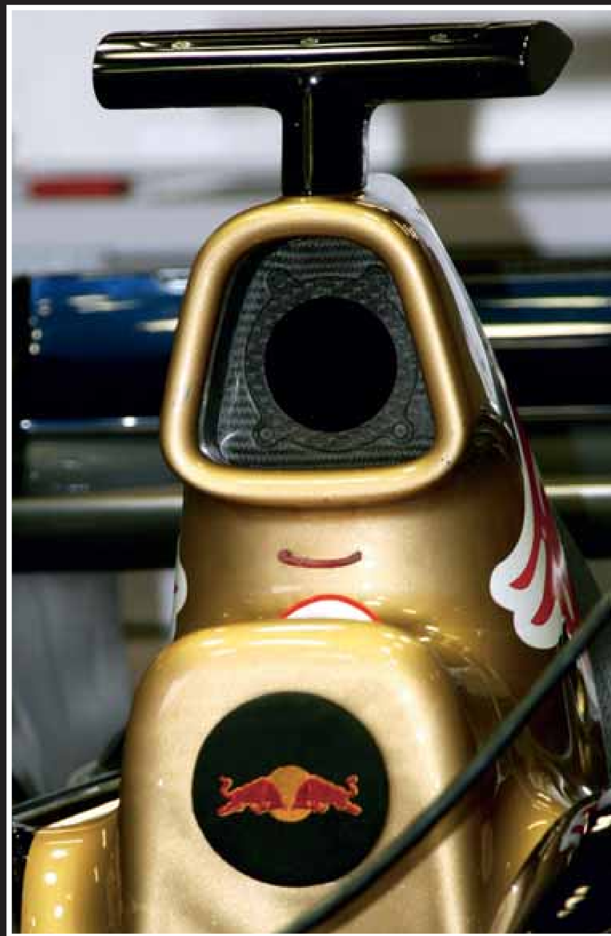
The McLaren front wing in plan form has a pronounced toe out to the front wing end plates, again in an effort to shroud the front wheels from as much airflow as possible. It will be at the expense of efficiency on the front wing, because if anything you want to be expanding the air underneath it to get more low pressure rather having air being squeezed under it.

The only regulation change affecting aerodynamics is a rule mandating the lower edges of the barge boards must be 50mm higher. While this was driven by safety in an effort to prevent splinters of carbon being left on kerbs, most teams have found a significant penalty from the change.

Less power has changed the approach to driving and set up. As Tiago Monteiro of Midland F1 points out 'minimum speed in the corner has become much more important. Before, you could brake deep into the corner then turn sharply to aim the car at the exit. Now you have to turn in more smoothly and try and carry more speed. So we need a car that has a more stable rear under braking and keep its front end nailed under power out of the corner.' Engineers are predicting traction as being less of an issue, which will have an influence on set-up and some feel that drivers who can handle a 'looser' car will shine this season.

Certainly the engines have introduced a wild card to the sport. However, the more specific engine rules had taken more differentiation away from the cars. This will undoubtedly blunt the effect of big budgets but will also reduce diversity in the cars' abilities, if any existed in the first place. This season should be interesting and, with another new set of rules for 2008, there won't be time for design practice to become too established before the apple cart is upset again.

V10's stay of execution



Two cars on the grid will be using 3.0-litre V10 engines this year, those of Scuderia Toro Rosso. With 77mm restrictors (above) being used to equalise performance, many are concerned that the greater torque of the V10s will give a significant advantage at certain tracks, including Monaco

BMW made good use of Sauber's extensive aero facilities to rework the C24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In at the deep end

For a new team, entering Formula 1 signifies a huge financial expenditure, but do the returns justify that investment?

Words	Paul J Weighell
Photos	BMW, LAT

There have been two empty FIA Formula 1 Championship team places since both Prost and Arrows teams failed some years ago. Even if SuperAguriF1, widely thought of as Honda's junior test team and still using many of the old Arrows' facilities and designs, do make it through 2006 unscathed there will still be an unfilled team place.

If one discounts the recent arrival of thinly veiled 'B teams' such as Scuderia Toro Rosso and SuperAguri, then the once full grid of totally different teams has now shrunk to just a shadow of its former self and gone now, for example, is the need to pre qualify. In any other marketplace such empty or 'makeweight spaces' would signal a lowering of the value of the grid and therefore a lowering of the cost of new entry, so why has Formula 1 not been besieged with new hopefuls eager to fill the spaces?

The answer is that although there have been about half a dozen new teams planned over the last few years they either bought out an existing team, were absorbed into a junior team or decided against entry for financial reasons. The planning done by one of the hopeful entrants forms the basis of this two-part feature that attempts to describe some of the machinations required in creating a new team. Part one will deal with the current Formula 1 environment, while part two will discuss an approach method and some costings for a proposed team.

So now you are in advertising

Formula 1 is perceived as a spectator sport by its loyal fans, an entertainment show by the more occasional viewer and an important business by the participating professionals. Crucially, however, Formula 1 is just another advertising medium for its paymasters – the sponsors who now fund the entire activity.

With growth in alternate advertising channels parallelling a decline in global advertising spend since the internet bubble burst, Formula 1 has been facing a turndown from its peak days when the grids were full and pay-per-view television companies bid up the price of its equity.

Those times are now past and the remainder of the mature cash cow that F1 has become is now largely owned by a City [London] based private equity investment fund group. Formula 1 is still a global business that attracts vast sums of money on an annual basis, and one would think that a dozen or so participating racing teams could make a good living from sharing that income stream and that new teams would wish to partake of the profits. But some of the major profits from Formula 1 however are not shared with its participants, due to the complex way the business has been structured over the last few decades.

Formula 1 has grown into a relatively mature network of teams, businesses and regulatory organisations that work together to provide an entertaining show for global television consumers. The participants' single shared goal is to attract the maximum number of viewing consumers who are prepared to buy the products and services advertised by the sponsors.

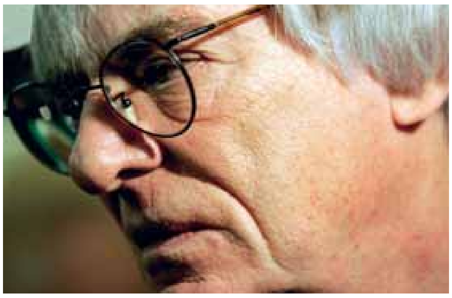
It is perhaps important to recognise that the Formula 1 administrative machine is internally cleaved into two parts and that the racing, sporting and technical side of Formula 1 is no longer directly in control of the commercial side. The two aspects, and indeed the teams, are tightly bound by the ubiquitous Concorde Agreement and the lease that allows the FIA-branded Formula 1 World Championship to be publicised, exploited and broadcast exclusively by the Formula 1 group of companies for very nearly the next century.

The two faces

The two faces of Formula 1, however, are not part of the same legal entity and one cannot pass the liabilities of one to the other. From a new team viewpoint the split is unfortunate as one has to deal with a number of entities but, most importantly perhaps, it means that formal acceptance to race by the FIA does not necessarily guarantee commercial acceptance by the Formula 1 group of companies. As we shall see in part two, this can pose a serious financial hurdle to a new team.

The two aspects to Formula 1 are:

1) The Federation Internationale De L'Automobile (FIA). The technical, rule making and competition running side of Formula 1 racing, headed by its recently re-elected president, Max Mosley. The FIA controls the intricate technical organisation of cars, teams, tracks and racing. Broadly speaking, it is the FIA's task to ensure the competition is run smoothly and to a set of rules that keeps it at the supreme head of motorsport, whilst retaining the fig leaf of an equal opportunity sport ie one where spending the most money does not automatically guarantee a win. The FIA owns the rights to promote and exploit the F1 brand but leased those rights for 99 years to the Formula 1 group of companies for a single payment of about $350m , plus a more modest annual payment. None of that money reaches either existing or new teams.



Max Mosley (top) heads the FIA, while Bernie Ecclestone heads the F1 group of companies

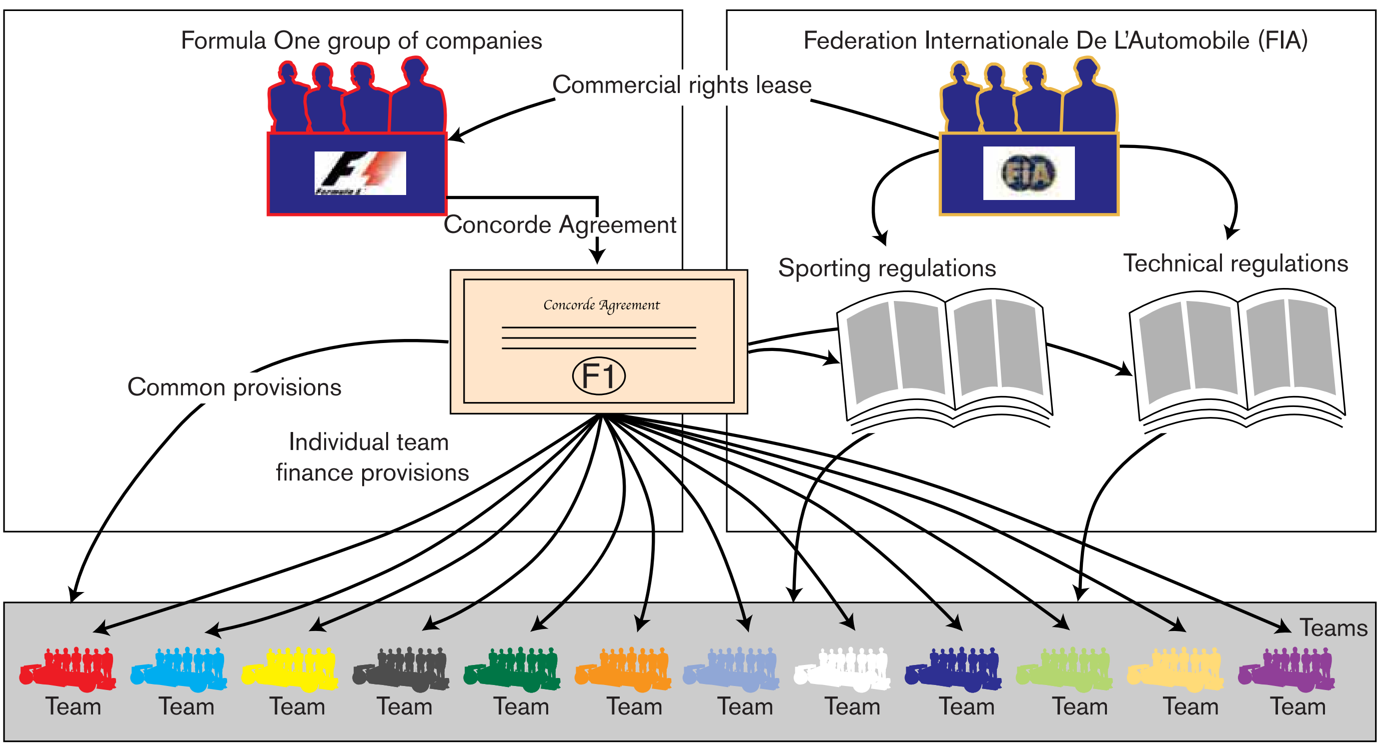
2) The Formula 1 group of companies. In contrast to the single entity that is the FIA, the broad range of commercial rights to the Formula 1 brand are exploited by a group of closely related commercial companies, nearly all of which were created by Bernie Ecclestone.

At the lowest administrative level each of these companies was formed to exploit one vertical facet of a Formula 1 commercial opportunity. For example, the Formula 1 Paddock Club provides team sponsorship hospitality facilities at each race, while the Formula 1 Licensing Company provides controlled promotional access to the various brand identities claimed by the Formula 1 group of companies, and so on.

After much complex interlinking, legal wrangles and transfers of ownership the largest beneficial owner of the entire Formula 1 group of companies is currently CVC Capital Partners, a London-based private investment fund group. At the time of publication, both Lehman Brothers bank and Bernie Ecclestone himself (and/or his Bambino organisations) are minor equity holders in the holding company Alpha Prema UK Ltd, formed by CVC Capital Partners to own and control the Formula 1 group of companies.

The largest single money spinner is the sale of licenses to television companies to broadcast races. Originally Bernie Ecclestone's Formula One Promotions and Administration company (FOPA) handled the TV contracts on behalf of the teams who were then paid 47% of the gross income with another 30% going to the FIA. Additionally the track promoters paid their money directly to →

One formula, two chemists

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FOPA who in turn doled it out as prize money to the teams, an arrangement which still exists albeit under a different company name. Over the last two decades FOPA has mutated into the Formula One group of companies and the teams have lost the right to negotiate TV contracts directly. The TV income spilt may have changed although the figure of less than half the gross income going to the teams seems likely to have remained.

It is to Bernie Ecclestone's enduring credit that he has almost single-handedly turned the commercial rights, and thus the entire Formula 1 shooting match, into the hugely successful advertising business it is today, and we understand that about 200 millionaires have been directly created within the sport during its primary growth phase.

From the new team viewpoint, however, it must be said that none of the money made within the Formula 1 group of companies makes itself available at the rear of the grid where a new team might be expected to start.

Money machine

The Formula 1 group of companies makes money by selling (or leasing) the rights to hold races to the circuit owners, the rights to broadcast races to television companies and a host of other rights related to all the individual activities from trackside advertising and corporate hospitality to promotional branding and merchandising. The total value of the businesses involved has been

Arrows eventually folded after a few seasons of financial uncertainty. SuperAguri has picked up the pieces and will return some of the Arrows cars to F1, even though Minardi had been banned from doing this

set by some at $3bn, although it is worth noting that the most recent sale of the largest equity stake – held by Bayerische Landesbank – to CVC Capital Partners was reported to have been for $1bn for 46.65 per cent of the whole. This, in turn, would value the entire brand at about $2bn if the other partners were to be offered the same deal conditions – a likelihood not at present thought to be a high probability.

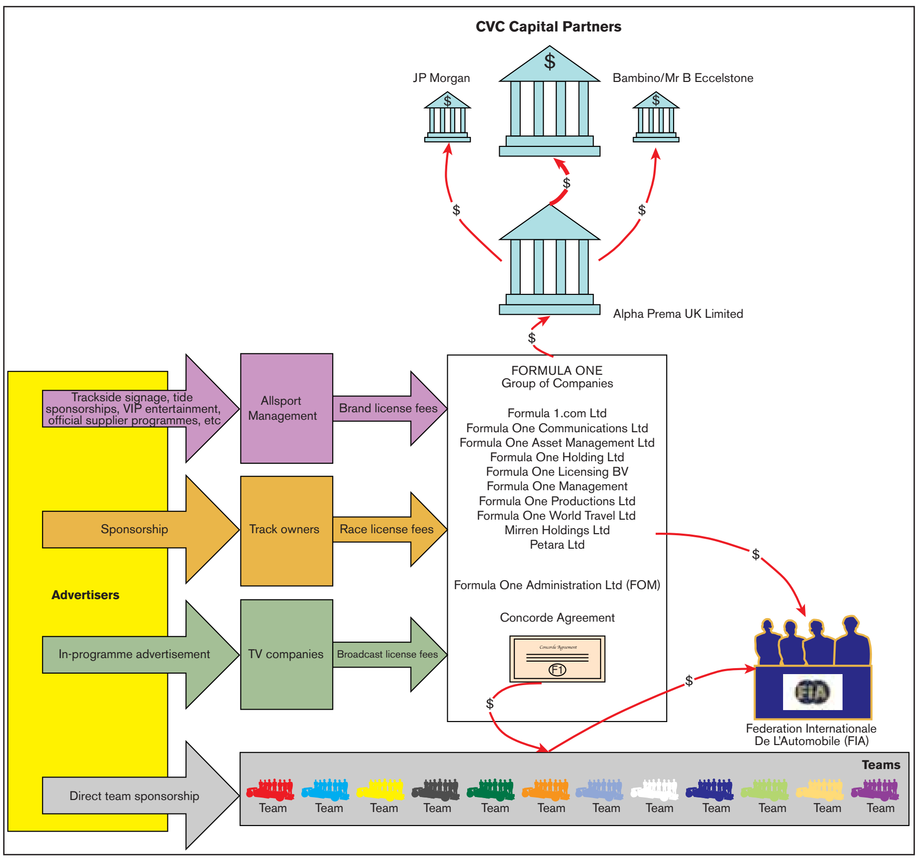
The commercial TV companies profit by selling retail advertising space in and around the race screenings. There is a higher level of the wealthier 'ABC1 male' that wishes to watch TV F1 than those that wish to watch football, for instance, but there is no guarantee that F1 in the future can continue to attract such an audience. Any move downmarket by hobbling the cars' performance, for instance, could lose money throughout the entire enterprise. It may be for this reason at least that the FIA seeks to retain a high standard of entrant and an expensive entry gate for prospective new teams to ensure they exude the right Formula 1 ambiance.

Amongst their other income streams the track owners sell tickets and franchise licenses to cater for the 100,000 or so trackside spectators at each F1 race. Whilst in recent years the attending spectator numbers have fallen, the cost of staging an F1 race has risen. It is thought that the tracks pay a minimum of $15m a year, with a contracted annual increase of 10 per cent. While Spa looks to have gone at least for 2006, Silverstone's troubles are well known and Monza is also reported to be feeling the pinch. It seems that although the newer, flyaway venues are expensive to build and maintain, the governments of the newer hosting countries are happier to subsidise F1 as advertising for their countries. If some tracks cannot run as profitable businesses in their own right then they will close and the races will move elsewhere, the A1 ring being a prime example of this. From the new team point of view this may be inconvenient as testing may move further away, but otherwise it is of little importance.

The FIA makes its Formula 1-related money from the commercial rights lease fee from the Formula 1 group of companies, as well as an annual $250,000 licence fee from each team.

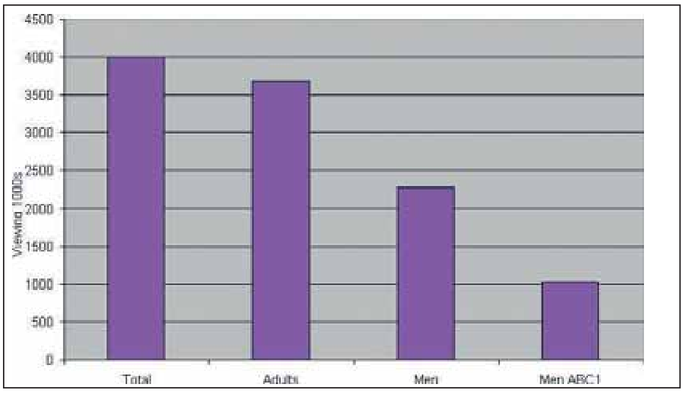
The teams, after at least two years existence, may receive money from their Concorde Agreement's commercial benefit provision. The exact amount that each team may receive is secret and likely to be different from any other team as the Concorde Agreement is negotiated between the team and Formula 1 Management Limited, another one of the Formula 1 group of companies. Having said that, the amounts received are roughly proportionate to a team's importance to the sport. Or, put another way, proportionate to the number of TV viewers they attract, with Ferrari, unsurprisingly, taking →

The money machine

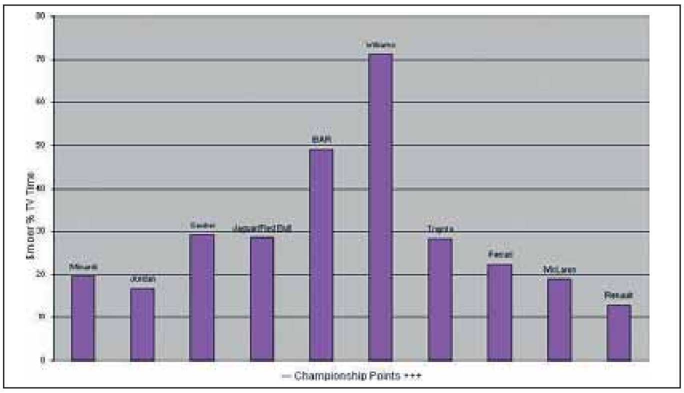


the largest share. Some money may be paid out earlier than the two-year limit if a team's racing performance rates the contracted performance rewards. Most team income however comes from selling their own brand name for partner use by an engine producer or other large manufacturer and also by selling the retail advertising space on the cars, driver apparel and ancillary racing equipment. Other deals include undertaking to use sponsors' products within the team or to share technical expertise with sponsors. All these methods must combine to produce sufficient wealth for the teams to race.

Enough income to race, however, is not the same as enough income to make a decent profit, and teams may scrape by without creating real capital wealth for those that own them. It is worth noting that several teams thought they had an agreement to share some of the capital realised when a major part of the sport was sold off some years ago by Bernie Ecclestone (that part bought eventually by CVC). Both Williams and McLaren were somewhat annoyed when they found out they were not in fact included in the profit share and subsequently sued their advisors. The advisors had seemingly advised the teams to contract to partake in the profits of one of the Formula 1 group of companies, but that particular company turned out not to have been the one which owned the rights that were later sold. It is important when dealing with the Formula 1 group of companies to ensure that one deals with the right company for the right task!



Breakdown of typical UK television viewing figures for Formula 1



Value for money, F1 style. TV time per dollar is what success is measured in and the more TV viewers a team attracts, the more it earns

Viewing time

In order to find the money to go racing the teams become commercial brands in their own right, such as McLaren did when it marketed hi fi and as Ferrari does when it sells hats. Cars become little more than moving billboards to display TV adverts and their value as billboards depends on the teams' attraction to the TV fans and the amount of TV screening time the team can achieve. In some cases it may be more lucrative for a team to lose a position on the track if it can gain additional TV time for its sponsors but, as a general rule, it behoves a team to do well and increase its championship points as that raises its longer term billboard value.

The amount of time that the F1 television show focuses on each car, and therefore its carefully placed advertising graphics, is logged and the data proves very interesting. As an example, new or small budget, low-performing teams are usually given less than four per cent of the talk/screen time. Calculating from the 2005 championship points and the percentage television time, the effective advertising data is charted as TV time per dollar.

During the 2005 season the lowest cost per percentage television time was Renault at about \$13m per one per cent time, using our informed estimate of Renault's expenditure for the season. Williams faired poorly for its main sponsor at a whopping \$71m per one per cent television time, and this factor may have played some part in BMW moving its advertising spend away from Williams to invest instead in its own F1 team ie buying and re-branding Sauber as BMW for 2006.

The best television exposure value was achieved both by the championship leaders — unsurprisingly — and the tailenders. The top and bottom four teams showed similarly good returns for their advertisers' investment, whilst the poorest spending decisions for advertisers seem to be those whose sponsored midfield teams. It is therefore some comfort for hopeful new teams that there is a threshold of minimum television time spent per team, and that seems to be more than might be thought on a simple championship points basis.

Brand new teams will also get some additional exposure just by being new Formula 1 teams. This is such a rare event these days that media attention will result from the first public announcement. One new hopeful during 2005 made the announcement that it wished to enter Formula 1 in the longer term and this alone generated several international broadcast media interviews and about 300 internet references.

Starting a new team from scratch then can present sponsoring advertisers with a competitive exposure advantage at a lower cost than funding an existing team, and it was partially on that basis that our hopeful entrants decided to plan for a new team.

To be concluded in part 2...

Prost was another example of a team that failed financially. A group of investors later purchased the Ferrari-engined cars with a view to returning them to the grid but the FIA prevented this from happening

Optimising education

A university most people have never heard of and a graduate degree programme many don't know about is producing some of racing's brightest new engineers

Words	Brett Becker
Photos	Becker; UCF

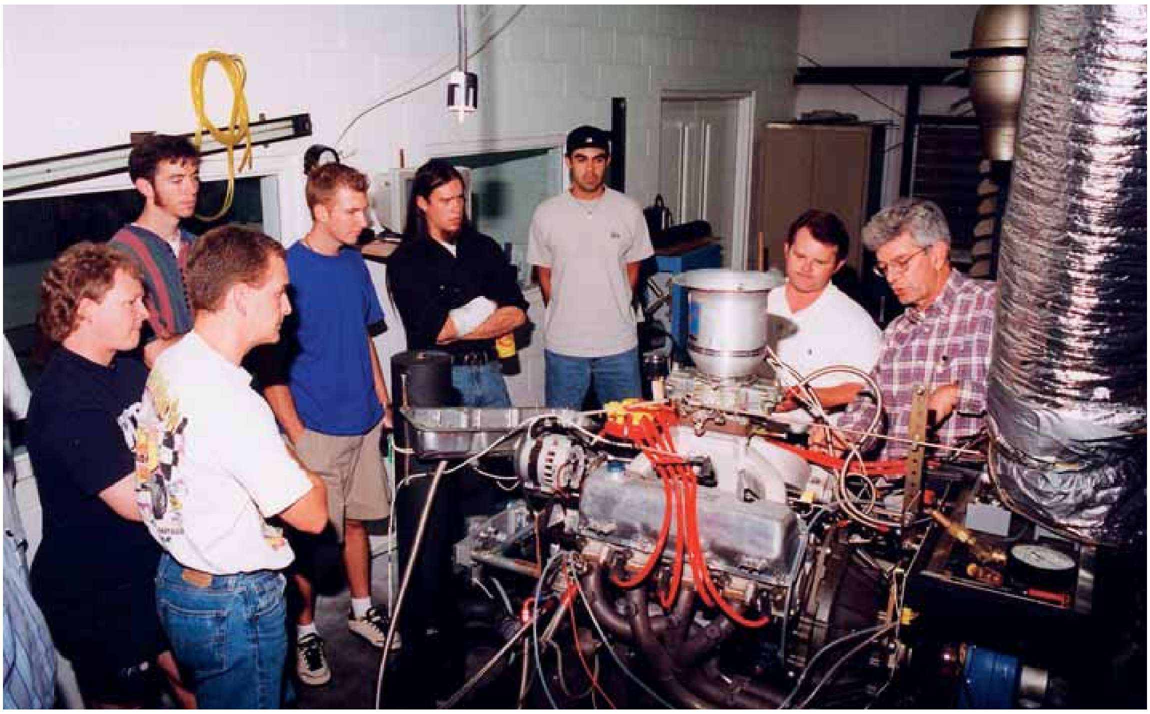
Sometimes, when the University of Central Florida campus is quiet and the wind is right, you can hear the faint roar of a Nextel Cup engine screaming at 9000rpm on the dynamometer in the university's engine lab. Yet most of the university's 40,000 students – and a large part of the motorsports community – don't even know the engine lab exists, which is something engineering professor Dr Robert Hoekstra would like to change.

Hoekstra has developed a graduate-level programme in race-engine optimisation that is a masters degree all its own. Now in its ninth year, Hoekstra's programme is still the only one of its kind in the United States but, other than word of mouth and a few scattered news clips, not many people have heard of it.

Students have come from as far afield as California and Montana to earn their masters degrees in engine optimisation, but many of the students seemed to hear of the school by pure chance. For example, Don Delias, one of the programme's first graduates, heard of it from a friend who saw a flier tacked up outside a University of Tennessee professor's office. While Ed Hilker was studying materials science at the University of Florida when he learned of the programme through a newsgroup on the internet. Another, Chris Wagner, who earned his masters in engine optimisation and has since gone on to study for his PhD at UCF read about it in a news brief in the *Wall Street Journal*.

In addition to being little known, Hoekstra's programme is limited access. To keep the professor-to-student ratio low, Hoekstra now only accepts between four and six students to study at a time because he is the only professor. He has had as many as 20 students in the past, but found it didn't allow him the scope to focus on their learning, his mentoring and research.

So what does it take to get in? 'One, you've got to be bright, but you don't have to be the brightest person that's ever walked,' Hoekstra said. 'You've also got to be smart and got to be able to learn, but you've got to want this more than anything else. Not "I want to someday design cars for General Motors, or I want to do the best engine General Motors has ever seen." Tell you what, go to MIT, go to University of Michigan. You want to be in racing, you come here. This is about racing,

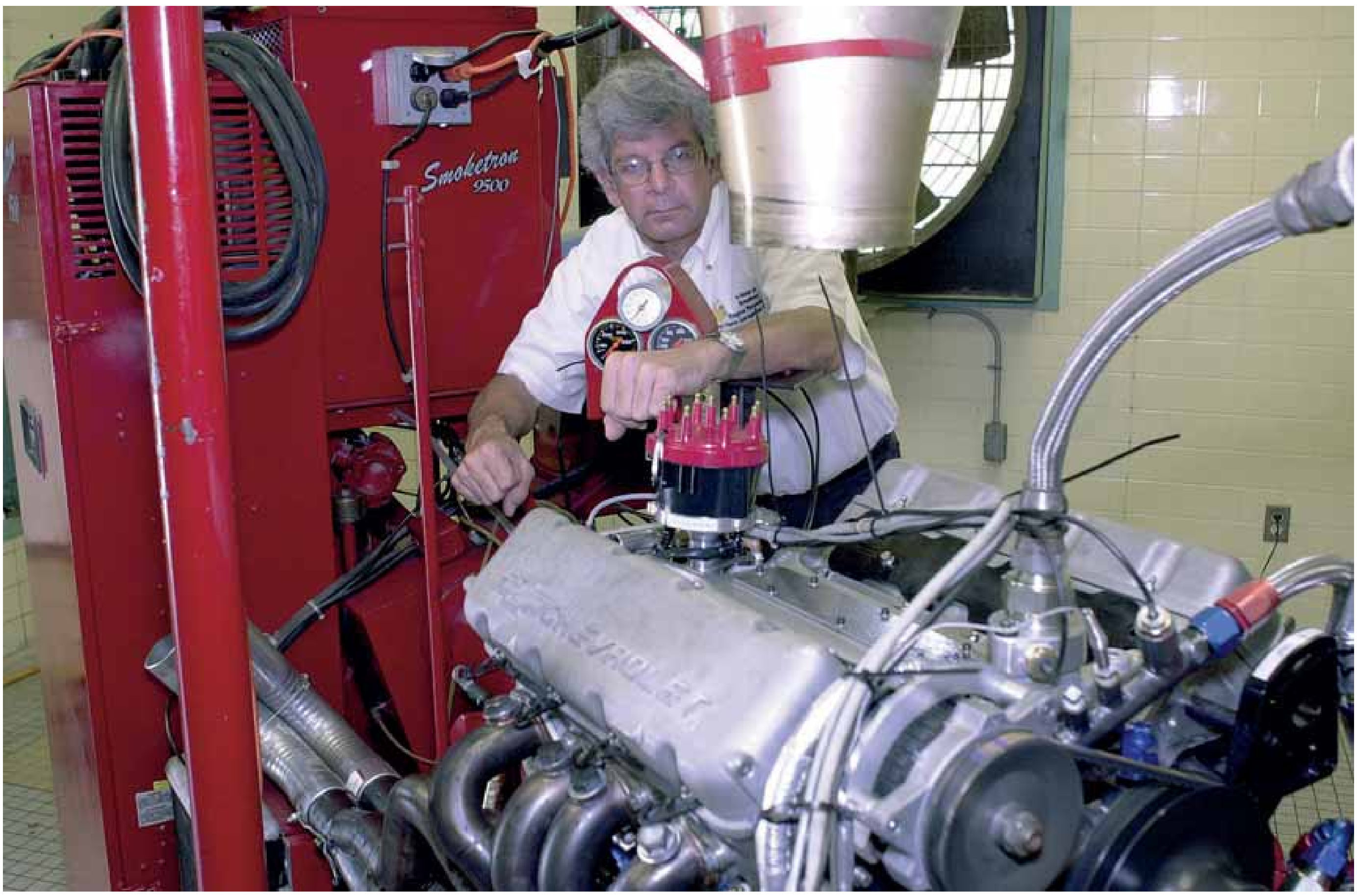


Hoekstra now only takes between four and six students on the masters degree course in order to be able to devote adequate time to their learning and mentoring

and specifically about racing engines.'

Hoekstra's programme got a boost in 2000 when the late, legendary engine wizard, Smokey Yunick, donated to the school his patented 'Smoketron', which can spin-test a full Nextel Cup race engine. Like a Spintron, which drives a cam gear, camshaft and valvetrain via a chain and sprocket fitted to a straight shaft mounted where a crankshaft normally would go, the Smoketron can rotate a full, non-firing race engine, complete with crankshaft, rods, pistons, balancer and flywheel, camshaft, valvetrain, fuel delivery and carburetion. To get a Nextel Cup engine to spin at 9000rpm takes a 300bhp electric motor that runs on 440V, three-phase power.

'Its main value is in studying parasitic losses in an engine,' Hoekstra said of the Smoketron. 'But you have to be very careful. If you make an improvement on the Smoketron, odds are very high that you've made an improvement on a running engine. But you may not have because when the engine's running on [the Smoketron] the pistons are not loaded the same way. Because they're not being driven down, they're always →



Hoekstra with the Smoketron, the machine Smokey Yunick built to spin test Nextel Cup race engines, donated to the engine optimisation programme in 2000

being pulled down and there are some real problems with ring seal. Pistons don't like to seal very well, and so you throw huge amounts of oil out the exhaust on there. Since we've got this different kind of oiling going on than what you have in a running engine, there are some things that are not the same. Those are things that we had to learn.'

Student Chris Wagner used the Smoketron to do research on oil pumps and oil pans in conjunction with Dodge Motorsports. Neither he nor Hoekstra were at liberty to provide any more detail, but they were studying rheology – how oil's density varies as it flows through the engine. 'I'm allowed to talk about the fact that we studied it, but I can't talk about the results,' Hoekstra explained. 'As a result of using it, we learned things about what goes on in the oiling system of an engine that people had been wondering about for a long time and hadn't been able to figure out. One of the projects we have to do is correlate that data in a running engine from the dyno.'

Hoekstra first met Yunick on a plane ride home from a trade show in the early 1990s and the two struck up a lasting friendship. After Hoekstra developed the university's engine programme, he would take his students on field trips to Yunick's 'Best Damn Garage in Town' – about an hour away in Daytona Beach.

> **"THE CURRICULUM CENTRES ON A DISCIPLINE UNIQUE TO INDUSTRIAL ENGINEERING"**

'I remember Dr. Hoekstra telling Smokey about tubular boosters that extended into the small plenum between the carburettor and the restrictor plate used to direct air flow through the restrictor,' said graduate Ed Hilker, who has worked for All Sports Telemetry and Hendrick Motorsports. 'Smokey said, "hold on Bob, wait a minute, here." He walked back and brought out this dusty old carburettor with extension tubes in each place for each booster. So it was something he'd tried maybe 10 or 15 years ago. It just shows the amount of things he's tried and the knowledge he had about engines.'

When Yunick donated the Smoketron, UCF named the engine lab in his honour. Yunick was suffering from the late stages of leukemia at the time. The school named the lab, what else? 'The Best Damn Garage on Campus.'

A challenge Hoekstra faced early on was establishing the degree programme under the industrial engineering umbrella, rather than mechanical engineering. Most students who have entered the programme have bachelors degrees in mechanical engineering but, Hoekstra points out, his curriculum centres on a discipline unique to industrial engineering: optimisation, specifically through the use of an advanced

East meets West

Headquartered in California, Toyota Racing Development has imported four graduates from the University of Central Florida's engine optimisation programme.

That Toyota Racing Development has hired four UCF graduates since 2000 might indicate the calibre of students who come out of the school's engine optimisation programme. Another, and perhaps stronger, indicator is that TRD mentions UCF in its media kit, along with other prestigious US engineering schools such as MIT and Caltech.

UCF grad Don Delias, a senior track support engineer, has been with TRD since 2000. Before landing a position with TRD, he interned with the Jasper Engines NASCAR racing team. His job at TRD has been to develop and calibrate engine control systems for Toyota's Indy Racing League engines.

'The work that I've done on the dyno and at the track, and the work I do at TRD is primarily just engine driveability, engine controls,' Delia said. 'We control the way the car shifts, the way it decelerates and the way it accelerates. We control everything from the fuelling to the way the traction control works. I think we have one of the most driveable, responsive engines in the IRL.'

Launched in 1979 as the US performance parts distributor for TRD Japan, TRD USA has grown to employ more than 240 engineers, designers, engine builders, technicians and administrative staff at three locations across the United States: Costa Mesa and Tustin, California, and High Point, NC.

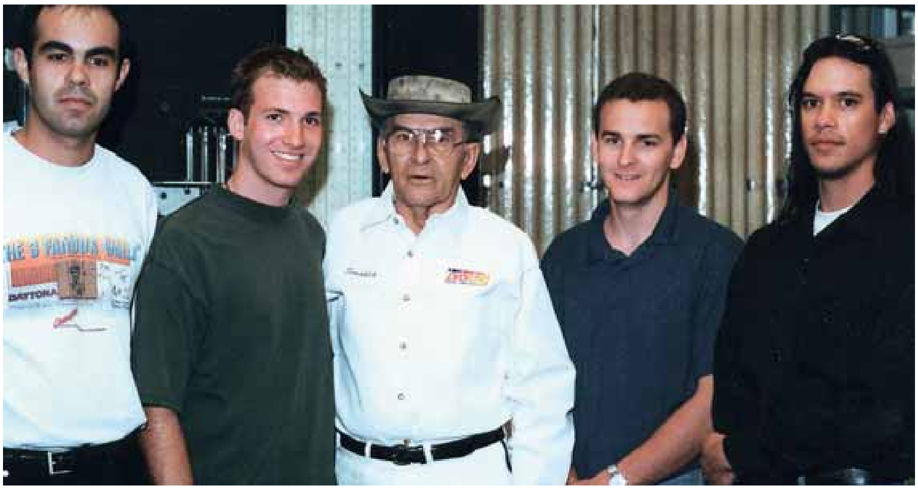
A subsidiary of Toyota Motor Sales USA, TRD has developed cars and trucks for competition in CART, IRL, Craftsman Truck Series, IMSA,

Don Delias, a graduate of UCF's engine optimisation programme, now works as a senior track support engineer at TRD where he is responsible for developing and calibrating engine control systems on Toyota's IRL engines

statistical method called response surface methodologies, or RSM.

'The mathematical model that you build of an engine is more than 10 per cent off,' Hoekstra said. 'Well, a model that's more than 10 per cent off is useless to me if I'm designing a race engine, as we're looking to improve the engine by one per cent. My model can't be off by 10 per cent.'

A mechanical engineering approach follows the scientific method in which researchers change only one variable at a time so as to pinpoint which variables effect specific changes in an engine. It's an effective methodology in many disciplines, but it falls short in extracting trace amounts more horsepower from a race engine, Hoekstra said. 'Say we want to find the optimum camshaft and head combination, what do we do? We swap camshafts until we find the very best camshaft because we change one factor at a time. Then we change heads. Why would you assume now that the camshaft is the right camshaft to match the different heads?



Smokey Yunick (centre) with a group of University of Central Florida race-engine optimisation students

'So, this whole thing about changing one variable at a time will never get you there,' Hoekstra added. 'The old scientific principle, you only change one variable because if you change more than one variable you don't understand what you've changed – that's absolute nonsense if you do it mathematically.'

RSM is what makes changing multiple variables possible, and it's the linchpin of Hoekstra's programme. The powerful statistical method allows Hoekstra and his students to find an optimum combination for any engine, even though they never physically tested the combination. Part of why a mechanical-engineering approach to getting the most from a race engine doesn't work as well as optimising with RSM is because it automatically assumes laminar flame travel within the cylinders, when the burn is known to be unsteady and chaotic.

"RSM MAKES CHANGING MULTIPLE VARIABLES POSSIBLE"

'We don't know how to model an unsteady burn. We don't know how to model chaos,' he said. 'One of the papers I wrote proved the entire combustion process is chaotic. How in the world can I write a theoretical, first-principles model of something that we have no modelling techniques to even describe? So what do you do? You assume it all to be laminar. As soon as you assume it all to be laminar, you're more than 10 per cent off.'

Hoekstra said that as a result of all the Society of Automotive Engineers papers he has written, major automobile companies have begun to teach courses on RSM. However, if a company or race team really intends to implement RSM, they'll need to spend time studying the method intensively, really getting it under their collective belts. But once an engineer is fluent in RSM, it can save a lot of time.

'As far as dyno work, RSM is really a good idea,' said graduate Don Delias, now a track support engineer with Toyota Racing Development. 'It →

TRD's Indy V8 engine

NHRA, Pike's Peak Hillclimb, Grand Am Rolex series, IPower Dash series, off-road truck racing and Toyota's signature open-wheel Atlantic cars, among other racing efforts. TRD now also develops aftermarket performance products for Lexus.

Despite 14 IRL victories – including the Indy 500 – 16 pole positions and both a drivers' and a manufacturers' championship for Toyota-powered cars in 2003, the company announced late in 2005 that it will no longer campaign in the IRL. But that doesn't mean TRD is scaling down its racing efforts. The company's recent successes in NASCAR's Craftsman Truck Series – four race wins in its initial 2004 season – have shifted the company's focus, Delias said.

'I think the company has a pretty good vision,' he continued. 'It had the foresight to see that CART was not going to succeed and took the initiative to switch to the IRL. Once we switched, Honda followed. Now we have re-directed our attention again,' he said. 'We're in the Truck Series right now and I'm pretty certain there are plans for us to be in the [Nextel] Cup Series in the near future.'

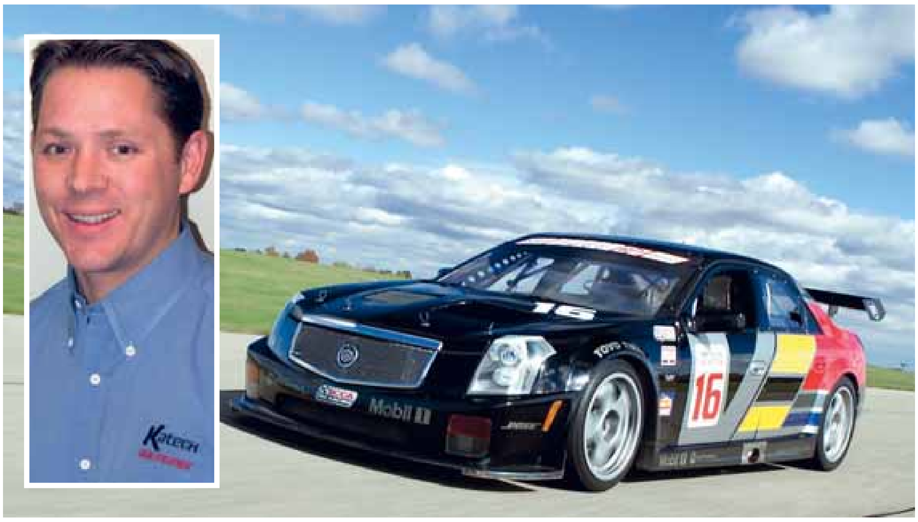
For Delias, a career in motorsports is something he has been targeting since studying for his bachelors degree at the University of Tennessee in Knoxville. 'Motorsports is kind of a dream,' he concluded. 'There are a lot of undergrads who have an interest in cars, and I think they fully realise they'll probably be working somewhere in production and that they might be involved in the design and development of a production vehicle. I don't think anyone really thinks they're going to end up in racing.'

Then again, a good education never hurt anyone.

Brett Becker

helps you produce useful results with a limited amount of time or effort. That's really what you need. If you tried to attack some complex application on an engine, it could take you weeks of running every day to get the result, whereas using response surface methodologies, you could actually kick out the result within a day, which is ideally what you want, before the weather changes or anything else goes on.'

The UCF programme provides students with a good general knowledge of theory, engines and engine building, experience through an internship requirement and the opportunity to explore specifics through their thesis work. Graduates have landed jobs with some of the top racing teams and motorsports companies, such as Roush/Yates Racing Engines, Toyota Racing Development, Katech and Hendrick Motorsports.



Caleb Newman, a UCF graduate now with Katech, and one of the Cadillac GTs using the company's engines

'I came to Katech knowing I was staying. They thought it was an internship but I knew it was long term,' said Caleb Newman, one of the programme's first graduates. 'It was my plan from the start that I was going to stay on at Katech.'

According to students and graduates, the programme isn't without shortcomings. For example, since most of Hoekstra's contacts within the racing industry are primarily from NASCAR, that means the bulk of study and research students do focuses on carburetted Nextel Cup engines. Students graduate with knowledge that allows them to learn electronic powertrain management, but it's not part of the curriculum.

'Our lab, all of the donated equipment we get is stock car-type stuff,' Hoekstra said. 'No one has ever donated to us an IRL engine or a real sportscar engine – I'd love to have one and we would do research on it – but everything that is donated to me is NASCAR stuff, so that's what we work on. It's where I had the best contacts. It's where I knew people I could call and get help.'

Another problem is funding. For students, most of whom come from out of state, it means tuition, lab expenses and some of the expense for parts they need to conduct their research all come out of their own pockets. A limited budget also means Hoekstra is the only professor. And when he retires, though that's still at least 10 years away, the programme may be retired with him.

"THE BULK OF STUDY FOCUSES ON NEXTEL CUP ENGINES"

Students and graduates interviewed point to another shortcoming, but its answer is more elusive than additional funding or changes in curriculum. Research projects are often tough to come by. Race teams would love to have Hoekstra's students do engine research for them, but any 'power secrets' a student finds become public when written about in a thesis, and race teams prefer to keep the findings to themselves. 'It has become so competitive in NASCAR that there is no way we can work with NASCAR teams because there is no way to ensure absolute security,' Hoekstra said. 'Once my students have it in their heads, they can sign a non-disclosure agreement and be absolutely ethical and never tell anybody what they did. But they know what they did and they're going to utilise it in their jobs; I would expect them to. That's why they went to school. It's an absolute Catch 22 – as it has become more and more competitive, it has become more and more difficult for us to work with teams. That's why we don't work with Penske or any of the other teams anymore. And they've all apologised and said, "We'd love to have you do it but we can't." And I understand that they can't.'

Once students graduate, they are certainly equipped to work in racing. The final catch – and this is why Hoekstra insists on a passion for racing before he admits a students – is that entry-level wages aren't the greatest. He tells them up front that with a bachelors degree in engineering, students can expect to earn a starting salary of about $40,000 (£23,000) a year. If they graduate with a masters, they can expect about $55,000 (£31,500). If they graduate from Hoekstra's programme, he can virtually guarantee them $25,000 (£14,300) to start. After students hear him repeat it enough, they realise he isn't joking.

'For anybody who might be thinking about contacting the school about the programme, it's definitely not for people who think, "Oh, motorsports is cool, let's go give that a shot," said graduate John Gross, who works for Roush/Yates Racing Engines. 'You definitely have to love it to do it. The programme is not easy, the classes are not easy and the work is not easy. Once you graduate, you're working like crazy. It's definitely something you have to be passionate about to succeed at. But given all that, if I had the chance to do it again, I'd do it in a heartbeat.'

John Gross, a UCF graduate now with Roush/Yates Racing – 'you have to be passionate to succeed,' he says

Fruits of the loom

An essential but often overlooked are a of racecar engineering, wiring looms can reward your care and attention more than you might think

Words	Sam Collins
Photos	Beru F1; Collins

'Right, we've finished the car – engine in, clutch aligned, fluids are in, better stick the electrics in then…' It happens like that more often than you might believe. A competition car's electrics are often an afterthought, which is fairly incredible when you consider just how vital they are. This is the point at which a comment such as 'it can't win you the race, but it might lose you the race' could easily be inserted, but in truth a well-prepared loom can give a car a performance advantage, not least by saving weight and reducing servicing time. Yet still few seem to consider this.

In Formula 1, where having a professional finish to every component borders on the obsessive, the looms are more fighter jet than racecar. Some of the components are not even designed for grand prix racing at all, but rather for aerial combat. It is genuinely cutting-edge technology, and cutting edge is usually another way of saying expensive. But it's not as bad as you may think. At the end of the day, like any wiring system, a racecar's wiring loom is just a few wires, various connectors and a bit of heat shrink. However, in professional motorsport looms can be fiendishly complex, and their construction is a specialist task. Consider that every single sensor on a grand prix car needs a complete circuit, then consider at times teams will use well over 100 of the things. Already that's a vast amount of wire, and there's a lot more than just sensors in the electrical system of a modern Formula 1 car. And the situation gets worse when you look at something like a World Rally Car with lighting systems, intercoms, various mode controls for the differentials, transmission and engine and so on.

> **"IT CAN'T WIN YOU THE RACE, BUT IT MIGHT LOSE YOU THE RACE"**

Interestingly, wiring loom design will be a victim of the 2008 F1 upheaval, loom components and function coming under the control of the FIA. In theory this will prevent teams from indulging in any electronic trickery outside of the rules, and the only significant difference between each teams' loom will be its shape and length, due to differences in chassis design.

Some teams build their looms in house and others outsource the work to companies like Beru F1 Systems, who'll prepare you a complete, bespoke loom, at a cost. When it comes to that

Aerospace-spec connectors ensure positive location and reliability – paramount concerns on a racecar

"WIRING LOOM DESIGN WILL BE A VICTIM OF THE 2008 F1 UPHEAVAL"

cost it really is a case of 'how long is a piece of string?' Or wire as the case may be. Full specification grand prix car harnesses can be in excess of £20,000 ($35,000) and take up to 300 hours to make, but other cars can be just a fraction of that.

Chicken or egg?

Whilst loom making (loomery?) is complex work it's often impossible for racecar manufacturers to prepare a loom before the car is built. Even in this age of CAD-designed teacups, it is not always possible to get an accurate 3D model of some substantial parts of a car, as Ewan Baldry of Juno Racing explains: 'we do the loom and plumbing after the car is built, but we would like to do it earlier and our CAD package has a bolt-on that allows you to design the wiring as you design the rest of the chassis. The problem is often the engine though, which you don't always have an accurate CAD model of, so the plumbing and wiring has to be done on a real engine in a real chassis.' This approach seems to work for Juno though as its neat looms have never experienced any significant problems.

With the notable exceptions of the works teams in the WRC and F1, all but a few design their looms after the chassis, meaning after the car →

Hints & tips on loom construction

Beru F1 System's principal technical director, Gary Norman, has put together a few dos and don'ts for making a loom exclusively for *Racecar*.

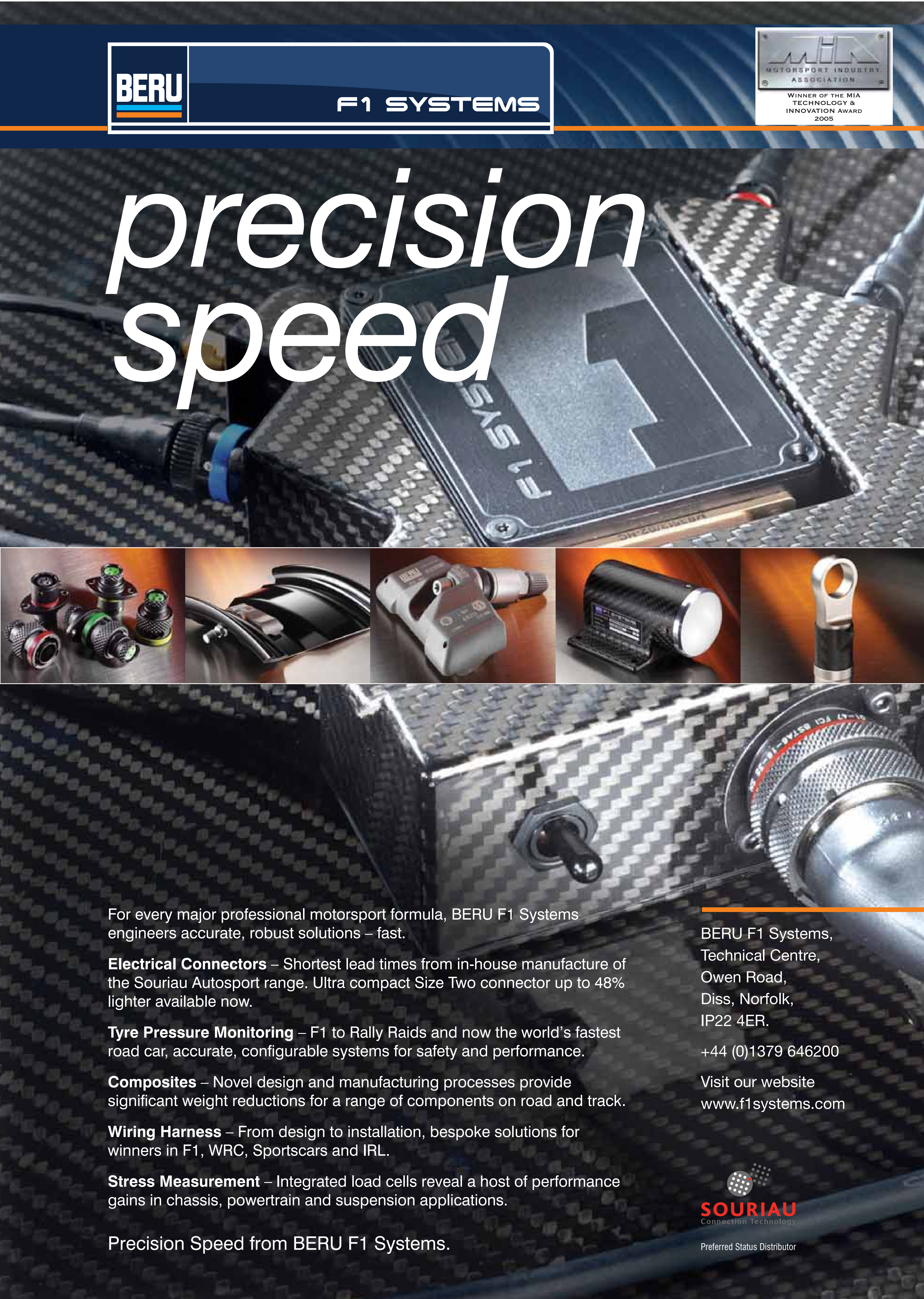
1. Create a pinout or schematic drawing of the car's electrical system.
2. Create an accurate layout drawing that details the dimensions of the loom.
3. Consider current requirements, wire sizes and type and voltage drop.
4. A racecar is a hostile environment. Consider that the loom is likely to come into contact with various fluids like water, oil, grease and fuel. The temperature in the engine bay and other areas is also a major design consideration – even if the engine bay is open it can still get very hot. Vibration is also pretty extreme, and running kerbs or on gravel can really shake things up.
5. Connectors – choose ones that will suit the environment and wires you are using.
6. Cable protection – there are a number of ways of doing this, but make sure you use a suitable product to protect the wires.
7. Serviceability – you might have to change something quickly when removing it from the chassis, it is all too easy to cut a wire whilst removing cable ties.
8. Avoid sharp edges when routing the loom through the chassis, particularly when passing through bulkheads. The car will flex when running and this could cause problems with the loom.

Norman also gave some pointers on assembling a loom:

A. Make sure you have the correct tools for the job
B. Check your work as you build the loom
C. The old adage of measure twice, cut once really does apply, but also make sure you don't stretch the loom. Start long and trim from there.
D. Check the loom once it's complete. Is everything connected as it should be?
E. Carry out a system or bench test before fitting the loom to the vehicle if possible. Some firms like WilliamsF1 have special rigs built to test their looms. If you have time it might be worth investigating constructing one of these.
F. Remember, smoke is bad.

Though most of this seems common sense, it's worth bearing in mind that even the professionals make mistakes. Apparently it is quite common for overworked mechanics to drill through the wiring loom by accident...

Loom construction is relatively straightforward but requires concentration, some specialist tools and nimble fingers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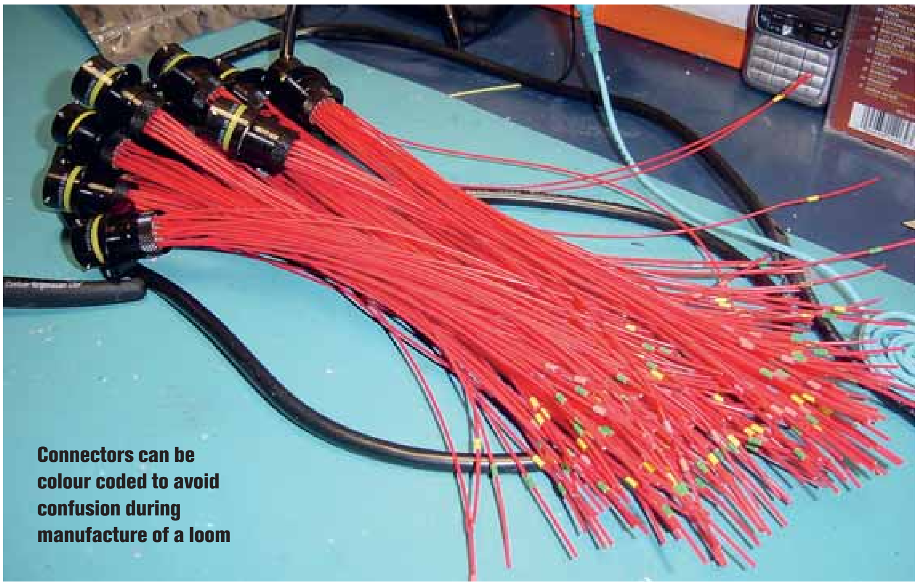
is completed and at least partially built it needs the loom to be constructed and fitted, fast.

Lead times for connectors – perhaps the most critical part of a loom – were a problem in the past. Twelve weeks was a common waiting time to receive product from market leaders Souriau and Deutsch. But then the latter adopted a system of 'value added distribution.' This meant that specialists in one market assembled the connectors from kits supplied by the manufacturer to whatever the clients' needs were. This way of working substantially reduced the lead times to days instead of weeks. Both manufacturers now operate this system, Souriau with Beru F1 Systems and Deutsch with Servo Ltd, both based in the UK.

Of course, not all racecars have such complex electrics and it seems that a lot of car constructors, including most Formula Student/SAE teams, do little more than rob old OE components, or their aftermarket equivalent. They also seem to take little care how the wiring is done – many cars under the skin looking like borrowed multicoloured wiring from a personal hi-fi system, with unshielded and poorly secured wiring running everywhere. And it's not just the FSAE either, numerous professionally-built racecars also suffer from this syndrome, and it causes countless unnecessary reliability and serviceability issues.

Connectors are one area where significant weight and serviceability gains can be made in a cars' wiring loom. Proper aerospace-spec connectors offer both weight saving and reliability, having been developed either for military applications or motorsport itself, whereas the plastic multiplugs sold in aftermarket shops or used on road cars are not really up to the demands of motorsport. Yet time and again they are found on newly built competition cars.

Vibration alone can do more than shake these cheaper products apart, it can cause the connector to resonate and erode the contacts away. Not so much a problem in a 40-lap Formula SAE Enduro event but crucial in a tough event like the Sebring 12 hours, where the cars run on →



Connectors can be colour coded to avoid confusion during manufacture of a loom

> **"PROPER AEROSPACE-SPEC CONNECTORS OFFER BOTH WEIGHT SAVING AND RELIABILITY"**

Souriau

One of the world's leading manufacturers of connectors for application in severe environments, supplying to everything from high-speed trains to satellites. Although its main facility is in Le Mans (there are others dotted around the globe) it only made its first steps into motorsport in 1990 with Renault Sport's grand prix engine programme. From there it moved on to work with Peugeot, supplying military-spec connectors for the 905 Le Mans racer. That association with Peugeot continues to this day.

In 1997 Souriau developed the fighter aircraft-derived 8STA range of connectors specifically for motorsport, and created a partnership with Beru F1 Systems to distribute and maintain the motorsport client base. Recently the firm has released its smallest ever connector for the motorsport market, the size two 8STA *(below)*.

Souriau's main facility is in Champagné, near Le Mans in France. It now has 1530 employees worldwide

"THE DAYS OF TRADITIONAL CONNECTORS AND LOOMS COULD BE NUMBERED"

rough airport runways for prolonged periods. And you don't see teams changing connectors after each event, so long-term reliability is key.

Even more important for the amateur racer is cost control. There is the opinion that if you start with a better quality product, you will spend less in the long run. Souriau's 8STA range, for example, was derived from connectors used in the Eurofighter Typhoon then adapted for motorsport usage, which makes them sound expensive but in fact they are reasonably affordable. Whilst the price is dependant on volume and materials, the price for a size six – the most popular for racecar applications – is around £11 ($19) per connector. Its newer, smaller and lighter brother, the size two, is only a pound more expensive. Whilst you may use around 50 of them on a typical, middle-of-the-spectrum car like an LMP3 (Radical, Juno, Ligier etc), it means that a good standard loom could be built for £1000 to £2000 ($1750-$3000) per car. When you consider that these cars cost in excess of £30,000, that extra expense is not too big a step.

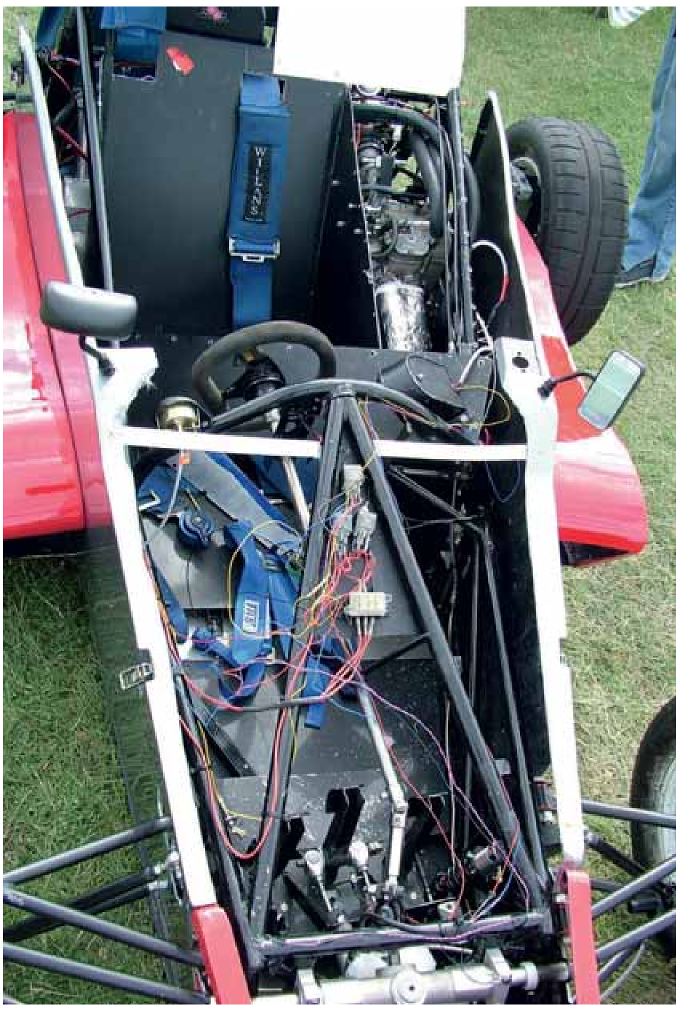
Heat shrinking a finished loom keeps things neat and provides a valuable barrier in a hostile environment

What is really expensive though, at least for the connector makers, is creating an entirely new product. Souriau estimates that it takes between £100,000 and £200,000 in development costs, but claims its latest, the series two, is now beginning to see a return.

The days of traditional connectors and looms could be numbered though, with the development of new technologies which some see as overdue, especially considering that making an electrical circuit out of metal wire is essentially 19th century technology. Fibre optics are one area of research that is ongoing, as is lighter and smaller than conventional wiring capable of much higher levels of data transfer. But this technology does have some inherent problems. Cables cannot be bent round tight corners (25mm being the typical radius limit for OEMs), making it hard to package the cables in the tight confines of a racecar. Also there are issues with heat, some fibre optic systems apparently shutting down around 75-85degC. Beru F1 comments: 'whilst fibre optics have been trialled, there does not seem to be a requirement in terms of data size on the car at present. It's more likely to be seen in the pits first (transmitting video etc).'

Another interesting technology was seen at last year's Formula Student event when a Swedish team from the Lulea University of Technology ran a car with very advanced electronics, including a Bluetooth-actuated gearchange with no loom from the driver controls to the transmission. Whilst there are obvious security risks, in the future it's questionable whether racecars will even have signal looms.

For the time being though, one of the first new areas the connector firms are researching is combining power and signal pins into the same connector – something we can expect to see on the market in the near future.



Here's an example of a wiring loom in an FSUK car that has not been properly thought out. It works, but for how long?

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Aero dynamics

Continuing our look at racecar wings, this month focusing on the issues surrounding their deployment on a racecar

Words	Simon McBeath
Images	Advantage CFD; LAT; McBeath

In issue V16N3 we looked at the basics of selecting a wing configuration and choosing suitable profiles, and we considered other factors including slot gap sizes, aspect ratios, end plate sizes and profile optimisation. But there are other issues to be addressed, some of which relate to the aerodynamic interactions between the wings and what's around them, be that other parts of the car, or the ground. And these issues can have a strategic bearing on how wings are best utilised.

Among the topics we'll consider further is ground effect, and how it can work for and against front wing performance. We'll look at the surprisingly far-reaching effects of flap angle adjustments on dual-element front wings and answer the questions, are two front flaps better than one? And is a wide front wing span necessarily best?

Rear wing issues include overhang behind the axle line, and whether running the wing at the maximum permitted height is always going to be best. And again, is utilising the maximum permitted span the way to go? What about interactions with the underbody? Let's look at some thought-provoking case studies.

> This month, in our need-to-know information section, we continue our in-depth look at racecar wings. How they relate aerodynamically to other parts of the car and the ground and how different aspects of their design can have a bearing on your decision at buying time

Front wings

In discussing how 'powerful' a front wing needs to be to balance rear generated downforce, reference is often made to the 'classic' view of ground effect. This has it that (front) wing generated downforce is amplified as the wing is moved closer to the ground, as depicted in figure 1. But this only holds true up to a point. Two other effects can come into play to spoil what looks like a free lunch. The first, as can be seen from figure 1, is that if the wing is operating in the regime at the left side of the graph, small changes in ground clearance (expressed here as a decimal fraction of overall chord) can produce quite significant changes in downforce, which can lead to inconsistent performance and feel.

Secondly, when the wing gets too close to the ground, viscous effects intervene and reverse the downforce gains made up to that point. This, combined with the above effect, can increase the inconsistency of the front end, and at its worst can generate the dreaded 'porpoising' effect. Figure 2 is from two-dimensional CFD studies done by Advantage CFD on Champ Car front wings, and shows the lift coefficients of four different dual-element front wings plotted against height (expressed here as a decimal fraction of mainplane wing chord, c). Pretty clearly all four wings see a decline in $-C_L$ below a height of 0.2c, a distance that corresponds to a ground clearance of 55-60mm on a wing with mainplane chord of 275-300mm. What is happening at these low ground clearances?

Figure 3 helps to explain. This shows pressure distributions plotted from the leading edge (left) to the trailing edge of one of these dual-element wings at four different ground clearances, once again expressed as a decimal fraction of mainplane chord. The pressures along the upper and lower surfaces of the mainplane and flap are plotted, and of particular interest is the 'suction' developed on the lower surfaces, shown by the curves that drop below the x-axis. As the wing height is reduced to 0.2c (yellow line) the suction under the mainplane increases to its maximum magnitude, and the flap underside also develops its maximum suction. However, at a height of 0.15c (blue line) the suction has reduced on both the mainplane and the flap. The cause? The blue line can be seen to level off towards the rear of the mainplane, and this is a clear sign of flow separation having occurred. The reasons for this are two-fold: first, the pressure gradient between the lowest point of the wing and the trailing edge has become too steep and this, combined with the shrinking wing to ground gap, has reduced the mass flow needed to sustain flow attachment on what is an over steep pressure gradient. This causes the flow to separate, which leads to a loss of downforce.

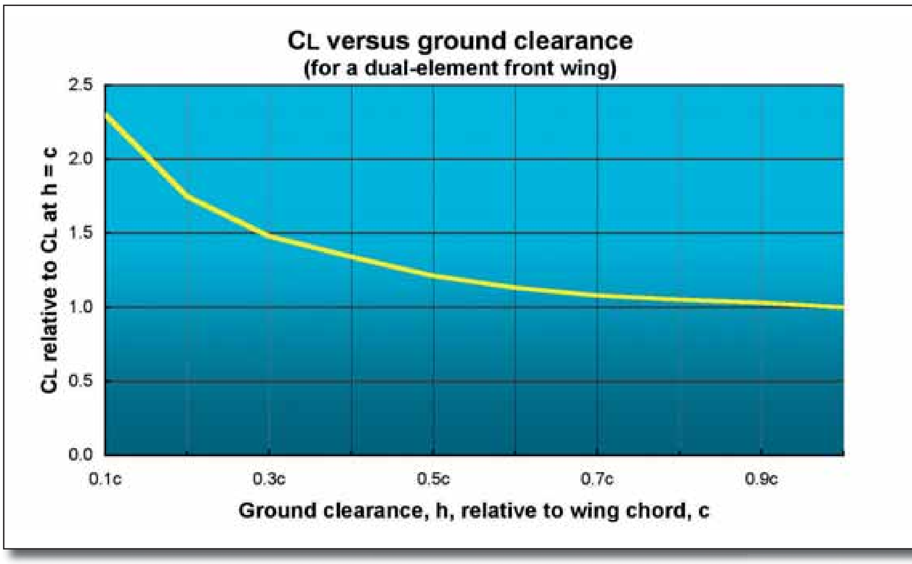


Figure 1 (above): the classic view of ground effect, CL being amplified as the wing is lowered towards the ground (*Competition Car Aerodynamics*, McBeath)

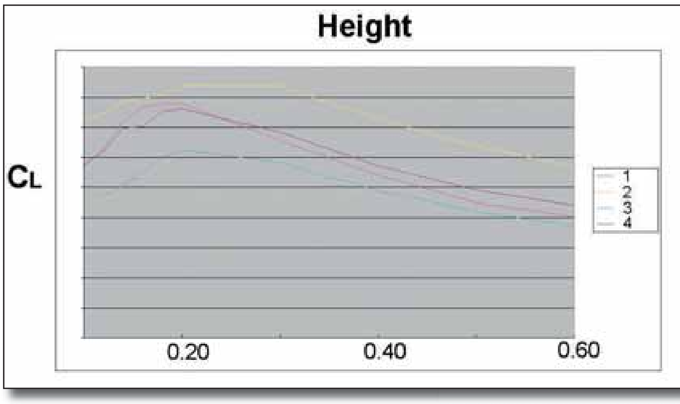


Figure 2 (left): but in reality, front wing performance reduces at low ground clearances. This plot shows the lift coefficients of four wings tailing off near the ground (Advantage CFD)

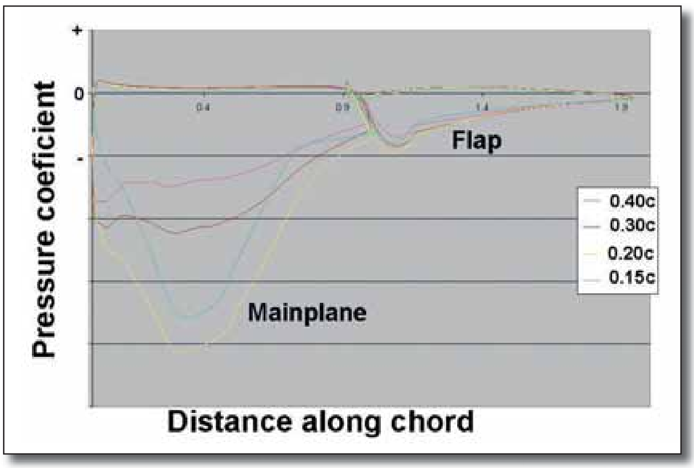


Figure 3: this pressure distribution plot shows a reduced pressure coefficient and flow separation on the mainplane at the lowest ground clearance tested here (Advantage CFD)

> **"FRONT WINGS SHOULD NOT BE RUN TOO CLOSE TO THE GROUND"**

So it appears that front wings should not be run too close to the ground in an excessively greedy attempt at exploiting ground effect. But does this apply to all configurations of front wing? Well, Advantage CFD also examined a dual-element configuration with a wider slot gap (vertical separation) between the mainplane and flap, and a triple-element configuration of similar overall shape. It seems that the larger slot gap on the dual-element configuration generated greater downforce than some of the earlier dual-element wings, and allowed downforce gains to continue to a somewhat smaller ground clearance, but separation still occurred as height reduced to 0.20c. However, when the wing was converted to three-element configuration, although the downforce generated at greater heights was less than the large slot dual-element wing (and no better than the other dual-element wings), gains continued below 0.20c height, and had only levelled off at around height = 0.15c. It would seem that the additional slot was preventing flow separation occurring at low ground clearances (and would probably therefore help at high flap angles as well). So if this sample is any guide, and if the rules allow low front wing heights, a three-element configuration could be the way to go. Interestingly, the raised front wing heights mandated in Formula 1 in 2005 saw fewer triple-element front wings being run, which perhaps bears out this study.

The effect of front wings on the aerodynamic performance of the rest of the car is reflected in some whole-car, three-dimensional CFD done by Advantage on Champ Car front flaps angles. As expected, increasing flap angles saw gains in front wing downforce (of about 10-12 per cent per three degree additional inclination). These contributed to a forward shift in balance, but the changes to balance were higher than could just be explained by the front wing downforce gains. In fact the downforce felt at the rear wheels also declined with each additional front flap increment. This is often put down to mechanical leverage (the front overhang levering up the rear wheels), and although that effect does occur, there are aerodynamic changes downstream that also contribute to the balance shift.

Figures 4 and 5 illustrate some of the far reaching effects of increasing the front flap angle from its lowest setting by just three degrees. These two figures are 'delCp' or 'delta Cp' plots that show the changes to the static pressures felt on the surfaces as the result of the change. →

Thus, reds and yellows show increases, and blues and greens show decreases in static pressure following the increase in front flap angle. Figure 4 shows there have been relatively minor changes to static pressures on the upper surfaces, although there is increased pressure on the front wing mainplane. There is also reduced pressure on the front of the rear tyres, and increased pressure on their tops. These two changes explaining not only reduced rear wheel lift, but also reduced rear wheel drag.

The view from beneath in figure 5 tells of more significant changes though. The much reduced static pressure (blue) on the underside of the front wing is very clear, the increased flap angle working the mainplane harder. This also results in a slight reduction in static pressure (green) under the nose and forward most part of the chassis. However, further downstream it is also clear that there has been a modest increase in static pressure (yellow) under much of the underbody,

> **"THE EFFECTS OF CHANGE AT ONE END ON WHAT HAPPENS AT THE OTHER END SHOULD NOT BE UNDERESTIMATED"**

and also under the outer portions of the rear wing. Both these changes mean these areas generate less downforce.

So the effect of changes at one end of the car on what happens at the other end of the car should not be underestimated, especially when making even small adjustments to powerful devices like the front wings. However, it is worth mentioning that this study also showed what is often not appreciated – that although adjustments to the front wing made appreciable differences to downforce levels and balance, total drag barely changed at all.

An oft-stated rule of thumb is to run wings at the largest span allowed, and it is true that, in general, a larger span makes for a more efficient wing, not to mention a greater plan area (assuming the chord dimension remains unchanged) to create downforce. However, there are exceptions to most rules, and the following CFD study shows how a narrower front wing proved to be of benefit. Advantage CFD evaluated the two front wings shown in figure 6 on a 2002 Reynard Champ Car. The results showed that overall downforce improved by two per cent and there was a small balance shift to the rear.

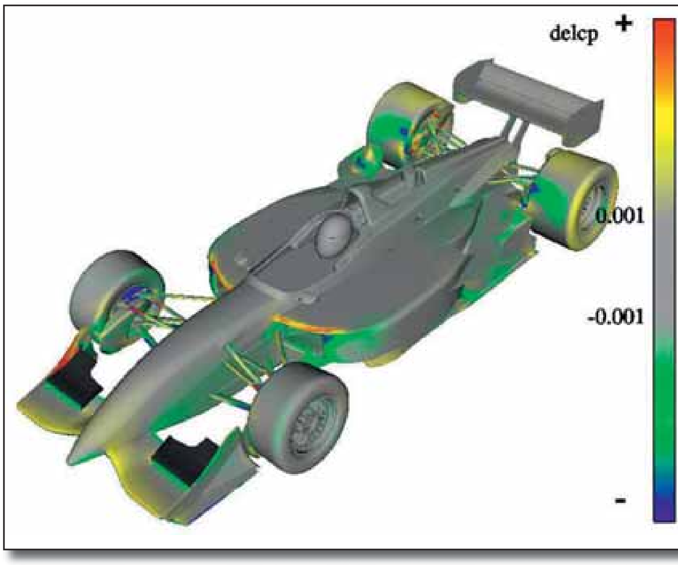


Figure 4: increasing the front flap angle produced relatively minor changes to static pressures on the upper surfaces... (Advantage CFD)

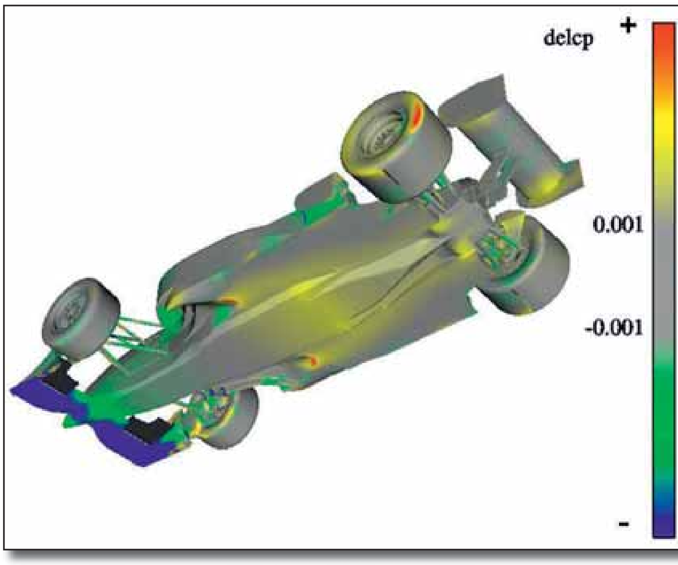


Figure 5: ...but the changes on the lower surfaces were much more significant

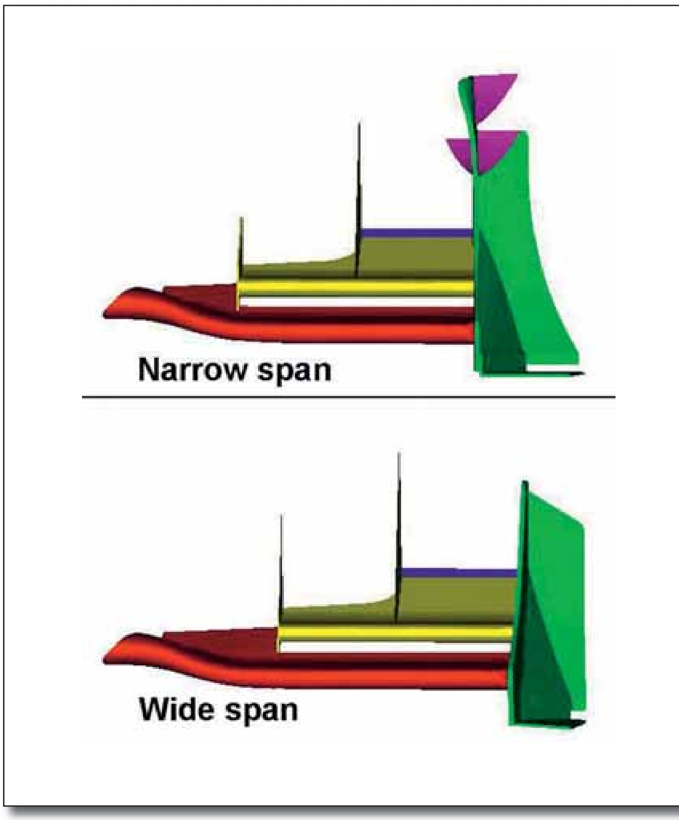


Figure 6: these two different span front wings were evaluated (Advantage CFD)

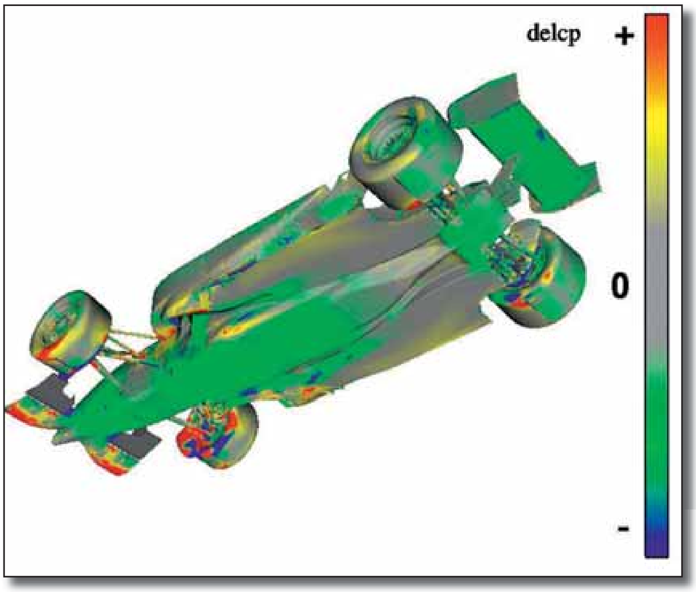


Figure 7: the narrower front wing produced gains in the underbody and under the rear wing (Advantage CFD)

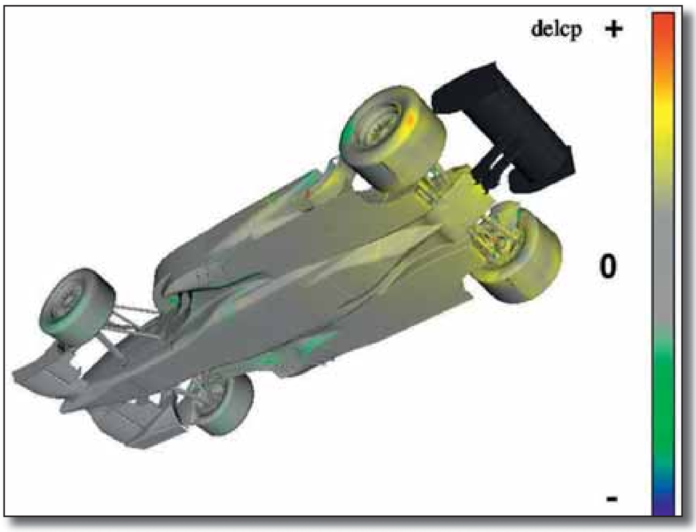


Figure 8: moving the rear wing backwards saw increases in static pressure in the rear underbody, which lost downforce there (Advantage CFD)

Intriguingly, front-wing downforce remained unchanged (the end plate assembly gained what the wing elements lost), but the rear wing gained 1.8 per cent downforce, while the underbody gained a worthwhile 2.4 per cent downforce. Total drag increased by 1.6 per cent so the overall downforce gain was moderately efficient.

Figure 7 shows a 'delCp' plot of the underside and shows the pressure changes resulting from fitting the narrower span front wing. Clearly some areas saw quite complex changes, but dominating the image are the green areas over much of the central underbody and the underside of the rear wing. These are where the downforce gains accrued. So in this case, a change that might have been expected to produce a modest loss of front downforce actually saw no change at the front, but more downforce being generated by the underbody and rear wing. However, for a team that isn't yet looking for the odd small percentage gain to fully optimise a racecar, such changes are probably so minor that they won't even make the job list – for now anyway.

"A LARGER SPAN MAKES FOR A MORE EFFICIENT WING"

Rear wings

Another accepted wisdom is that it is best to run a rear wing as far back and as high up as the rules allow. But there are aerodynamic reasons for supposing that this might not necessarily always be true, even if the logic of trying to mount the wing in the least disturbed air is sound. Advantage CFD evaluated a 2002 Reynard with two different rear wing positions, one about 0.4 mainplane chord distance further rearwards than the other. The forces generated by the wings themselves were unchanged, but the car lost approximately one per cent total downforce with the wing in the rearwards location. Alternatively stated, the forwards location was worth one per cent additional downforce, although this was at a penalty of two per cent extra drag. But perhaps what is of most interest is the loss of downforce in the rear underbody as the wing was moved rearward, as shown in the delCp plot in figure 8. The yellow shading shows that static pressure increased here as the rear wing moved rearward, which therefore means the opposite would be true as the rear wing was moved forward. If development budget was available it might be worth looking at other more forwards locations for the rear wing, or even lower positions, that might amplify the interaction with the →

GT and touring car regulations force rear wings to be masked by the body making them much less efficient

underbody without compromising the wing's own downforce.

Picking up the above point, a glance at some total pressure plots of one of Advantage CFD's Champ Car 'test mule' models is illuminating. Total pressure is an indication of the energy level in the airflow. In these plots, red areas show where the airflow has full freestream energy, and all other colours show where the air has lost energy, due variously to interactions, separations and viscous effects. Figure 9 shows four longitudinal slices showing total pressures around the car: the top one is along the centreline; second from top is 350mm from the centreline; second from bottom is 525mm from the centreline, in line with the inside of the rear wing end plate; and bottom is 100mm outboard of the rear wing end plate.

> **"COMBINED WAKES HAVE AN INFLUENCE ON THE ENERGY OF THE AIRFLOW BENEATH THE WING"**

In relation to the airflow approaching the rear wing along the centreline, the wake from the wastegate atop the engine obviously reaches the wing, but the downwash that the wing induces ahead of itself brings 'fresher', more energetic air downwards towards it. At y = 350mm, outboard of the centreline, there is no engine or cockpit ahead of the wing and it receives the most energetic flow of anywhere along its span, and as a result this region is where it achieves its maximum lift coefficient. However, just inside the end plate at y = 525mm it is clear that the combined wakes of the driver's mirror, the radiator outlet, the flip-ups ahead of the rear wheel and the rear wheel itself are having an influence on the energy of the airflow beneath the wing. Although once again the wing's own downwash seems to be dragging down more energetic air from higher up. And outboard of the end plate we can see the rear wheel and its wake (and that of everything in front of the wheel). The low total pressure in the rear wing tip vortex is also visible at centre right.

What might we deduce from figure 9? That while the wing's downwash has the effect of dragging more energetic air onto its surfaces, it would seem probable that moving the wing significantly forward or downward would take it into less energetic airflow, and we'd see a drop off in the downforce it generated. So while the interaction with the underbody may benefit from moving the wing forwards and downwards, there will presumably be a point at which overall gains will cease because the wing itself loses out. Nevertheless, in circumstances where such freedoms are allowed, this might be a concept worth visiting.

A look at the total pressures from above also yields food for thought. Figure 10 is a horizontal slice taken at the height of the rear wheel tops, level with the bottom of the rear wing mainplane (only the left side of the car is shown here). The wheel wakes are very evident, as is the wake from the centre portion of the car, leaving a narrow strip of energetic air reaching the regions of the wing at about one third (and two thirds) across the span. But notice how this strip widens just ahead of the wing – that's the effect, mentioned earlier, of the wing's downwash bringing more →

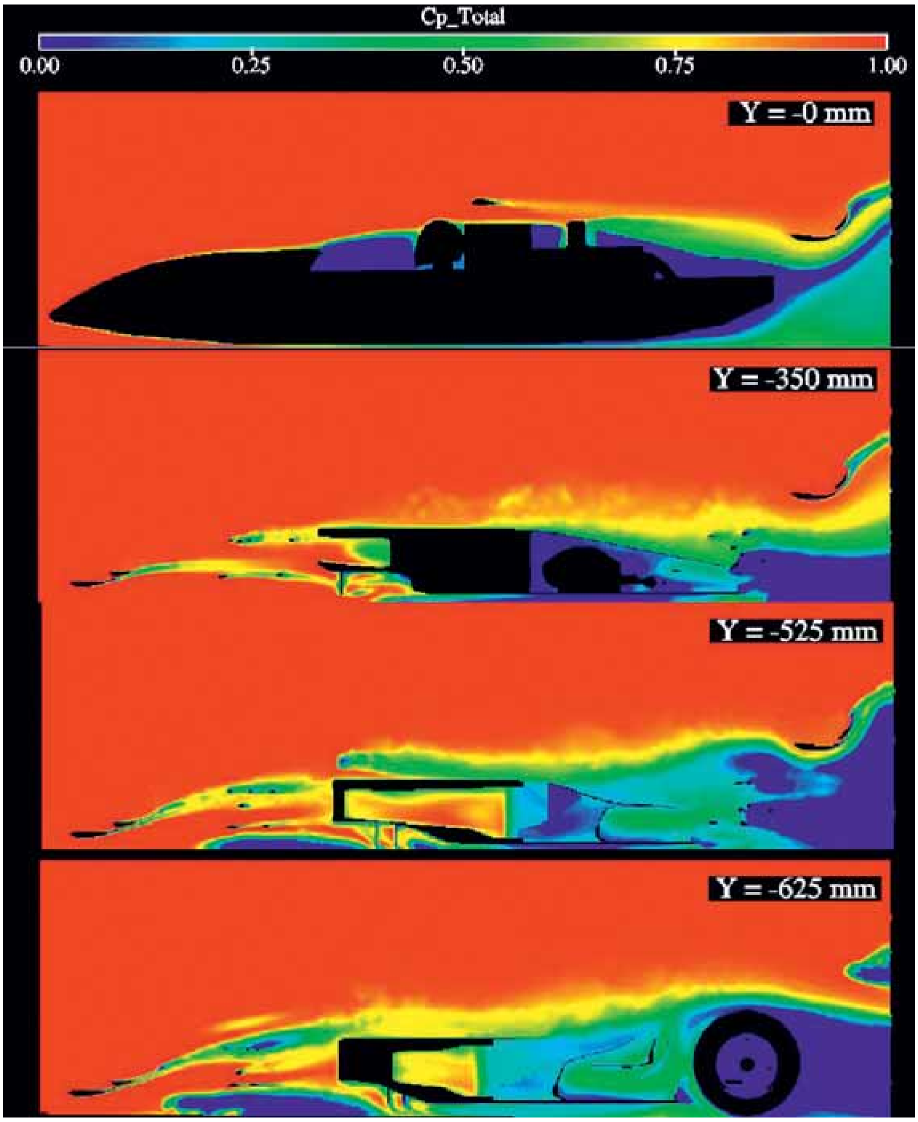


Figure 9: these total pressure 'slices' at different stations across the width of a Champ Car reveal the 'quality' of the airflow reaching the rear wing (Advantage CFD)

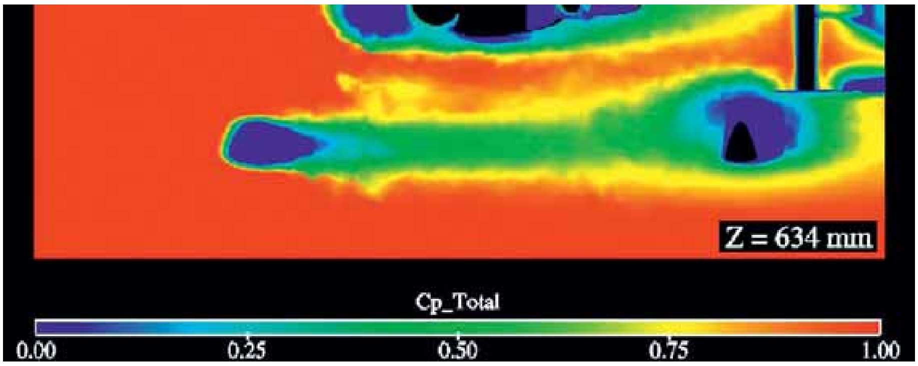


Figure 10: this horizontal total pressure slice is taken level with the bottom of the rear wing mainplane (Advantage CFD)

energetic flow towards itself. However, it is clear that in categories where wider wings are permitted, the wheel wakes would definitely impinge on the flow to the region under the outer portions of the wing, and this in turn would be bound to reduce the effectiveness of these outer regions.

Furthermore, taking figures 9 and 10 into account, how effective will a lower tier to a rear wing be in airflow that, on this model at least, is highly disturbed? Obviously this car was not optimised with that configuration in mind because lower rear wing tiers are not permitted. Had they been permitted, one would have expected optimisation to take different routes. UK hillclimbing permits rear wings of 1400mm (55.1in) span, much wider than Champ Car allows, and also allows as many elements or tiers as a designer thinks appropriate. The GWR Predator featured in V15N11 features twin triple-element rear wing tiers (see figure 11), but designer Martin Ogilvie decided not to run the lower tier at full span, reasoning that efficient performance would

"THE QUEST IS FOR AN EFFICIENT YET BENIGN SET-UP"

not be available in the rear wheel wakes. Our total pressure plots here seem to back up that judgement call.

Of course the situation is rather different for closed-wheel cars, including sports prototypes and GT cars. Katz tells us that lowering the rear, dual-element wing on a generic sports prototype car fitted with underbody tunnels dramatically improved overall downforce, up to a point at least. The wing was positioned so that it could interact with the diffuser exits, and as it was lowered towards the body, downforce kept climbing. Katz refers to this interaction as the 'pumping action' of the wing on the airflow through the tunnels, and goes on to say that the low static pressure induced by the wing at the diffuser exits helps reduce flow separation in the diffusers and increase mass flow. This in turn would help increase mass flow through the whole underbody, which would explain why there was a beneficial reduction in static pressure right to the front of the car's underbody. The effect worked until the wing was about half its own chord dimension above the rear deck. At this point it is suggested that the car's boundary layer started to block the flow to the gap between the wing and the car, which lessened the interaction between the wing and the underbody. So this configuration can be highly beneficial, but again relies on keeping the wing in clear air, away from airflow that has lost significant energy, such as in the boundary layer over the rear bodywork, or in the wakes of upstream components.

Figure 11: the GWR Predator uses the maximum permitted span for its upper wing tier but the lower tier was kept narrow to avoid the rear wheel wakes (the central battery location was temporary by the way!) (McBeath)

Figure 12: positioning a rear wing to better interact with the underbody can yield gains in downforce (McBeath)

Having examined total pressures around single seaters in this article it's impossible not to start speculating on the FIA's latest proposal to slow Formula 1 cars – the Centreline Downwash Generating (CDG) rear wing. This concept involves putting two narrow span wings (seemingly) right in the rear wheel wakes. The CFD image released by the FIA of the total pressure around the car with CDG wings in place, apparently taken on the centreline to best illustrate their sales pitch, does not of course illustrate what might happen along a longitudinal slice taken through the wheels and the out rigged wings. So while the narrow centre portion of the airflow coming off the car might initially approach a following car at a more favourable angle (a debatable point, too), the air coming off the wheels and wings is going to be very disturbed indeed. We must all be eagerly awaiting some hard, independent data to better inform us...

Meantime, most of us do not have access to CFD or wind tunnels, so pragmatically speaking our best guesses on utilising wings on our racecars are almost always going to have to do. But hopefully this consideration of some of the issues will assist in the quest for an efficient yet benign aerodynamic set-up. RE

References

1. *Race Car Aerodynamics*, J Katz, Robert Bentley, 1995
2. *Competition Car Aerodynamics*, S. McBeath, Haynes, 2006
3. Thanks to Advantage CFD (www.advantage-cfd.co.uk) for exclusive access to several reports in the compilation of this article.

Keep on the grass

The clinical world of an F1 research and development department is a very long way removed from the quarter-mile dirt tracks of Britain's Autograss racing scene

Brown (above) and Moss (left) – both drive and both had a hand in engineering this intriguing racecar

Words & photos | Tim Whittington

Autograss as a sport is a bastion of free engineering and an arena in which the self builder can, and regularly does, take on and beat commercial car builders. Which is pretty much what Steve Brown aims to do with his self-built Class Nine special. In real life Brown works in the R&D department at Honda Racing F1 but in his own time he and partner Jo Moss have designed and built one of the most intriguing Autograss cars to hit the tracks in recent years. Moss has worked for Lola, Reynard (head of aero), Toyota (head of aero/race engineer) and Vauxhall's British Touring Car team, Triple Eight, before moving to metrologists Mitutoyo, where she works with the company's automotive and motorsport clients.

Autograss and motor racing is deeply ingrained in Brown's psyche – he hails from Wales (one of the sport's strongholds), and his parents both competed very successfully for many years. Moss has been dragged into this particular type of dirty weekend by Brown and shares the driving in the sport that runs its 10 technical categories twice, once for male drivers and again for female racers.

With career paths that have already covered Champ Car, sportscar racing, F1 and BTCC, the pair can call on a wealth of motorsport knowledge and know-how in the build and preparation of their own car. The result is probably one of the most thoroughly designed and thought out cars of its type ever constructed.

The basic structure of the car is governed by the National Autograss Sport Association (NASA) that sanctions the sport in the UK and Ireland. The only real constraints are on the materials used in structural areas of the car – for instance, the main elements of the rollcage must be at least 32mm in diameter and of 2.5mm wall tube. There is a complete ban on any form of composite or plastic material in the body panels, and limits on the capacity of the engine. There are seven saloon categories and three classes (Eight, Nine and Ten) for open-wheel specials: up to 1420cc, 1421 to 2070cc and over 2070cc. Brown and Moss have pitched at Class Nine with its 2070cc maximum capacity and ban on motorcycle engines.

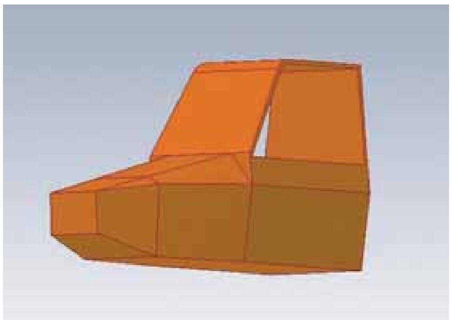
> **"THE ENGINE AND DRIVELINE IS FROM A BTCC-SPEC VAUXHALL ASTRA"**

Moss narrowed the choice of class after identifying some very useful characteristics in the Z22SE-based Vauxhall touring car engine while she was working at Triple Eight. Having targeted Class Nine and secured a deal to acquire a complete Vauxhall engine and transmission package, Brown and Moss set about designing a chassis. The initial sketches were done on bits of scrap paper while the couple were on holiday, those ideas then modelled/drafted on CAD to produce a working design.

'Steve came up with the idea of making a mock-up chassis using wire mesh before finalising the design,' explains Moss, 'thus giving us the opportunity to make sure you could get in and out, position components, that kind of thing.' The design was tweaked following this trial process before the final spec of the car was locked down.

The pair have conceived the chassis with the primary aim of being as light and stiff as possible, as well as allowing them to adapt and develop the suspension geometry as they go along. 'It doesn't matter how good your suspension is if there's a big sponge between the front and rear wheels,' says Moss. Although they maintain that stiffness to weight is always a trade off or balancing act.

The suspension too has not been left to chance. The set-up is again the result of an extensive computer design process that has resulted in geometry that offers eight inches of wheel travel but produces no bump steer at the front, while some toe change is employed at the rear. Additionally the design allows both bump steer and roll steer to be accurately controlled and adjusted. As well as being a good basic principle, this is vital in an Autograss car that – because of



Chassis was mocked-up in wire mesh first to ease placement of components and seating position, then CAD modelled prior to final build

the sideways, opposite lock style of driving – has prodigious steering lock and a very fast rack, just one turn lock to lock. Brown has engineered the car so that front camber change is just 2min/10mm of wheel travel and 5min/10mm at the rear. Brown says his theory being that the front requires less camber change due to the camber change with caster through steering angle and also to keep the front on a more stable and predictable platform.

At the front there are double, unequal length wishbones with inclined coilover damper units. Suspension items used on the car in its two outings late in the 2005 season are due for replacement and/or refinement before it races in 2006. The dampers are set to be replaced with more sophisticated items and the fronts will migrate inboard (as per the car's original design

spec), purely to remove them from the elements rather than for motion ratio or aerodynamic reasons. The current fabricated uprights are also to be superseded, by lighter and stronger machined billet alloy items.

'Using fabricated uprights is fast, cheap and easy,' says Moss. 'You can design the car around what it should be doing but when it's on the track it may do something different, especially when you're racing on dirt and you never get two laps the same. This way allows us to decide what →

Front suspension (above) features double unequal length wishbones, fabricated uprights and 8in of suspension travel

Rear has converging link suspension rather than more conventional swinging arm. This allows accurate tuning of bump and roll steer

Brakes are unusually large but use narrow discs to reduce rotational mass

Ancillary components are carefully sited for a low polar moment of inertia

Tilton pedal set and unassisted rack and pinion steering are simple and effective

EFi Gear Dash offers a wealth of instant feedback through 16 input channels

EFi Technology ECU allows driver to switch between maps to suit track conditions

the car needs, then re-assess and perhaps make changes. Flexibility is key.'

The car's converging-link rear suspension caused a great deal of head scratching when it first appeared in public, largely because this kind of 'radius rod' arrangement has been almost totally eclipsed by what 'grassers colloquially refer to as 'swinging arms' (see sidebar).

'The multi-link set-up has more flexibility than swinging arms because you can tune individual aspects of its performance,' says Brown. 'Arms are stronger in some aspects, particularly if you get knocked around, but they compromise the set-up of the car. The multi-link set-up allows us, for example, to tune bump and roll steer independent of camber change.'

The two end-of-season events did reveal the car was getting too much squat, therefore reducing bump travel and this is a characteristic that will be reduced ahead of the 2006 season.

'This is the sort of car that will never be finished because we will keep on tweaking and improving it. Our philosophy was that you get one shot at the chassis – nobody wants to make unscheduled, fundamental chassis changes halfway through a season – but that everything attached to it can be changed and developed. Your imagination never stops so the car will always evolve. The chassis isn't expensive in material terms, there's only around £500 of steel in it, but it's very time

The specials

Just about the grassiest, rootsiest form of motorsport you are ever likely to find, Autograss has developed from 'jalopy' racing that took part in rural areas of the UK in the post-war years. In 1976 it was formalised and brought under the control of a single national body, NASA (National Autograss Sport Association). The sport has developed rapidly in the last decade during which a handful of businesses offering proprietary chassis and/or complete cars have grown up.

Autograss specials began as stripped down, front-engined saloons, but soon developed into conventional rear-engined, single-seat, open-wheel racecars. Double wishbones and outboard inclined spring/damper units remain standard fare at the front (though inboard pushrod set-ups are now coming through) while multi-link, radius rod rear ends have now been almost eclipsed by swinging arms.

Pioneered by Chris Allanson (*Racecar Engineering* V6N5 and V8N4) and his Z-Cars marque, this design has now been interpreted by every other car builder in the sport. Allanson originally used semi-trailing arms from a Triumph 2000, but later replaced these with fabricated steel items, initially with a cantilever action on horizontally mounted spring/damper units. Allanson, and his imitators, have subsequently replaced this with a longer spring/damper unit that is inclined slightly inwards and towards the front of the car. The system soon gained favour as it appeared to give better startline performance and, in a sport with 10 car abreast starts, any advantage gained here is vital.

"SIDEWAYS IS THE RIGHT WAY IN AUTOGRASS"

consuming to build and to control the welding and manufacturing process to ensure the chassis is as accurate as possible to the design,' says Moss. As 'accurate as possible' because it's not possible to replicate the accuracy of CAD's fractions of a millimetre in such fabrication work.

Autograss cars are softly sprung – this one has a frequency of 1.2Hz front and 1.4Hz rear. An anti-

"THE 'LEARNING' FUNCTION OF THE ECU COULD BE AN ACE UP THE SLEEVE OF THIS CAR"

roll bar will be added to the rear end in the winter and, when we saw the car, Brown was narrowing his damper choice and looking to have three or four-way adjustable units that would allow accurate control of high and low-speed characteristics in what he refers to as a 'traction-limited' sport.

Autograss specials, particularly those with a transverse engine installation, have a natural predilection towards a rear-heavy weight distribution (as much as 80 per cent, as more rear weight equals more traction). Some also employ the Porsche theory with the engine overhanging the rear axle centre line. The Vauxhall engine, however, has to be mounted in the chassis with its induction side between the engine and cockpit, so Brown and Moss have opted for a reduction in this trend with their car. Instead they have worked hard to position the major components to give a low polar moment of inertia.

Brown says the big deficit from such high rear weight bias relative to overall mass, together with high power output, is the tendency to suffer →

Tech specs

Chassis:	steel spaceframe
Bodywork:	aluminium panels
Engine:	Sodemo Vauxhall Z22SE
Number of cylinders:	four
Displacement:	2.0-litres
Valve operation:	double overhead camshafts
Sparkplugs per cylinder:	one
Power:	300bhp/260Nm torque
Front suspension:	unequal length double wishbones and inclined spring/damper units
Rear suspension:	converging multi-link, inclined spring/damper units
Steering:	unassisted rack and pinion
Brakes:	Alcon 240mm (F) and 280mm (R) discs and four-pot calipers
Wheels:	front – 6×13in magnesium Minilites; rear – 6 or 7×15in aluminium alloy
Tyres:	front – 165/70 R13; rear – 185 or 195/65 R15
Transmission:	Xtrac six-speed, sequential-shift
Data acquisition/ECU:	EFi Technology
Wheelbase:	2082mm
Front track:	1524mm
Rear track:	1473mm
Weight:	499kg

Now, however, with this system almost universally adopted, its handling characteristics leave the majority of racers seeking the same piece of racetrack, so Brown and Moss believe that returning to a traditional set-up, and optimising the car to handle well in all conditions, will allow them to race in areas of the track the swinging-arm cars can't easily use.

Sideways is the right way in Autograss but, with some cars now set up in such a way that merely lifting off the throttle provokes oversteer, Brown argues that his unique car gives him more options: 'If the car oversteers as soon as you lift off you are committed to one approach, one line, and if someone is doing something different in front of you, you are stuck. Our car will turn in and work all over the racetrack. I can use a line that doesn't favour others.'

When the Brown/Moss car first appeared in public it wasn't difficult to find 'experts' ready to take a cheap shot at its design, in much the same way some racecar engineers and designers have in the past looked at Autograss cars with swinging arms and pronounced that they could not possibly work. But they do, and looking at the sound principles and practices that underpin the Brown and Moss car it should be plain that this car will work, too.

All that remains to be seen is whether the car is quick enough from starting gate to first bend to allow its drivers to exploit its handling advantage to the full.

In only its second trial event Brown won one race and crashed just after the start in the second, but was happy with his day's work. Why? Because the driver he tangled with is Class Nine national champion, drives one of the fastest starting swinging arm cars currently in the country, and Brown was level with him in the dash to turn one...

By returning to an older style of suspension and optimising the set-up the duo hope to be able to take full advantage of the track in a way the swinging arm cars cannot

Placement of engine with induction side inboard reduces rearward weight bias. Sodemo engine and Xtrac gearbox are exactly as per BTCC spec Astra, bar the ECU

from excessive torque reaction – the front wheels of some specials are lifted clean off the floor on hard acceleration. With a slightly longer than normal wheelbase and lower rear weight distribution they hope to balance the traction/torque reaction equation.

Static roll centres are ground level front and 100mm at the rear, which is quite different to their dynamic positions due to the pitch seen in these cars. 'Autograss racers are, perhaps, unaware,' says Brown, 'that they make considerable use of the dynamic roll centre positions of their cars, to help promote understeer/oversteer through pitch.' Taken together, this highly engineered set-up endows the car with very neutral handling characteristics.

The car is currently fitted with Alcon discs and four-pot calipers, but both the 250mm front and 280mm rear items will be machined down to 6mm in thickness as part of the winter changes to the car. Again Brown and Moss have departed from current Autograss trends here. While many racers are simply bolting on small discs and motorcycle calipers, they've opted for relatively large diameter discs to gain better braking and temperature control characteristics and afford themselves the option of reducing the width of the solid discs. The modification to the discs, which will also be drilled, will bring the welcome side effect of slightly reducing unsprung weight and, more beneficially, reducing the rotational mass/inertia.

The entire engine and driveline is lifted from a BTCC-spec Vauxhall Astra touring car (the touring car programme uses a 2.2-litre motor sleeved down to 2.0-litres). Mechanically, the Z22SE-based motor is exactly as it was when Sodemo dispatched it for BTCC use. It is rated at 300bhp and 260Nm/192lb.ft of torque and breathes through a carbon fibre airbox and inlet tracts of the same material. The exhaust is a work of art and is as well protected as possible within the rearmost elements of the chassis. The car drives through its BTCC regulation six-speed sequential Xtrac gearbox and driveshafts, and is currently geared to achieve 130mph in sixth. The gearbox incorporates a plate-type limited-slip differential with variable ramps and pre-load settings.

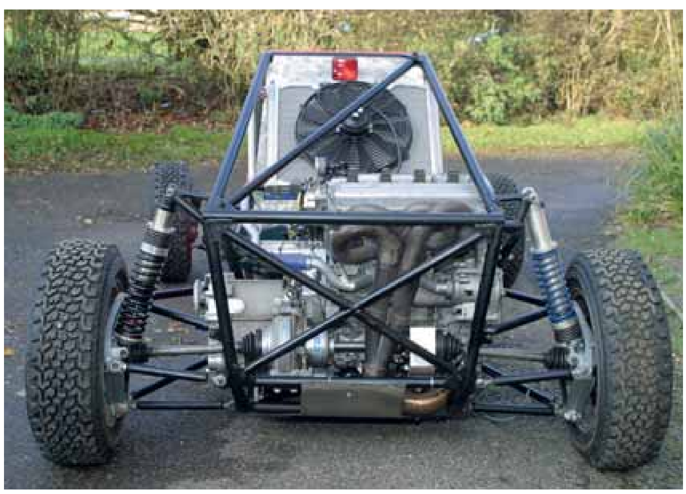
The only difference from the BTCC set-up is in the EFi Technology ECU. The automatic self-mapping ECU, which also has a closed loop idle speed control, is an unrestricted version of the control-spec item used in the BTCC. The 'learning' function of the ECU could be an ace up the sleeve of this car. At championship level Autograss events a driver can quite easily be in the race holding area for 15 minutes, during which the track conditions are constantly changing. There's also the added difficulty of the racing surface being watered to lay the dust. And it's every driver's nightmare to be sitting on the grid looking at a dry track, with the appropriate tyres on their car, only then to see the track watered. However, having a system as flexible as EFi allows them to tailor two high-resolution fuel and spark maps, one for each condition. At the flick of a switch, combined with the self-learn function, it delivers optimum power delivery (to maintain traction) and top end power for the conditions.

"YOUR IMAGINATION NEVER STOPS SO THE CAR WILL ALWAYS EVOLVE"

'The most difficult thing to appreciate is the sheer acceleration of the cars,' commented Ole Buhl of EFi. 'The power-to-weight ratio of Autograss cars ranks them amongst the most impressive anywhere in modern motorsport.'

The car also incorporates EFi's companion 2D 'gear dash' which can utilise up to 16 input channels and shift lights, in addition to a separate gear selection indicator and offers the driver a wealth of instant feedback through three configurable pages.

This will be coupled with data logging for the 2006 season, but Brown and Moss are already wondering what would be possible if they could go for broke with the engine: 'The engineers at Sodemo are interested in what we are doing because it's an unusual application. The engine is good in this spec even though it's restricted. Just wonder what you could do with it if money wasn't an object...' RE



Static roll centre at the rear is 100mm, but is quite different in dynamic mode due to large suspension travel. A rear anti-roll bar is next to be added to the Brown/Moss Special, as well as three or four-way adjustable dampers

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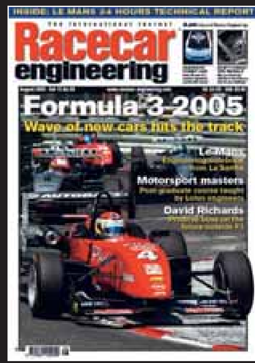

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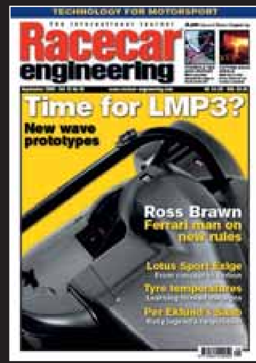

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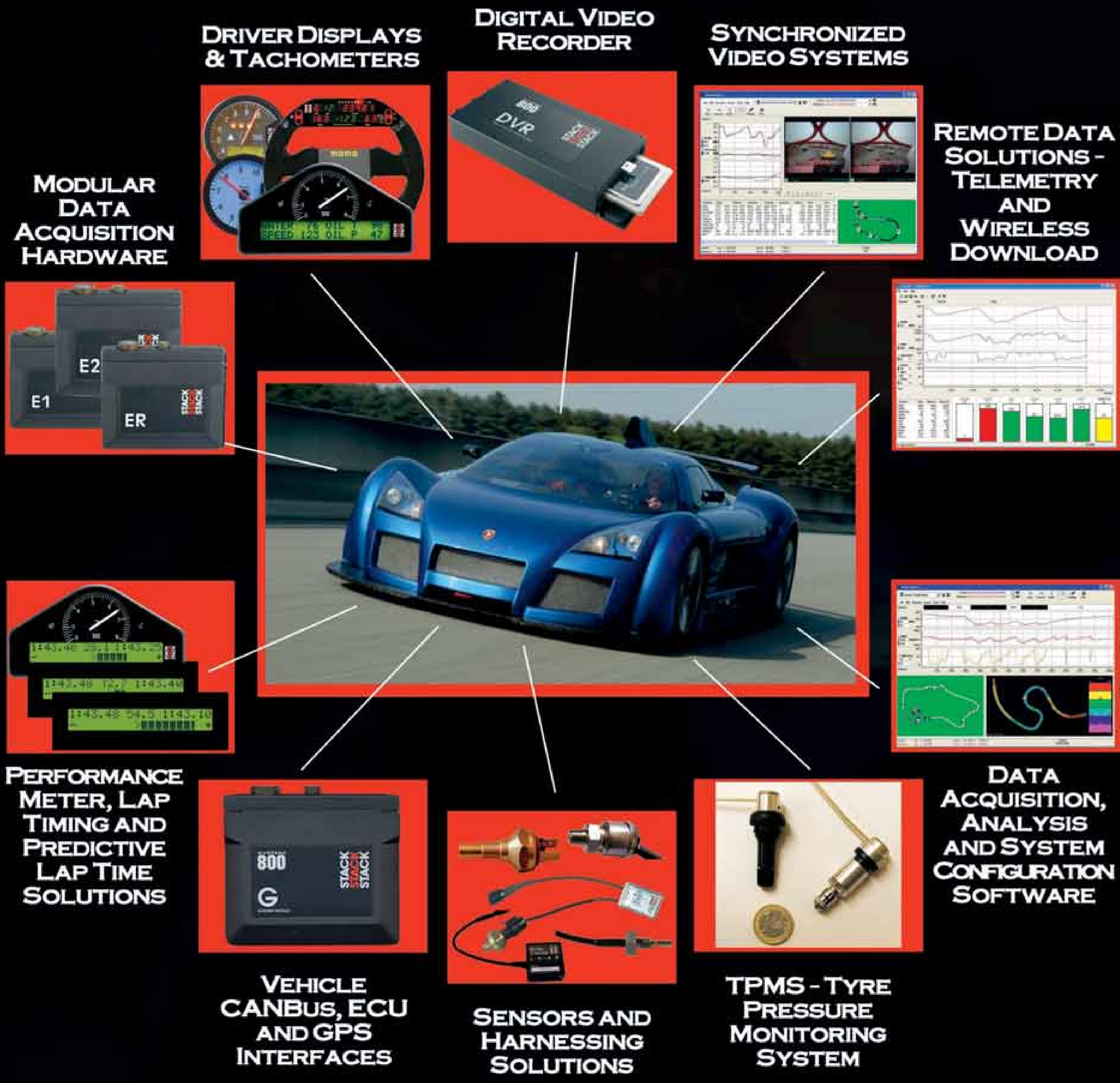

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Raceshop

Raceshop is a section of *Racecar Engineering* written for people who are in the process of designing, building or running racecars. Raceshop is designed to be interactive. We want you, our readers, to let us know about your company, your new products and your engineering problems. Raceshop can provide you with a showcase for your products or the answers to your engineering questions.

Send your details to those listed below for each of Raceshop's sections. You can either send material direct to the Leon House address on Page 5, or to the email addresses below…

Racegear: racecar@ipcmedia.com

Database: Tony Tobias
tony_tobias@ipcmedia.com

The Consultant: Mark Ortiz
markortiz@vnet.net

Aerobytes: Simon McBeath
via: racecar@ipcmedia.com

Information stations

Dashes have come a long way from the multi-gauge confusions of old. Now, one pod does all. Here's **Racecar's** round-up of the latest modules

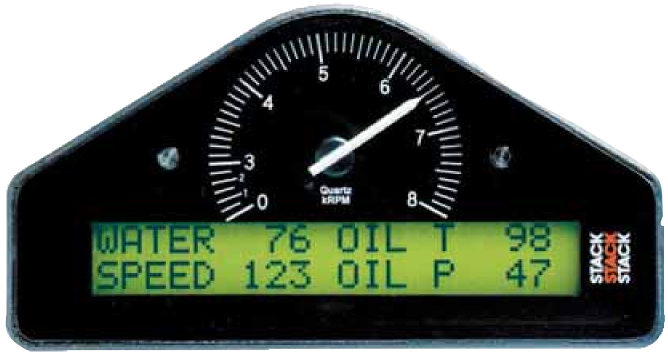
Words | Ian Wagstaff

Long gone are separate gauges to monitor engine function. Easy-to-read, multi-function units are now the only way to go

In the past, the analogue display on the dashes of racecars featured a number of gauges with separate sensors for each gauge. Dashboards had a tendency to be over populated and the result was very confusing for the driver. It was also complex for the team to set up the system. Modern technology has overcome this with far more compact, fully-customised systems that reduce the weight of the wiring. What Pi Research describes, when referring to its X Sport dash, as an alternative to traditional, bulkhead-mounted gauges. All conventional dashboard instruments including tachometer, oil pressure, fuel pressure, water temperature, oil temperature and voltmeter can now be replaced by a single display module, as in Stack's carbon composite ST800 series. Another great advantage over 'old-fashioned' instruments is that modern dash systems can carry out a monitoring function, too, while intelligent alarms mean the driver no longer has to keep an eye on minor gauges.

Such systems can either appear as a conventional-style dash or mounted on the steering wheel. While the latter is fine if dashboard space is restricted it is, as manufacturer Stack points out, not ideal for the simple reason that steering wheel displays are just not as easy to read when the driver is turning into a corner. Having said that, there are times when a steering wheel display system is the only way to go, and for this Stack has produced its ST8600 unit, which was updated in May of last year. This is available in standard specification or as an 'M' version that adds a speed sensor, infrared lap timing, performance meter and predictive lap →

Steering wheel displays, such as this from Farringdon (left), are suitable for cars with limited space. Stack multi-function ST700 tach is also very compact



Stack dash displays such as its 81 00 (right) are fully programmable yet retain an analogue tach, as it claims most racers prefer it. 81 30 series (left) is street unit

timing system. Improvements for 2005 include new shift light LEDs with higher colour contrast to aid visibility and improved actuation of the switches. Options are available for 270mm and 340mm steering wheels.

British firm Farringdon Instruments, like Stack, opted to integrate its dash into the steering wheel, and offers three levels of its SWIS10 system, the highest of which includes performance and data logging.

Autosport International saw the first appearance for a number of new dash displays from Stack, which has now been operating in the motorsport field for about two decades. Its ST8800 user-configurable display offers the user complete flexibility over which channels to monitor, as well as over layout of the display and all alarm conditions. It features three pulse inputs and five analogue inputs enabling the user to choose from a wide variety of sensors. Also new was an Action Replay dash display that has been designed to offer an alternative to PC-based data acquisition systems. It is said to provide an introduction to multi-channel data recording for oval, sprint, hillclimb and drag racing. RPM, speed, temperatures, pressures and lap times can be recorded on the track and replayed in the pits on the display. All Stack dash displays can drive another new product from the company, a five-LED, multi-stage shift light module. Using the dash display menus, each of the five shift lights can be independently programmed to a specific RPM value.

“MODERN DASH SYSTEMS CAN CARRY OUT A MONITORING FUNCTION, TOO”

MoTeC offers a variety of dashes to suit all needs. Its SDL entry level, base product can be used as a display-only dash or can be upgraded and wired to an ECU to carry data logging. Because each SDL has data logging capability built in, a display-only one can be upgraded at any time using a password.

The SDL, which was introduced in March 2005, is aimed at club-level motorsport and is used in a variety of racecars from hillclimbers to club saloons, as well as Superbikes. By contrast, the ADL2 (Advanced Dash Logger) is designed for the more sophisticated user and is an evolution of MoTeC's original ADL unit.

The SDL has the same technology as the ADL2 but comes with a package of features tailored to suit more moderate system requirement. Its high contrast, reflective LCD screen has been designed to be viewed in direct sun and artificial light. An optional, adjustable backlight enables maximum visibility in low light or during night races. A 70-segment curved bar graph can be configured to display any channel, with optional shift markers. The SDL also allows for up to 20 customised warning alarms that can be displayed on the screen as a visible warning or, if data logging is enabled, be stored in the units' logging memory. The SDL supports up to 12 analogue inputs, six digital/speed inputs, eight auxiliary outputs and a single wideband lambda input. The figures for the ADL2 are 28, 12, eight and two respectively.

The ADL2 has a similar screen but its display has three programmable modes that operate independently of each other: practice, which is more focused on laps times and comparison; warm-up; and race, which cuts down the amount of information to that which is necessary. This system prevents clutter allowing the driver to see what is most appropriate for the time. An enclosed version with no display screen of the ADL2 is available as the EDL2. This can be hooked up to a steering-wheel display, the MDD, which MoTeC also offers. This latter is used in such as the Lola B05/40, GP Masters and Daytona Prototypes. Three models are available, using 260mm and 270mm diameter Momo wheels and a 330mm Sparco. They can be customised in a number of ways, with a variety of buttons, button material, switch positions, etching of logos or text, quick-release mechanism and electrical connection method all user specifiable.

Bosch Motorsport is another company in direct competition with MoTeC, pitching for the professional motorsport market with its comprehensive DDU range, fitted on a number of leading racecars. The range offers both wheel and panel-mounted dashes.

The Italian company Aim (Applicazioni Industriali Microprocessori)

MoTec ADL2 (above) is state-of-the-art in dash loggers, while SDL (above right) is aimed more at clubman racers. MoTeC MDD steering wheel displays (right) is fully customisable and available for 260, 270 and 330mm wheels

Aim professional MXL series displays come with integrated data acquisition capability and can be linked to most popular motorsport ECUs

points out that its professional MXL combines all the functions of a digital dash with integrated data acquisition. It shows and records a number of parameters through eight analogue input channels, including pressures, temperatures and potentiometers. The MXL offers a link, by CAN or RS232 protocols, to the most popular motorsport ECUs. The MXL is available as the MXL Pista or the MXL Pro, which has the same characteristics as the Pista but includes two Deustch connectors and four speed inputs.

Aim, which first became involved in motor racing 11 years ago, also now offers the MyChron 3 Plus and Gold (the latter more suitable for track work). These lightweight dashes are particularly suited to analysing various data such as engine, speed and vehicle dynamics. This is also the case with the MyChron 3 XG Log, which has been designed to be installed on a steering wheel. Also for installation on the wheel is the MyChron3 Visor that includes a tachometer, one speed input, gear position and lap time. A kart version, MyChron 4, was launched at Autosport International.

It may also be that a dash is 'dumb', or in other words is driven by the data logger, or the logger driven by the dash. This can be illustrated by Pi Research's steering wheel offering with its 'dumb dash', as opposed to 2005's Pi Xpress X Sport dash, which can both instruct the data logger or operate as a 'dumb' unit itself. In designing the X Sport, with its semi-logging capability, Pi Research took the best elements of a professional product and cut them down to make a dash affordable at club level. That it is still effective higher up the scale can be seen by its use in GT3 racing. If

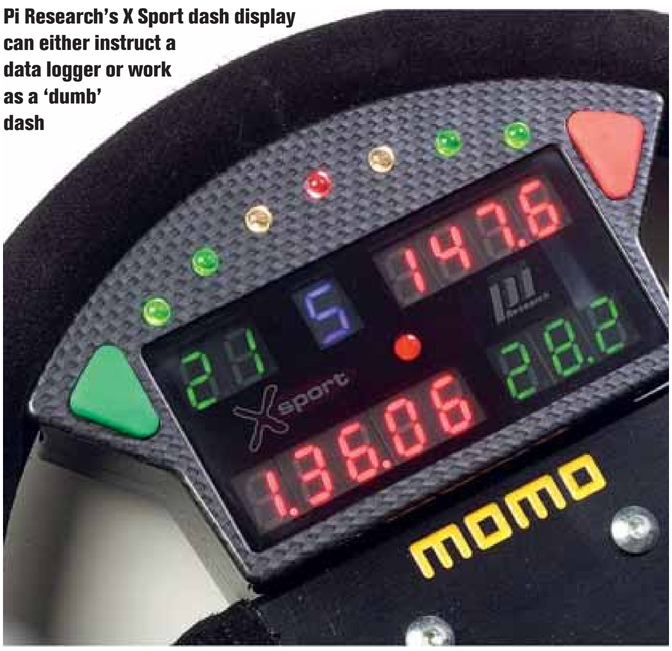
Aim units are available as in-dash displays or as steering wheel versions under the company's MyChron brand. A smaller kart version has also recently been launched

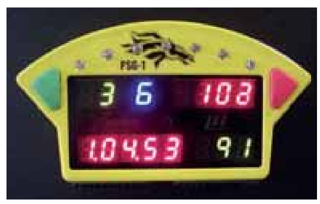
used simply as a display it can operate alongside either the Pi Xpress range of data loggers or the Pectel range of engine controllers. The X Sport dash, which is suitable for steering wheel or bulkhead mounting, features four analogue channels plus digital channels for wheel speed, RPM and beacon.

In addition to the X Sport, which was designed by Jaguar's Ian Callumn, Pi Xpress offers the clubman a Mini dash for steering-wheel mounting and the C-dash, an LED dash which connects to the company's Delta Lite logger.

Pi Research's professional system kits are supplied with a choice of dashboard display and/or satellite modules as standard. Its Satellite steering wheel dash incorporates a gear position indicator, shift lights and two numeric displays, while the Sigma steering wheel dash kit is a unit that comes complete with power loom, switch loom and fitting kit. RE

Pi Research's X Sport dash display can either instruct a data logger or work as a 'dumb' dash





Pi Xpress X Sport (above). Compact C-dash (below) connects to Pi Research's Delta Lite logger

Core value

Tooling costs need no longer make casting an uneconomic alternative for the short production runs typical in motorsport

Complex shapes can be produced affordably as one-offs

Words Charles Armstrong-Wilson

Unsintered sand is poured away leaving the shape of the cores

Metal casting is a cost-effective way of producing large batches of identical components making it a popular process in the automotive industry. But for racecars, where the batch sizes are typically tiny, the cost quickly becomes prohibitive. While the price of having patterns and core moulds made, if spread across thousands of units, is insignificant; for a small batch it can become the dominant overhead. Even with modern CNC techniques the cost of machining a pattern is substantial. Add into this the price of making moulds for complex sand cores to create waterways or cylinder ports and the cost can quickly rule out the process.

Now a process offered by German company AC Tech could change all that. It operates on a system similar to normal stereolithographic rapid prototyping, but rather than curing resin a layer at a time this process sinters casting sand into a solid. Two lasers are used to heat a thin layer of the foundry sand into the shape of a slice of the desired core making it bond together. Then another 0.2mm-thick layer is spread over the surface and the process repeated with the next slice of the core. Gradually it builds up the sand cores that afterwards can be separated from the loose sand.

> “THE PROCESS IS PARTICULARLY ATTRACTIVE FOR THE SHORT PRODUCTION RUNS TYPICAL IN MOTORSPORT”

The moulds and cores produced are suitable for all kinds of casting including alloys of aluminium and magnesium as well as iron and steel. Apart from avoiding the cost of patterns, the process can also create core shapes that would not be possible with normal techniques. Undercuts in complex shapes can be accommodated because the core does not have to come out of a mould. Iterative changes are also easily made allowing developments to be incorporated without expensive changes to the pattern.

The process is particularly attractive for the short production runs typical in motorsport and the company often finds that runs of up to 40 or 50 components can work out cheaper than conventional pattern making. Alternatively, the system can be used in conjunction with conventional patterns. Typically a pattern would be used to create the main outer mould but laser-sintering would be employed to create the finer and more complex internal cores.

It can also be very successfully employed in historic vehicles to replace worn out cast parts for which patterns have long since been lost or destroyed. RE

ACTech GmbH
Halsbruecker Str. 51
09599 Freiberg, Germany
Tel: +49 3731 169 0
www.actech.co.uk
prototype@actech.co.uk

In the UK:
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Sedgley
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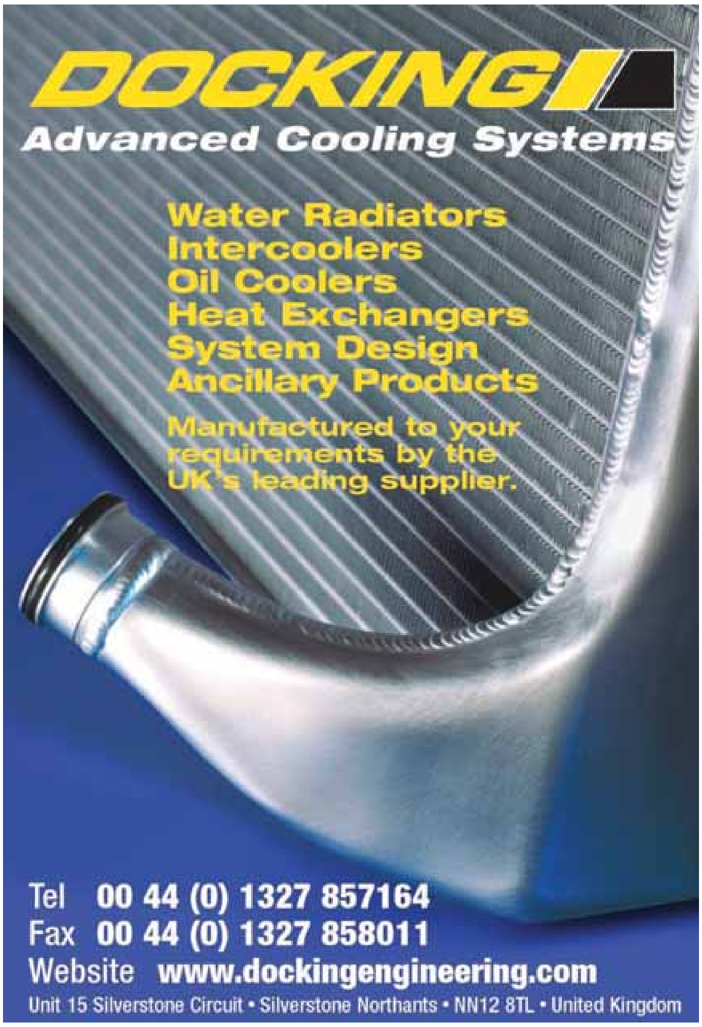
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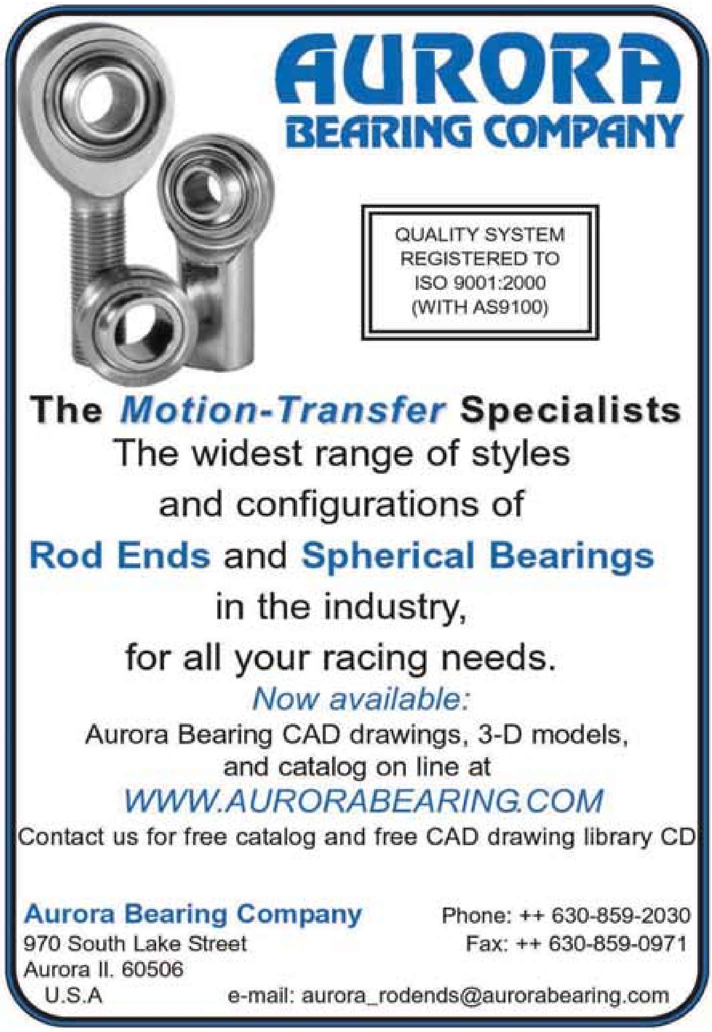
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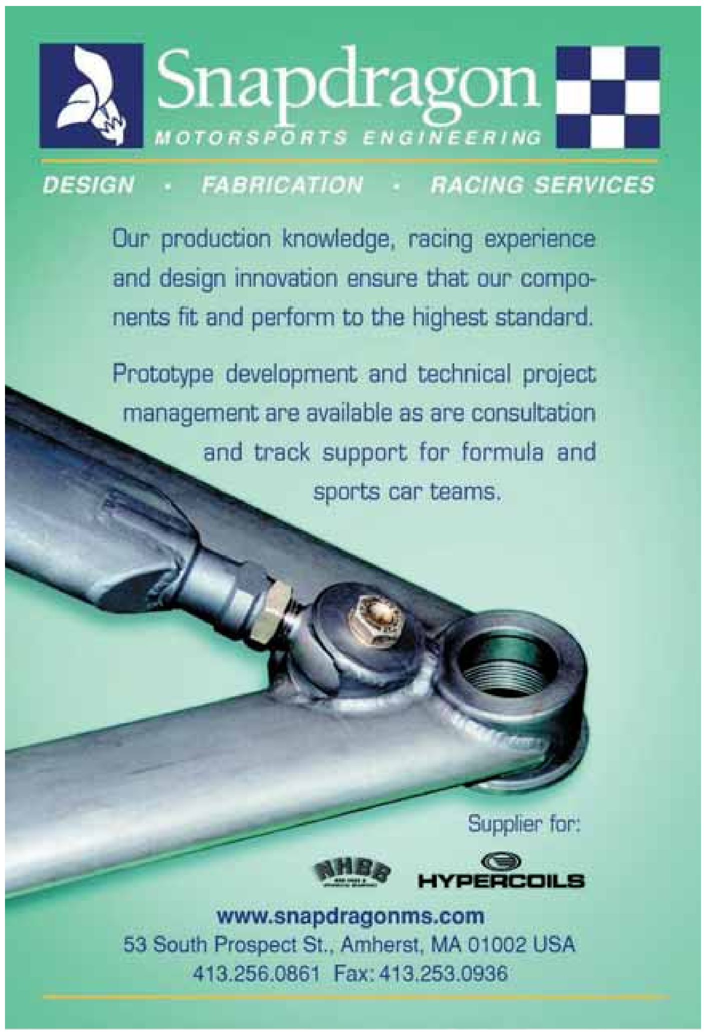
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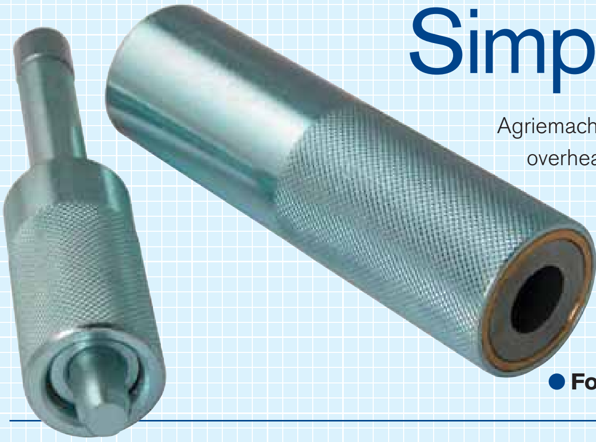


Simple spring remover

Agriemach has replaced the old-fashioned style valve spring compressor with this new overhead valve tool.

The device is adaptable for all petrol and diesel overhead valve engines including motorcycle, aircraft and marine variants. Its compact size makes it small enough to fit in any toolbox and it functions by removing and replacing the valve keepers.

It is priced at £32.17 ($56) including VAT and comes complete with full user instructions. To order please quote part number PM-2211.

● **For more information call +44 (0) 1342 713743 or visit www.agriemach.com**

Accurate readings

Longacre Racing Products has introduced a new set of computerised corner weight scales to offer racers accurate and fast percentage readings, with four displays showing four separate wheel measurements. With one push of a button, the Matrix can measure whatever percentage is required and can hold up to eight various set-up modes in its memory.

It can measure up to 1500lbs (680kg) in weight within a claimed 1/10 per cent accuracy. Each pad measures 15 x 15in (38cm^2) and is priced at $1249 (£714), complete with carry case, heavy-duty cables, battery and charger.

● **For more information call +(1) 360 453 2030 or visit www.longacreracing.com**

Lucy in the sky

Wasting time fixing the flex and lenses on conventional lights could now be a thing of the past thanks to a new LED light, designed by Hampshire-based company Luceotech.

Called Lucy, the new cordless workshop light clips into place with a clamp and shines bright white light for eight to 10 hours before needing to be recharged. Being only half the size of an ordinary light, it fits in tight, awkward spaces and can be rotated through 360 degrees. Lucy can be fully recharged in two hours via a 240V mains or 12V vehicle charger and comes with a replaceable lens to prevent weld splash.

Priced at £40 ($70) plus VAT.

● **For more information call +44 (0) 1489 878344 or visit www.luceotech.com**

180-degree hoses

High quality silicone hose manufacturer, SFS Performance, has developed a range of 180-degree elbow hoses for motorsport use.

Capable of withstanding 220degC, the hoses are made from high grade silicone, reinforced with three-ply polyester and specially formulated compounds to guarantee tensile power and resistance. Sizes available are 16mm (0.63in), 22mm (0.87in), 25mm (0.98in), 28mm (1.10in), 32mm (1.26in), 35mm (1.38in) and 38mm (1.50in) bore sizes, with 90 degree, 45 degree and 135 degree angles also available. Hoses come in blue as standard but other colours are available on request.

● **For more information call +44 (0) 1582 488040 or visit www.sfsperformance.co.uk**

Digi pressure

Beru F1 Systems has launched a low cost digital tyre pressure monitoring system to reduce costs but not performance.

The new Digi Tyre Lite now provides F1 technology to single seaters, saloons and GTs. Simplified electronics and a standard wiring loom installation has enabled a cut in production costs, yet the turnkey system still provides accuracy and high performance in harsh and extreme conditions.

The kit is complete with four wheel sensors with valves, an ECU and four digital antennae. A compact display to record temperature data and real-time pressure is available for endurance racers, as is a mini trigger to allow pit crew interrogations via a wireless LF protocol. Prices start at £1960 ($3427) for a standalone system.

● **For more information call +44 (0) 1379 646229 or visit www.f1systems.com**

Stinging systems

The Stinger 4 is a new, faster ECU from EMS that offers high quality performance in engine management at a low cost price.

Designed for simpler applications whilst maintaining the ECU's high quality, the Stinger analyses each cylinder individually before firing the ignition and injectors and studies every engine parameter over 600 times per second.

With user-friendly calibration tables which can easily be saved to file, the ECU is capable of reading numerous different sensors. The trigger signal is always sustained at a 100 per cent accuracy level by an automatic filter which triggers inputs for noise. The risk of misfired and lean strokes is also minimised by advanced research in programming the micro code to preserve the exact synchronisation of the engine.

Priced at $959 (£549).

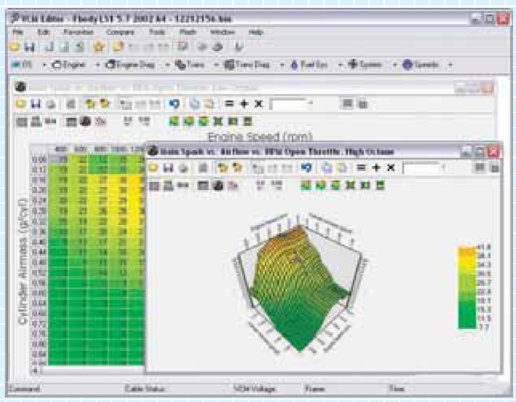
● **For more information call +(1) 877 936 7872 or visit www.fuel-injection.com**

Fine tuning

HP Tuners has created a new software called VCM Suite 2.0 to fulfil a wide range of tuning requirements. Designed for Ford, GM and Dodge engines, the VCM Suite is intended to offer the ability to increase horsepower, fuel mileage and driveability. The list of modifications the software is capable of includes timing, air/fuel ratio, shift points, speed limiters, RPM limiters, idle injectors and torque management.

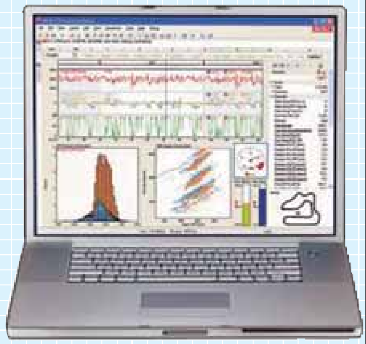
A variety of aftermarket modifications are open for alteration and vehicles can then be re-programmed via an OBD port. The software also allows log files such as performance diagnostics to be scanned, recorded and played back, and diagnostic trouble codes can be read and cleared.

Prices start at $499 (£286).



● **For more information visit www.hptuners.com**

i2 data analysis



MoTeC has continued to extend its range of user-friendly data acquisition software and remains at the forefront of engine management technology by introducing its new i2 data analysis software to the market.

Years of research and valuable assistance from professional race teams worldwide has resulted in the successful completion of the pioneering i2 software, which includes an extensive package of analysis tools with a number of inventive data management features.

The software, with its simple and user-friendly interface, is easily adaptable for personal preference and to suit a diverse range of users. This exceptional level of customisation makes it ideal for both professional and amateur racers to adapt the software to suit their needs. The menus also have the option of specific set-ups for a number of motorsport categories, including circuit racing and drag racing.

i2 uses a workbook and worksheet structure for flexibility, providing users with organised and intuitive screen layouts, while analysis components such as graphs, histograms and gauges are all included within each worksheet.

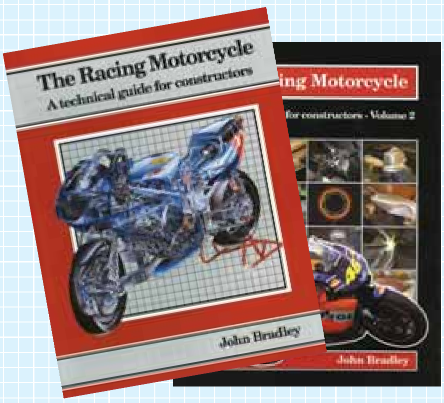
Other components featured include track reports, frequency (FFT) plots and synchronised video and scatter plots, all of which can be individually configured. The software is available in two formats for varied use – i2 Pro and i2 Standard. Standard is free for all users while the Pro version requires the Pro Analysis upgrade.

● **For more information or to locate your local MoTeC dealer in the UK call +44 8700 119 100 or visit www.motec.com.au to find the dealer nearest to you worldwide**

The Racing Motorcycle

A Technical Guide for Constructors Vols 1 & 2

By John Bradley



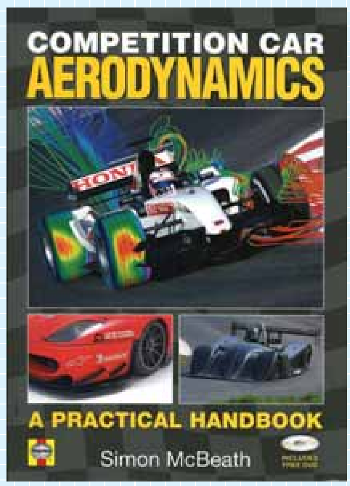
The first of these enormously comprehensive volumes came out 10 years ago, followed more recently by a second. Within a few pages it becomes clear though that the title is somewhat misleading, for whilst the books use two wheelers to show practical applications, almost all of the principles discussed apply equally to racecar construction. Seemingly everything is covered to some degree, from welding and tube bending to materials engineering, and vehicle dynamics feature heavily, including aerodynamics, rolling resistance and many other areas. Whilst buying both volumes may seem expensive initially, you really do get what you pay for. An essential pair of editions for the workshop shelf.

● **Published by Broadland Leisure publications (www.broadlandleisure.com) and distributed in the USA by Eurospares (www.eurospares.com); vol 1 ISBN 0-9512929-2-7; £32 ($80) and vol 2 ISBN 0-9512929-3-5; £38 ($95)**

Competition Car Aerodynamics

A Practical Handbook

By Simon McBeath



English wing maker and aerodynamics guru Simon McBeath must spend much of his spare time blowing pieces of paper about to see pressure changes and extinguishing candles so he can look at the flow of smoke and it's these real world comparisons and everyday language that makes this book so readable.

Readers of Aerobytes will recognise some sections as they were adapted from McBeath's inclusions in this magazine but simply, if you enjoy Aerobytes you must buy this book. It will no doubt become a fixture on all motorsport engineering university reading lists, and is highly recommended for all those with an interest in aero, whatever their existing knowledge.

● **Published by Haynes Publishing (www.haynes.com); ISBN 1-84425-230-2; hardbound; £25 ($44.95)**

Database

Section 1 lists manufacturers of Brand-Name Racecars.

Sections 2-3 list component manufacturers. Section 2 is dedicated to Chassis Components, Section 3 to Engine and Transmission Components

Sections 4-5-6 list equipment manufacturers Section 4 is dedicated to Factory Equipment Section 5 to Circuit Equipment Sections 6 to Driver Equipment

Sections 7-8-9-10 list companies that supply services. Section 7 is devoted to Chassis Engineering Services, Section 8 to Engine / Transmission / Suspension Services Section 9 to Testing Services Section 10 to Non-Engineering Services

To get your company listed in the racecar database please contact Andy King - 0208 726 8329 andy_kings@ipcmedia.com

Costs listed below:
Name and number £50 - 12 issues
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£420 - 12 issues including web, address, email etc etc
£210 - 6 issues

www. racecarengineering.com

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Database 1

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BRD Race Cars Inc. Tel (1) 716 637 9467
16 Hollybrook Road, Brockport, NY 14420, USA

BODOLA Tel Sweden 46 171 27690
Fax Sweden 46 171 27690
Bodin ChassiTeknik, Skalbygatan 8, 745 37 Enkoping, Sweden

BREDA Italy (39) 049 9001895
Fax (390) 49 900 2821
Breda Racing s.r.l, via Buonarotti 10a, 35035 Mestrino,PD, Italy

BRYTEC Tel 01772 786500
Fax 01772 786500
Lower College, Hothersall Lane, Longridge, Preston, Lancashire PR3 2XB

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Fax (1) 262 375 1602
Carbir Race Cars Inc, 1220 Falls Road, Grafton, WI 53024, USA

CHEEK Norway (47) 90 78 70 32
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Cheek Racing Cars, Flatebyvn 3, 1792 Tistedal, Norway

CHEETAH USA (1) 408 492 1331
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Omni Fab, 380 Martin Avenue, Santa Clara, CA 95050

CHEVRON Tel 01300 348499
The Chevron Centre, Piddle Trenthide, Nr Dorchester, Dorset DT2 7RF, England
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Unit 10, Britannia Rd Est, Buxworth, Nr Whaley Bridge, High Peak, SK23 7NF

DOME CO. LTD 198-1 Hanajiricho, Yase, Sakyoku, Kyoto, Japan
Tel 81 (0)75744-3131
Fax 81 (0)75744-3035

DOME CARS. LTD Roebuck House
Cox Lane, Chessington, Surrey KT9 IDG England
Tel 0208 397 9999
Fax 0208 397 6830

DOWNS ENGINEERING Tel USA 707 938 1001
Fax USA 707 935 0481
19564 8th St. East, Sonoma, CA 95476 USA

DRAGON USA (1) 413 267 0904
Small Fortune Racing, 77 Stafford Hollow Road, Monson, MA 01057, USA

ELISE France (33) 1 47 49 15 66
1 Rue Pierre Cassin, 92500 Rueil Malmaison, Paris, France

EUROCAR Tel 01353 861168
Fax 01353 861877
SHP Motorsport, Unit 7 Farraday Business Park, Littleport, Ely, Cambridgeshire CB6 1SE, England

EXTREME CARS Australia (61) 396 822225
(61) 396 821119
(61) 396 900809
Email mrpro07@tpg.com.au
King Way House, 188-190 Kings Way, South Melbourne, Victoria 3205 Aus.

FABCAR USA (1) 317 872 3664
Fax (1) 317 872 3835
4148 West 99 Street Carmel Indiana

FORCE RACING CARS Tel/Fax 01823 698117
Clyse Farm, Stathe, Nr Bridgwater TA7 OJN England

GRAN TOURING CLASSICS 001 562 596 9242

GOULD Tel 01635 44466
Fax 01635 30056
Gould Engineering Services, Unit 7, Arnhem Road, Newbury, Berks, RG14 5RU

ICP/CITATION USA (1) 317 273 0089
Indianapolis Competition Products, 1717 Expo Lane, Indianapolis, IN 46214, USA

JADE Tel 01883 744 443
Fax 01883 744 443
Address Jade Motorsport Engineering, Unit 2 Pendell Farm, Pendell Road Bletchingley Surrey RH1 4QH

JEDI Tel 01933 440774
John Corbyn Motors, 36A Stanley Road, Wellingborough, Northamptonshire NN8 1DY, England

KBS USA (1) 909 355 4800
Fax (1) 909 355 5933
KBS Engineering, 8296 Fremontia, Suite B, Fontana, CA 91404, USA

KUDZU USA (1) 404 457 6300
Fax (1) 404 458 6118
5096 Peachtree Road, Atlanta, GA 30341, USA

LAZER USA (1) 906 863 5003
Campbell Motorsport, W7719 Fernwood Drive, Menominee, MI 49858, USA

LOLA Tel 01480 451301
Fax 01480 456722
Lola Cars International, Glebe Road, St Peters Hill, Huntingdon, Cambridgeshire PE18 7DS, England
US Importer
Tel (1) 317 244 2277 Fax (1) 317 390 2121
Lola Cars Inc, Suite B, 2801 Fortune Circle East, Indianapolis, IN 46241, USA

LUCCHINI Italy (39) 0376 391271
Fax (39) 0376 391200
Lucchini Engineering, via Valeggio 2, 45100 Mantova, Italy

LYNCAR ENGINEERING Tel 01635 860066
Fax 01635 860066
Email: lyncar001@btopenworld.com
Briff Lane, Bucklebury, Reading, Berkshire RG7 6SN

MAGNUM Tel 01933 442861
Fax 01933 22552
141 Laurence Leyland Industrial Estate, Wellingborough, Northamptonshire NN8 1RA, England

MALLOCK Tel 01604 863504
Fax 01604 863807
Mallock Racing, Rowley Wood Lane, Hartwell, Northamptonshire NN7 2QT, England

MARK BAILEY RACING Tel 01380 850130
Fax 01380 850140
MBR Building, 8A Jockey Lane Bromham, Chippenham, Wiltshire, SN15 2EZ

MATT WATERMAN MOTORSPORT DESIGN
Tel 0408 216357

MYGALE Tel France 33 3 8621 8621
Fax France 33 3 8621 8622
Technopole du Circuit, 58470 Magny-Cors, France

OSELLA S.R.L Tel 0972 715852
Fax 0972 715391
Z.I Valle di Vitalba, 85020 Atella, (PZ)

PANOZ Tel USA (1) 770 967 2310
Fax USA (1) 770 965 8762
5294 Winder Highway, Braselton, GA 30517, USA

PHOENIX USA USA (1) 813 655 1199
Phoenix Race Cars, 364 Hairpin Drive, Sebring, FL 33870, USA Fax (1) 813 665 1199

PICCHIO S.p.A Tel 0039 0861 816015/16
Fax 0039 0861 86246/805651
Email: picchio@picchio.com or picchiospa@email.it
Website: www.picchio.com
Zona Industriale Ancarano 64010 - Ancarano (Teramo) Italy

PILBEAM Tel 01778 424838
Fax 01778 393032
Pilbeam Racing Design, Graham Hill Way,Cherry Halt Road, Bourne, Lincolnshire, PE10 9PJ

PIPER USA (1) 708 365 5334
Piper Engineering, 5N461 Meadowview Lane, St Charles, IL 60175, USA

PREDATOR USA (1) 313 681 1377
Fax (1) 248 681 1377
Crossroads Fabrication, 265 Hillcliff, Waterford, MI 48328, USA

PROTECH COMPOSITES LTD
Tel: +44(0) 1420 471 400
Fax: +44 (0) 1420 487 047
www.protechcomposites.co.uk
Unit 62, Woolmer Trading Estate
Bordon, Hampshire, GU35 9QF, UK

PROTOFORM USA (1) 607 739 7345
Protoform Race Engineering, 51 Ponderosa Drive, Horseheads, NY 14845, USA

RACEFAB USA (1) 713 694 8335
Fax (1) 713 694 8335
8307 Beauman Road, Houston, TX 77022, USA

RALT 01865 883354
Fax 01865 883789
Ralt Engineering, Sutton Farm House, Sutton, Witney, Oxfordshire OX29 SRD, England
US Importer
Tel (1) 310 533 1144 Fax (1) 310 530 0139
Ralt American, 23110 Kashiwa Court, Torrance, CA 90505, USA

RAPTOR USA (1) 215 775 1938
Performance Engineering, RD5 Box 5435, Mohnton, PA 19540, USA

RAY Tel 0208 680 9418
Fax 0208 688 4026
15 Silverwing Industrial Park, Horatius Way, Croydon, Surrey CR0 4RU, England

RILEY & SCOTT USA (1) 317 248 9470
Fax (1) 317 248 0182
1200 Main Street, Speedway, Indianapolis IN 46224, USA

RML LTD Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Ind Est, Wellingborough, Northants NN8 6TY England

SABRE USA (1) 714 693 0296
USA Race Cars, 1535 Harmony Circle, Anaheim, CA 92807, USA Fax (1) 714 693 3164

SCCA USA (1) 303 693 2111
Fax (1) 303 680 5633
Spec Racer, 7476 South Eagle Street, Unit 5, Englewood, CO 80112, USA

SCARAB Tel 01636 822033R
RS Racing & Specialised Services, High House,Kirton Road, Egmanton, Newark, Nottinghamshire NG22 0HF, England

SEZIO FLORIDA RACING
Tel: 001 776 878145

SHELBY USA (1) 310 538 2914
Fax (1) 310 538 0126
Shelby Can-Am, Shelby Technologies Inc, 19021 South Figueroa, Gardena, CA 90248, USA

SPECTRUM Australia (61) 3 95 80 52 36
Fax (61) 3 95 80 53 31
Spectrum Racing Cars, Borland Racing Developments, 39 Industrial Drive, Braeside, Victoria, Australia 3195

STRYX Tel 01789 750567
Fax 01789 292183
Minerva Developments, Grafton Lodge, Binton, Stratford-on-Avon, Warwickshire CV37 9TX, England

SPICE RACING CARS LTD Tel 01483 203956
Fax 01483 203956
Int House, 31 Church Road, Hendon, NW4 4EB, England

SWIFT US Importer International Racing Products
Tel (1) 800 793 0496
1034 Riva Ridge, Great Falls, VA 22066, USA

SYMBOL Italy (39) 0362 903967
Symbol Team srl, via Fiume 17, Carate Brianza, 20048 MI, Italy

TAMPOLLI Italy (39) 055 8873268
Fax (39) 055 8825777
Tampolli Engineering, via degli Artigiani 44-46, Calenzano, 50041 FI, Italy

TOM'S Japan (81) 3370 46801
Fax (81) 3370 46805
6-13-10 Todoroki Setagaya-ku, Tokyo, Japan 158

TPG 0039 682 32225

VAN DIEMEN Tel 01953 888195
Fax 01953 888178
Van Diemen International Racing Services, Chalk Road, Snetterton, Norfolk NR16 2JZ, England
US Importer Primus Racing
Tel (1) 813 522 7544 Fax (1) 813 522 7417
3608 Morris Street, St Petersburg, FL 33407, USA

Database 2
COMPETITION CAR CHASSIS COMPONENTS

2.1 Chassis/BodyWork Ancillaries

AEROFOILS
- ACTIVE ENG — USA (1) 714 637 1155
- AERODINE COMPOSITES GROUP, LLC — Tel: 317 271 1207 Fax: 317 271 4455 — www.aerodinecomposites.com — 8201 Indy Lane, Indianapolis, Indiana 46214
- ANDREAM LTD CUSTOMIZED COMPOSITE WINGS — Tel: 01953 885775 / Fax: 01953 884176 — Email: dave.greenwood@eidisnet.co.uk — Unit 12 Norwich Road Industrial Estate, Watton, Norfolk IP25 6DR
- CGB CONSULTANTS — (0) 1202 673666
- DJ RACECARS LTD — 01663 734518
- JANUS TECHNOLOGY — 01753 869996
- PROTECH COMPOSITES LTD — Tel: +44(0) 1420 471 400 Fax: +44 (0) 1420 487 047 — www.protechcomposites.co.uk — Unit 62, Woolmer Trading Estate Bordon, Hampshire, GU35 9QF, UK
- LOLA — Tel 01480 451301 / Fax 01480 456722 — Lola Cars International, Glebe Road, St Peters Hill, Huntingdon, Cambridgeshire PE18 7DS, England — US Importer — Tel (1) 317 244 2277 / Fax (1) 317 390 2121 — Lola Cars Inc, Suite B, 2801 Fortune Circle East, Indianapolis, IN 46241, USA
- ROAD & STAGE M/SPORT — 01524 844066
- SARDOU — France (33) 1 60 01 03 67
- THE WING SHOP — Tel: 01258 860716 — Fax: 01258 860716 — E-mail: info@wingshop.co.uk — Web: www.wingshop.co.uk
- SPA AEROFOILS LTD — 01827 260026
- UNI OF MARYLAND — USA (1)301 405 6861
- QINETIQ — 02700 100942
- ZEUS MOTORSPORT — 01604 878101

FASTENERS
- ABC AUTOSPORT BEARINGS - COMPONENTS — Tel : +44(0)1932 225777 Fax : +44(0)1932 222215 — Unit 3 Shepperton Business Park Shepperton, Middlesex TW17 8AA
- ALL WAYS FORWARD — 01242228111
- ARP — USA (1) 805 525 5152
- ARROW SUPPLY — 01234 840404
- CLARENDON — 01455 841200
- COAST FABRICATION — USA (1) 714 842 2603
- DATUM ENGINEERING — 02476 383032
- DZUS FASTENERS EUROPE — 01252 714422
- FASTENER FACTORY — 01327 311018
- FLUID CONTROL PRODUCTS INC — USA (1) 217 324 3737 — Fax (1) 217 324 3717
- PROTEX FASTENERS LTD — 01527 63231
- SPECIALITY FASTENERS — 01803 866371
- STAUBLI — France (33) 4 50 65 60 60
- TRIDENT RACING SUPPLIES — TEL 01327 857822 — FAX 01327 858096 — Unit 31, Silverstone Circuit, Northants NN12 8TN

FIRE EXTINGUISHERS
- LIFELINE — 02476 712999
- LINREAD NORTHBRIDGE MOTORSPORT — 01162 572924
- RALLY DESIGN — 01795 531871
- SAFETY DEVICES — 01353 724202
- SPA DESIGN — 01827 288328
- SPA TECHNIQUE — USA (1) 317 271 7941
- ATL — USA (1) 201 825 1400 Fax (1) 201 825 1962 — Aero Tec Laboratories Inc. Spear Road Industrial Park, Ramsey, NJ 07446-1221, USA

FUEL CELLS
- ATL — UK 01908 351700 Fax 01908 351750 — Aero Tec Laboratories Ltd (Europe), 1 Patriot Drive, Rooksley, Milton Keynes MK13 8PU
- FUEL SAFE SYSTEMS — USA (1) 714 842 2211
- GOMM METAL DEVELOPMENTS — 01483 764876
- KS MOTORSPORT — Germany (49) 2271 44905
- PRONALS — France (33) 320 99 75 10
- TRANSAUTOSPORT — 01772 454647
- ACTIVE ENG — USA 001 714 637 1155
- GARTRAC — 01428 682263
- ROLLCENTRE — 01480 464052
- SAFETY DEVICES — 01353 724202
- SIGMA — Switzerland (41) 61 9717600
- CORBEAU — 01424 854499
- GRAND PRIX RACEWEAR — 020 8987 5500
- MOMO — USA 001 714 637 1155
- EARS MOTORSPORTS — 01625 433773
- KS MOTORSPORT — Germany (49) 2271 44905
- OMP — USA (1) 973 361 0508
- MOMO — USA 001 714 637 1155
- LUKE — 01323 844791
- Total Restraint Systems — 01722 326080
- TRW SABELT — 020 7736 2881
- WILLANS — 01264 810712

RUBBER & ELASTOMERIC COMPONENTS
- BUTSER RUBBER LTD — Tel: 01730 894034

2.2 Electrical Systems

- REDLINE MOTORSPORT — Tel 01606 737500 — Fax 01606 737683

ALTERNATORS
- BOSCH — 01895 834466 — Germany (49) 711 8111 USA (1) 312 865 5200
- BRISE AUTO ELECTRICS — 01322 277622
- MM COMPETITION — 08707 444666
- McCLAREN ELECTRONICS — 01483 261400

CABLES
- CENTURY CABLES — Tel 01733 211600 / Fax 01733 211082 — Email kwhincup@yahoo.com / web www.centurycables.com
- IS MOTORSPORT — USA (1) 317 244 6643
- PERFORMANCE WIRING SOLUTIONS — +44 (0)1954 253620
- RINGSPANN — 01234 342511
- SPEEDY CABLES — 020 7226 9228
- SPOT ON CONTROL — 0118 979 0682
- TRIDENT RACING — 01327 857822
- CONTINENTAL — USA (1) 513 459 8863

CONNECTORS
- BERU F1 SYSTEMS — 01379 646200
- DEUTSCH — 01424 852721
- IS MOTORSPORT — USA (1) 317 244 6643
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- PERFORMANCE WIRING SOLUTIONS — +44 (0)1954 253620
- SAKATA MOTORSPORT ELEC. INC. — (714) 446 9473
- SERVO & ELECTRONIC SALES LTD — 01797 322500
- SPECIALITY FASTENERS — 01803 868677
- RAYCHEM — 01793 572217

DISTRIBUTORS
- IS MOTORSPORT — USA (1) 317 244 6643
- MM COMPETITION — 08707 444666
- PALLAS CONNECTIONS — 01869 277053
- PAD RACING — NZ (64) 3 3386 288

IGNITION SYSTEMS
- BOSCH — UK 01895 834466 — Germany (49) 711 8111 USA (1) 312 865 5200
- SBD MOTORSPORT — 0208 391 0121
- EFI TECH — USA (1) 310 793 2505
- HELLA UK — 01295 272233
- LUMENITION — 020 7403 4334
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- MOTEC — Australia (61) 3 9761 5050
- MOTEC (EUROPE) — UK 08700 119100
- MOTEC JAPAN — Japan (81) 489 46 1734
- MOTEC SYSTEMS USA — USA (1) 714 897 6804
- MSD IGNITION — USA (1) 915 857 5200
- PI RESEARCH — 01954 253600
- PIAA (UK) — 01934 814812
- STACK — 01869 240404
- McCLAREN ELECTRONICS — 01483 261400

- THE STRAIN GAUGING CO — 01256 320666

LIGHTS
- HELLA — 01295 272233
- PIAA — 01934 818 430
- PRODRIVE — 01295 254400

LOAD CELLS
- NOVATECH MEASUREMENTS — 01424 852 744

SPARKPLUGS
- BERU — 01295 272233
- BOSCH — Germany (49) 711 8111 — UK 01895 834466 USA (1) 312 865 5200
- CHAMPION AUTO — 0151 522 3000
- KS MOTORSPORTS — Germany (49) 2271 44905
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- NGK — Japan (81) 52 872 5937 UK 0208 202 2151

SPARKPLUG LEADS
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION UK — 08707 444666

WIRING HARNESSES
- A.N. MOTORSPORT DESIGN — 01628 776320
- COMPETITION DATA SYS — USA (1) 716 631 2880
- DC ELECTRONICS — 01621 856451
- SBD MOTORSPORT — 0208 391 0121
- EFI TECH — USA (1) 310 793 2505
- BERU F1 SYSTEMS — 01379 646200
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- MOTEC — Australia (61) 3 9761 5050
- MOTEC (EUROPE) — UK 08700 119100
- MOTEC JAPAN — Japan (81) 489 46 1734
- MOTEC SYSTEMS USA — USA (1) 714 897 6804
- PALLAS CONNECTIONS — 01869 277053
- PERFORMANCE WIRING SOLUTIONS — +44 (0)1954 253620
- RAYCHEM — 01793 572217
- SAKATA MOTORSPORT ELEC. INC. — Tel (714) 446 9473 — Fax (714) 446 9247 — Website www.sakatamotorsport.com — 689 S. State College Blvd, Unit F Fullerton, CA 92831
- SERVO & ELECTRONIC SALES LTD — 01797 322500
- SIMTEK (UK) — 01706 877644
- THE STRAIN GAUGING CO — 01256 320666
- TONY JAMES — 01379 854485
- ZICA CONSULTANCY LIMITED — Tel: +44 (0) 8700 272072 — Email: sales@zica.uk.com Website: www.zica.uk.com — 21 Anglevale, Top Angel, Buckingham, Buckinghamshire, MK18 1TH

2.3 Controls

GEARSHIFT SYSTEMS
- CENTURY CABLES — Tel 01733 211600 / Fax 01733 211082 — Email kwhincup@yahoo.com / web www.centurycables.com
- DAVID BROWN — 01484 422180
- SBD MOTORSPORT — 0208 391 0121
- HEWLAND ENG — 01628 827600
- JACK KNIGHT — 01483 764326
- PRODRIVE — 01295 273355
- QUAIFE ENGINEERING — 01732 741144
- RICARDO MIDLANDS TECHNICAL CENTRE — 01926 319399
- RINGSPANN (UK) — 01234 342511
- THE STRAIN GAUGING CO — 01256 320666
- STONE FOUNDRIES — 020 8853 4648

HYDRAULIC VALVES
- A.N. MOTORSPORT DESIGN — 01628 776320
- LEE PRODUCTS — 01753 886664
- MOOG CONTROLS — 01684 296600

INSTRUMENTATION
- ACTIVE SENSORS — 01202 480620
- CRANFIELD IMPACT CENTRE — 01234 750944
- LMI STACK — USA 001 714 637 1155
- LUMENITION — 020 7403 4334
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- MOTEC — Australia (61) 3 9761 5050
- MOTEC (EUROPE) — UK 08700 119100
- MOTEC JAPAN — Japan (81) 489 46 1734
- MOTEC SYSTEMS USA — USA (1) 714 897 6804
- PENNY & GILES — 01202 409409
- PI RESEARCH — 01954 253600
- QINETIQ — 08700 100942
- SPA DESIGN — 01827 288328
- STACK — 01869 240404
- McCLAREN ELECTRONICS — 01483 261400
- THE STRAIN GAUGING CO — 01256 320666
- VARIOHM — 01327 351004

MIRRORS
- GRAND PRIX RACEWEAR — 0208 987 5500
- SPA DESIGN — 01827 288328

PEDALS
- AP RACING — 02476 63595
- CHEVRON RACING — 01565 777395
- LOLA — Tel 01480 451301 — Fax 01480 456722
- TILTON — USA (1) 805 688 2353
- WILWOOD ENG — USA (1) 805 388 1188

STEERING SYSTEMS
- FLAMING RIVER — USA (1) 440 826 4488
- MOBILIS — Canada (1) 450 647 1890
- RALLY DESIGN — 01795 531871
- ZF — Germany (49) 7541 772543 — UK 0115 9869211
- WOODWARD MACHINE CORP — TEL: USA (1) 307 472 0550 — FAX: USA (1) 307 235 1551 — Website: www.woodwardsteering.com — PO Box 4479, 3592 Burd Road, Casper, WY82604, USA

STEERING WHEELS
- DEMON TWEEKS — 01978 664466
- MOUNTNEY — 01525 383055

SWITCHES & KILL-SWITCHES
- IS MOTORSPORT — USA (1) 317 244 6643
- MAGNETI MARELLI — Italy (39) 02 972 27570
- MM COMPETITION — 08707 444666
- SAKATA MOTORSPORT ELEC. INC. — (714) 446 9473
- TONY JAMES — 01379 854485
- TRIDENT RACING — 01536 770777

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- CENTURY CABLES — Tel 01733 211 600 / Fax 01733 211 082 — Email: kwhincup@yahoo.com — Web: www.centurycables.com
- JLS MOTORSPORT — 0121 525 7733
- KINSLER — USA (1) 810 362 1145
- LUMENITION — 020 8403 4334
- RALLY DESIGN — 01795 531871
- SPOT-ON CONTROL — 0118 9790682
- RINGSPANN — 01234 342511

2.4 Suspension Systems

- DEREK BENNETT ENG — 01565 777433
- DON FOSTER RACING — France (33) 4 70 58 0308
- DYNAMIC SUSPENSIONS — 01842 755744
- GROUND CONTROL — USA (1) 916 638 7888
- LOLA — Tel 01480 451301 — Fax 01480 456722
- PROFLEX UK — 01200 442345
- RICARDO MIDLANDS TECHNICAL CENTRE — 01926 477208
- ROD MILLEN MOTORSPORT — USA (1) 714 8472111

2.5 Suspension Components

ANTIROLL BARS
- COIL SPRINGS — 01142 758573
- COMPTECH USA — USA (1) 916 933 1080
- DEREK BENNETT ENG — 01565 777395
- DON FOSTER RACING — France (33) 4 70 58 0308
- DTM CONSULTANTS UK — 01865 407726
- GROUND CONTROL — USA (1) 916 638 7888
- KIC INT MOTORSPORTS — USA (1) 604 589 3354
- HARROP — Australia (61) 3 9499 7433
- PRECISION — USA (1) 708 766 4402

BEARINGS & BUSHES
- ABC AUTOSPORT BEARINGS - COMPONENTS — Tel : +44(0)1932 225777 — Fax : +44(0)1932 222215 — Unit 3 Shepperton Business Park Shepperton, Middlesex TW17 8AA
- AURORA BEARING — USA (1) 630 859 2030
- FASTENER FACTORY — 01327 311018
- GETECNO — Italy (39) 010 835 6016
- QINETIQ — 08700 100942
- GOLDLINE BEARINGS — Tel 01952 292401 — Fax 01952 292403 — Stafford Park 17, Telford, TF3 3DG
- GROUND CONTROL — USA (1) 916 638 7888
- RESB — 0121 520 8271
- ROSE BEARINGS — 01522 500933

COILSPRINGS
- COIL SPRINGS — 01142 758 573
- COMPTECH USA — USA (1) 916 933 1080
- EIBACH — 01455 285850
- EIBACH — Germany (49) 2721 511220
- GROUND CONTROL — USA (1) 916 638 7888
- HYPERCOILS — USA (1) 574 753 6622
- HERBERT TERRY — 01527 64261
- PERFORMANCE SPRINGS — 01253 716900
- WOODHEAD — 0113 2441202

DAMPERS
- DTM CONSULTANTS UK — 01865 407726
- DYNAMIC SUSPENSIONS — 01842 755744
- PROFLEX UK — 01200 442345
- GROUND CONTROL — USA (1) 916 638 7888
- JRZ SUSPENSION — +314 02619155
- MONROE AUTO EQUIPMENT — 01904 631441
- MORRIS DAMPERS INC — USA (1) 586 826 9141
- MOTON — Netherlands (31) 413 259838
- OHLINS RACING — UK 0208 974 1615
- PENSKE RACING SHOCKS — USA (1) 215 375 6180 — UK 01827 288328
- ROEHRIG — USA (1) 336 431 1827
- SPAX UK (Worldwide HQ) — Tel: 01869 244771 — Fax: 01869 240536 e-mail: sales@spaxperformance.com — Website: www.spaxperformance.com
- SPAX USA — Tel: (443) 557 0086 — Website: www.spaxusa.com
- SPAX Deutschland — Tel: 01801 7729 33 (01801 SPAX DE) — Fax: 01801 7729 00 (01801 SPAX 00) — e-mail: spaxde@spaxperformance.com — Website: www.spaxperformance.com
- SPAX France — Tel: 0478 9042 43 — Website: www.spaxfrance.com

RODS & ROD-ENDS
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KINSLER USA (1) 810 362 1145
RESB INTERNATIONAL 0208 390 8076
ROSE BEARINGS 01522 500933
SPECIALITY FASTENERS 01803 866371

SEALS
SPECIALITY FASTENERS 01803 866371
WALTHER 01442 891929

STRUT BRACES
DEMON TWEEKS 01978 664466
EIBACH Germany (39) 2721 5110
UK 0455 285850
USA (1) 714 727 3700
FASTENER FACTORY 01327 311018
OHLINS RACING UK 0208 974 1615

2.6 Braking Systems

ALCON COMPONENTS 01827 312500
AP RACING 02476 639595
ATE 0208 654 8836
CARBONE INDUSTRIE France (33) 0472 355700

CIRCUIT SUPPLIES (U.K.) LTD

CIRCUIT SUPPLIES (UK) LTD Tel 01525 385888
Fax 01525 385898
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Web: www.circuitsupplies.com
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
DELPHI BRAKE SYSTEMS 01926 472472
EBC BRAKES 01604 583344
ENDLESS BRAKES Japan (81) 267 68 0071

brembo

GRANDPRIX RACEWEAR
Tel: 01908 220777
Email: info@grandprixwear.com
Web: www.grandprixwear.com
Unit 3 Fitzhamon Court, Featherstone Road,
Wolverton Mill, Milton Keynes MK12 6LB
GOODRIDGE UK 01392 369090
USA (1) 310 533 1924 USA (1) 317 244 1000 USA (1) 704 662 9095
MOSA FREIN Belgium (32) 81 73 32 73

PERFORMANCE FRICTION BRAKES

PERFORMANCE FRICTION (1) 800 521 8874
EUROPE +44 (0) 1280 843 390

RedLine MOTORSPORT

REDLINE MOTORSPORT Tel 01606 737500
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk
WILWOOD ENG USA (1) 805 388 1188

2.7 Brake Components

CALIPERS
ALCON COMPONENTS 01827 312500
AP RACING 02476 639595
BREMBO Italy (39) 035 605111
UK 02476 679168
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
GKN SQUEEZEFORM 01952 244321
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
EUROPE +44 (0) 1280 843 390
PROFESSIONAL M/SPORTS 01626 332289
QINETIQ 08700 100942
RACE BRAKES New Zealand (64) 9377 2000
TAR.OX Italy (39) 039 587814
WILWOOD USA (1) 805 388 1188

DISCS
ALCON COMPS 01827 312500
AP RACING 02476 639595
ATE 020 8654 8836
BREMBO Italy (39) 2 240 9631
UK 01280 700664
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
CARBONE INDUSTRIE France (33) 0472 355700

HAWK PERFORMANCE

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Tel: 01908 220777
Email: info@grandprixwear.com
Web: www.grandprixwear.com
Unit 3 Fitzhamon Court, Featherstone Road,
Wolverton Mill, Milton Keynes MK12 6LB
PERFORMANCE FRICTION USA (1) 803 222 2141
EUROPE +44 (0) 1280 843 390
MARDI GRAS M/SPORTS 01327 858 006
RAYBESTOS USA (1) 815 363 9000
TAR.OX Italy (39) 039 587814
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

FLUIDS
ALCON COMS 01827 312500
AP RACING 02476 639595
BENDIX France (33) 14 972 2305
UK 01942 723828
CASTROL 01793 512712
CASTROL Malaysia (603) 245 2642
CASTROL USA (1) 305 270 9433
CASTROL USA (1) 973 305 3912
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

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ALCON COMPS 01827 312 500
AP RACING 02476 639595
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
CARBONE INDUSTRIE France (33) 14 972 2305

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EUROPE +44 (0) 1280 843 390
EBC BRAKES 01604 583344
ENDLESS BRAKES Japan (81) 267 68 0071
FERODO 01298 812520
FGR 01885 400639
MINTEX 01274 854000
PAGID MOTORSPORTS USA (1) 941 772 4261
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
RAYBESTOS USA (1) 815 363 9000
TAR.OX Italy (39) 039 587814
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

VALVES
ALCON COMPS 01827 312 500
AP RACING 02476 639595
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

2.8 Wheels

DYMAG RACING UK 01249 655481
HILLGARD Sweden (46) 300 60590
KINESIS MOTORSPORT USA (1) 760 598 5300
MOMO Italy (39) 0276 111072
SPARCO Italy (39) 011 470 2343

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CO-ORD SPORT 01384 226102
DUNLOP 0121 306 6000
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Ireland (353) 178 3599

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VINTAGE TYRES LTD
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Fax Canada (1) 902 2282241
Email vintyre@aol.com
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Nova Scotia, Canada, B0J 1T0
GOODYEAR Germany (49) 2234 82031
USA (1) 216 796 2121
Canada (1) 416 684 7418
MICHELIN 01782 403284
France (33) 73 90 77 341
TOYO 01933 411144
YOKOHAMA 01582 613339
Japan (81) 33 432 7111

2.10 Fuels & Lubricants

AGIP Italy (39) 65 9981
BP 01442 232323
BURMAH 01793 511521
PETROCHEM CARLESS 01372 380532
CASTROL 01793 512712
CASTROL Malaysia (603) 245 2642
CASTROL USA (1) 305 270 9433
CASTROL USA (1) 973 305 3912
CENTURY 01782 202521
DUCKHAMS OILS 0208 290 0600
ELF France (33) 1 4744 4546
UK 0208 902 8820
ESSO UK 01372 222000
MILLERS OILS 01484 713201
QINETIQ 08700 100942
RED LINE OILS 01476 861195
REPSOL Spain (34) 91 456 53 00
UK 0207 581 1933
SLICK 50 UK 0116 2881522
USA (1) 713 932 9954
STP USA (1) 305 771 1010
UK 01488 682655
TECH-LINE USA (1) 919 480 0905
TEXACO UK 0207 719 3000
VALVOLINE USA (1) 606 264 7222

Database 3
ENGINE & TRANSMISSION COMPONENTS

3.1 Engine Components

BEARINGS
BRITISH TIMKEN 01604 730047
CONNAUGHT 01795 843802
FASTENER FACTORY 01327 311018
RESB 0121 520 8271
QINETIQ 08700 100942
QUAIFE ENGINEERING 01732 353747
VANDERVELL 01788 538500

BLOCKS
INTEGRAL POWERTRAIN 01908 278600
PERFORMANCE CONNAUGHT 01795 843802
MILLINGTON 01746 789268
STONE FOUNDRIES 020 8853 4648
TREMELLING PATTERN 01494 533897

CAMSHAFTS
AUTOSPRINT 01675 464857
CAT-CAMS Belgium (32) 3 320 2560
COMPETITION CAMS USA (1) 901 795 2400
CONNAUGHT 01795 843802
CROWER USA (1) 619 422 1191
DAVID NEWMAN 01689 857109
SBD MOTORSPORT 0208 391 0121
DUNNELL ENGINES 01449 677726
FGR 01885 400639
HARROP Australia (61) 3 9499 7433
KATECH USA (1) 313 791 4120
KENT CAMS Tel 01303 248666
KENT CAMS BY JT FRANCE (33) 3207 46480
LUNATI USA (1) 901 365 0950
PAD RACING New Zealand (64) 3 3386 288

PIPER CAMS

PIPER CAMS Tel 01233 500200
Fax 01233 500300
www.pipercams.co.uk
2 St. John's Court,
Ashford Business Park,
Ashford, Kent, TN24 0SJ
QUAIFE ENGINEERING 01732 353747
SWINDON RACING ENGINES 01793 531321
TWR ENGINES 01993 871000
ULTRADYNE USA (1) 601 349 4447

CAMSHAFT DRIVES
CONNAUGHT 01795 843802
DAVID BROWN 01484 422180
SBD MOTORSPORT 0208 391 0121
KENT CAMS 01303 248666
PIPER CAMS 01233 500200
QUAIFE ENGINEERING 01732 353747
SWINDON RACING ENGINES 01793 531321

CONRODS
ARIAS FORGED PISTONS USA (1) 310 532 9737
ARROW PRECISION 01455 234200
ATECH MOTORSPORTS USA (1) 330 630 0888
CLARENDON ENG 01455 841200

ARROW

ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 1455 234200
Fax +44 (0) 1455 233545
Website www.arrowprecision.co.uk
Email: enquiries@arrowprecision.co.uk
12 Barleyfield, Hinckley, Leicester LE10 1YE
CARILLO IND USA (1) 949 498 1800
CONNAUGHT 01795 843802
CO-ORD SPORT 01384 216102
CROWER USA (1) 619 422 1191
SBD MOTORSPORT 0208 391 0121
ENGINES & DYNO SERVICES 01708 857108
FARNDON ENG 02476 366910
MANLEY PERFORMANCE USA (1) 732 905 3366
OLIVER USA (1) 616 451 8333
PANKL Austria (43) 3862 512500

JACQUEMIN TUNING

SAENZ EUROPE-JACQUEMIN TUNING
France Tel: +33(0)320746480
Fax: +33(0)320746489
Email: jmjacquemin@nordnet.fr
Website: www.jacquemintuning.com
SAENZ USA (1) 305 717 3422
SCHRICK Germany (49) 21 91 9500
SWINDON RACING ENGINES 01793 531321

CONROD BOLTS
ARIAS FORGED PISTONS USA (1) 310 532 9737

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A.R.P. USA Tel: (1) 805 339 2200
Fax: (1) 805 650 0742
Website www.arp-bolts.com
1863 Eastman Avenue, Ventura 93003

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Email: enquiries@arrowprecision.co.uk
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BLANC AERO France (33) 296 68 33 39
CARRILLO INDUSTRIES USA (1) 949 498 1800
COAST FABRICATION USA (1) 714 842 2603
COSWORTH 01604 752444
USA (1) 310 534 1390
CROWER USA (1) 213 543 1390
SBD MOTORSPORT 0208 391 0121
LINREAD NORTHBRIDGE MOTORSPORT
Tel 0162 572924 Fax 0162 572901
Viking Road, Wigston, Leicester, LE18 2BL
PANKL Austria (43) 386 251 2500
ATECH MOTORSPORTS USA (1) 330 630 0888

Co-ordsport

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Fax: +44 (0)1384 216109
Email: sales@coordsport.com
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DKE 01455 273738
EAGLE USA (1) 901 345 5886
FARNDON ENG 02476 366910
GRAINGER & WORRALL 01902 324460
LAYSTALL ENGINEERING 01902 451789

NORTHBRIDGE MOTORSPORT

LINREAD NORTHRIDGE MOTORSPORT Tel 01162 572924
Fax 01162 572901
Viking Road, Wigston, Leicester, LE18 2BL
MILLINGTON 01746 789268
SWINDON RACING ENGINES 01793 531321

CRANKSHAFTS
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Fax: 01902 422133
Web: www.customcrank.co.uk
Email: markhenry.rigg@btinternet.com
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VIBRATECH USA (1) 716 895 8000

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ALVIS ATL 02476 539311
ARROW PRECISION ENGINEERING LTD
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Fax +44 (0) 01455 233545
COMPTECH USA USA 001 916 933 1080
FARNDON ENG 02476 366910
HARROP Australia (61) 39 499 7433
KAITEN PRODUCTS USA (1) 714 220 2227
QUARTERMASTER USA (1) 847 540 8999
SWINDON RACING ENGINES 01793 531321

GASKETS
COMETIC BY JT FRANCE (33) 03207 46480
GOETZE Germany (49) 221 21 74690
GORE-TEX USA (1) 410 392 3200

HEADS
INTEGRAL POWERTRAIN 01908 278600
DUNNELL ENGINES 01449 677726
KENT AEROSPACE 01795 415000

INJECTORS
ASNU 0208 420 4494
HOLLEY PERFORMANCE USA (1) 502 781 9741
KINSLER USA (1) 810 362 1145
KS MOTORSPORT Germany (49) 2271 44905
MARREN USA (1) 203 732 4565

INTAKE MANIFOLDS
SBD MOTORSPORT 0208 391 0121
DUNNELL ENGINES 01449 677726
EDELBROCK USA (1) 310 781 2222
GRAINGER & WORRALL 01902 324460

- JENVEY DYNAMICS 01746 768810
- KINSLER USA (1) 810 362 1145
- **LINGENFELTER** **USA (1) 219 724 2552**
- SCHRICK Germany (49) 21 91 9500
- SWINDON RACING ENGINES 01793 531321

LINERS
- AE PISTONS 01274 729595
- APPERLEY HONING 01242 525868
- DATRON SLEEVES USA (1) 760 603 9895
- GKN SQUEEZEFORM 01952 244321
- LAYSTALL ENG 01902 451789
- MAHLE Germany (49) 217 4690

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- **RACETEK NAK** **02380 246986**

PISTONS
- **ACCRALITE PISTONS** **Tel 0121 525 6450** **Fax 0121 553 5951** **Accralite Piston Division, Spon Lane South, Smethwick, West Midlands B66 1QJ**
- AE PISTON PRODUCTS 01274 729595
- ARIAS 01403 784022
- ARIAS FORGED PISTONS USA (1) 310 532 9737
- BATTEN PERFORMANCE USA (1) 313 946 9850
- COSWORTH 01604 752444 / USA (1) 310 534 1390
- JE PISTONS USA (1) 714 898 9763
- MALVERN RACING USA (1) 804 971 9668
- MANLEY PERFORMANCE USA (1) 732 905 3366
- OMEGA PISTONS 0121 559 6778

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ROSS PISTON STOCKITS **Tel 01384 216102 Fax 01384 216109** **Website: www.coordsport.com** **Email: sales@coordsport.com** **Kings Street, Dudley West Midlands DY2 8PX**

- SWINDON RACING ENGINES 01793 531321
- TOTAL SEAL USA (1) 602 678 4977
- WISECO PISTON USA (1) 216 951 6600 / Canada 800 265 1029

PISTON RINGS
- AE PISTON PRODUCTS 01274 729595
- ARIAS FORGED PISTONS USA (1) 310 532 97371900
- CORDS PISTON RING 0208 998 9923
- FORD AUTO ENG USA (1) 805 2983785
- GOETZE Germany (49) 221 217 4690
- HI-TECH USA (1) 801 972 8766
- TOTAL SEAL USA (1) 602 678 4977
- TWR ENGINES 01993 871000

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- FERREA USA (1) 954 733 2505
- GGS VALVES LTD 01483 415444
- QINETIQ 08700 100942
- MANLEY PERFORMANCE USA (1) 732 905 3366
- RACING ENGINE VALVES USA (1) 954 772 6060
- SCHRICK Germany (49) 21 91 9500
- SUPERTECH PERFORMANCE USA (1) 408 448 2001
- SWINDON RACING ENGINES 01793 531321
- VALVE TECHNICS 01604 706541
- XCELDYNE TECHNOLOGIES USA (1) 336 472 8281

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- **ARROW PRECISION ENGINEERING LTD** **Tel +44 (0) 1455 234200** **Fax +44 (0) 1455 233545**
- **CHE PRECISION INC** **Tel (1) 805 499 8885** **Fax (1) 805 499 7810** **2640 Lavery CT,Unit C, Newbury Park, CA91320, USA**
- SERDI 01895 232215
- SWINDON RACING ENGINES 01793 531321

VALVESPRINGS
- CONNAUGHT 01795 843802
- DIAMOND USA (1) 313 792 6620
- EDELBROCK USA (1) 213 781 2222
- HERBERT TERRY & SONS 01527 64261
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- KURT KAUFFMANN Germany (49) 711 518300
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3.2 Engine Ancillaries

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- K&N FILTERS (EUROPE) UK 01925 636950
- KINSLER USA (1) 248 362 1145
- **PIPERCROSS** **01604 671100**

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- WEBER Italy (39) 51 417995
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ICENGINEWORKS tel (512) 858 2232 fax (512) 858 2282 Website: www.icengineworks.com Email: info@icengineworks.com 3996 Hwy 290E, Suite C, Dripping Springs, TX 78620 USA

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- SPECIALISED EXHAUST 0208 648 4786

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- **AN MOTORSPORT DESIGN** **01628 776320**
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- **EARL'S PERFORMANCE** **UK 01327 858221** **Fax 01327 858473** Unit 17 Silverstone Circuit, Towcester, Northamptonshire NN12 8TL, England
- ED PINK RACING ENGINES USA 818 785 6740
- **EXACT ENGINEERING** **01803 866464**
- **FHS MOTOR RACING** **01753 513080**
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- FRAM EUROPE 01443 223000
- KINSLER USA (1) 248 362 1145
- LEE PRODUCTS 01753 886664
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- THINK AUTOMOTIVE 0208 568 1172
- TJ FILTERS 01752 667675
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- ASNU Tel 0208 420 4494
- BGC MOTORSPORT 0208 880 4205
- BOSCH 01895 834466 / Germany (49) 711 8111 USA (1) 312 865 5200
- CONNAUGHT 01795 843802
- SBD MOTORSPORT 0208 391 0121
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- GENESIS ELECTRONIC SYSTEMS 01635 582255
- **INDUCTION TECHNOLOGY** **02476 305386**
- JENVEY DYNAMICS 01746 768810
- JOHN WILCOX COMPETITION 01455 230576

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- MM COMPETITION SYSTEMS 08707 444666
- MARREN USA (1) 203 732 4565
- MILLINGTON 01746 789268
- MOTEC Australia (61) 3 9761 5050
- MOTEC (EUROPE) UK 08700 119100
- MOTEC JAPAN Japan (81) 489 46 1734
- MOTEC SYSTEMS USA USA (1) 714 897 6804
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ATL **UK 01908 351700 / Fax 01908 351750** **Aero Tec Laboratories Ltd (Europe), 1 Patriot Drive, Rooksley, Milton Keynes, MK13 8PU**

- BROWN AND MILLER UK 01753 553610 / USA 704 793 4319
- CONNAUGHT 01795 84380
- **EXACT ENGINEERING** **01803 866464**
- **FAE MACHINE** **USA 317 243 3092**
- **FLEXOLITE** **01684 891898**
- FUEL SAFE UK 01799 541955 / USA (1) 714 842 2211
- **GOODRIDGE CA** **USA (1) 310 533 1924**
- **GOODRIDGE INDY** **USA (1) 317 244 1000**
- **GOODRIDGE EAST** **USA (1) 704 662 9095**

GOODRIDGE UK Tel 01392 369090 / Fax 01392 441780 **Exeter Airport Business Park, Exeter, EX5 2UP**

- HENRY'S ENG USA (1) 410 535 3142
- **JLS MOTORSPORT** **Tel 0121 525 7733**

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- PRONAL'S France (33) 320 99 75 10
- SPECIALTY FASTENERS 01803 866371
- SPV RACING Australia (61) 2 791 9899
- THINK AUTOMOTIVE 0208 568 1172
- **FLEXOLITE** **01684 891898**
- GOODRIDGE 01392 369090
- PRONALS France 33 3 20997510
- RACETECH 01327 359912
- WELDON RACING PUMPS USA (1) 216 232 2282

XRP INC **Tel USA (1) 562 861 4765** **FAX USA (1) 562 861 5503** **5630 Imperial Highway, South Gate, CA 90280, USA**

FUEL VALVES
- **AN MOTORSPORT DESIGN** **01628 776320**
- **ATL** **USA (1) 201 825 1400** **UK 01908 351700**
- **EXACT ENG** **01803 866464**
- KINSLER USA (1) 248 362 1145
- **PRONALS** **France 33 3 20 997510**
- SPECIALTY FASTNERS 01803 866371

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- **AN MOTORSPORT DESIGN** **01628 776320**

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- **DELPHI BRAKES SYSTEMS** **01926 472472**
- **EARL'S** **USA (1) 310 609 1602**
- **EXACT ENG** **01803 866464**
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- **FHS MOTOR RACING** **01753 570863**
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- **GOODRIDGE UK** **01392 369090**
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- **GOODRIDGE INDY** **USA (1) 317 244 1000**
- **GOODRIDGE EAST** **USA (1) 704 662 9095**
- HCL FASTENERS 01282 411992
- HENRY'S ENG USA (1) 410 435 3142
- **JLS MOTORSPORT** **0121 525 7733**
- KINSLER USA (1) 248 362 1145
- SAMCO SPORT 01443 238464

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- SPEED FLOW 0208 530 6664
- THINK AUTOMOTIVE 0208 568 1172
- UNICLIP AUTOMOTIVE 01932 355277
- XRP INC USA (1) 562 861 4765

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- AH FABRICATIONS 01432 354704
- ALLARD MOTOR CO. 01425 500 333
- **FLUID CONTROL PRODUCTS INC** **USA (1) 217 324 3737** **Fax (1) 217 324 3717**
- PACE PRODUCTS 01440 760960
- SERCK MARSTON 0208 965 2151
- SFS PERFORMANCE 01582 412 697

OIL COOLERS
- AEROQUIP USA (1) 419 238 1190
- CV PRODUCTS USA (1) 910 883 4096
- DOCKING & CO 01372 857164
- **EARL'S** **USA (1) 310 609 1602**
- **EXACT ENGINEERING** **01803 866464**
- **FAE MACHINE** **USA 317 243 3092**
- **FLUID CONTROL PRODUCTS INC** **USA (1) 217 324 3737** **Fax (1) 217 324 3717**
- **GOODRIDGE UK** **01392 369090**
- **GOODRIDGE CA** **USA (1) 310 533 1924**
- **GOODRIDGE INDY** **USA (1) 317 244 1000**
- **GOODRIDGE EAST** **USA (1) 704 662 9095**
- LAMINOVA Sweden (46) 85 907 4045
- PROCOMP 0121 350 3258
- SECAN France (33) 14 790 6512
- SERCK MARSTON 020 8965 2151
- SETRAB Sweden (46) 40 158060
- SPECIALTY FASTNERS 01803 866371
- SPV RACING Australia (61) 2 791 9899
- THINK AUTOMOTIVE 020 8568 1172
- TREVOR MORRIS ENG 01547 530289

OIL FILTERS
- **AN MOTORSPORT DESIGN** **01628 776320**
- **COSWORTH** **01604 752444** **USA (1) 310 534 1390**
- **EARL'S** **USA (1) 310 609 1602**
- **ED PINK ENGINES** **USA 818 785 6740**
- **EXACT ENGINEERING** **01803 866464**
- **FLEXIBLE HOSE** **01753 570863**
- **FRAM FILTERS** **01443 223000**
- KINSLER USA (1) 248 362 1145

OIL PUMPS
- **ED PINK RACING ENGINES** **USA 818 785 6740**
- **KENT CAMS** **01303 248666**
- PACE PRODUCTS 01440 760960
- PACET 01628 526754
- SPV RACING Australia (61) 2 791 9899
- SWINDON RACING ENGINES 01793 531321
- TITAN MOTORSPORT 01480 474402

OILS & LUBRICANTS

OLD HALL PERFORMANCE LTD **+44 (0) 24 7671 7100** **Fax +44 (0) 24 7671 7400** **email sales@redlineoil-europe.com** **www.redlineoil-europe.com**

OIL SEALS
- RACE-TEC NAK 02380 246986
- PIONEER WESTON (WYKO) 0161 703 2011

OIL SUMPS
- AH FABRICATIONS 01432 354704

A.R.E DRY SUMP SYSTEMS **USA: (1) 916 987 7629** **www.drysump.com**

- **CONNAUGHT** **01795 843802**
- JENVEY DYNAMICS 01746 768810
- MILODON USA (1) 818 407 1211
- PACE PRODUCTS 01440 760960
- STONE FOUNDRIES 0208 853 4648
- SWINDON RACING ENGINES 01793 531321
- TITAN MOTORSPORT 01480 474402
- TREVOR MORRIS ENG 01547 530289

OIL TANKS
- BS ENGINEERING 01908 618080
- GARTRAC 01428 682263
- GOMM METAL DEVELOPMENTS 01483 764876
- KS MOTORSPORT Germany (49) 2271 44905
- MIDAS METALCRAFT 01933 355512
- PACE PRODUCTS 01440 760960
- THINK AUTOMOTIVE 020 8568 1172

RUBBER & ELASTOMERIC COMPONENTS
- BUTSER RUBBER LTD Tel: 01730 894034

STARTER MOTORS
- ARK RACING 01785 715234
- **EARL'S** **USA (1) 310 609 1602**
- **RTRAC** **Germany (49) 9725 5075**
- **STARTLINE UK LTD** **01933 665752**

THROTTLE BODIES
- **JENVEY DYNAMICS** **01746 768810**
- KINSLER USA (1) 248 362 1145
- **LINGENFELTER** **USA (1) 219 724 2552**
- LUMENITION 0207 403 4334
- SWINDON RACING ENGINES 01793 531321
- **TWM INDUCTION** **USA (1) 805 967 9478**

THROTTLE VALVES
- **JENVEY DYNAMICS** **01746 768810**
- KINSLER USA (1) 248 362 1145
- LUMENITION 0207 403 4334
- TREVOR MORRIS ENG 01547 530289
- **TWM INDUCTION** **USA (1) 805 967 9478**

TURBOCHARGERS
- GARRETT AUTOMOTIVE 01695 22391
- HOLSET ENG 01484 422244
- INTERPRO ENGINEERING 01454 412777
- QINETIQ 08700 100942
- TURBO TECHNICS 01604 764005
- ALLARD MOTOR CO. 01425 500 333

WATER COOLERS
- AH FABRICATIONS 01432 354704
- DOCKING & CO 01327 857164
- DENSO MARSTON 01274 582266
- NIPPON DENSO Japan (81) 56 625 5511 / UK 0208 591 7700
- PACE PRODUCTS 01440 760960
- SERCK MARSTON 0208 965 2151

WATER INJECTION
- ERL 01273 581007

WATER PUMPS
- DAVIES, CRAIG Australia (61) 39 499 7433
- ED PINK RACING ENGINES USA 818 785 6740
- EDELBROCK USA (1) 213 781 2222
- TREVOR MORRIS ENG 01547 530289

3.3 Engine Electronics

COMPUTER SUPPLIERS

ACES	01206 395324
ADVANCED AUTOMOTIVE	01753 642019
COMPETITION DATA	USA (1) 716 631 2880
FUELTRONICS	Australia (61) 88363 2199
PAD RACING	New Zealand (64) 3 3386 288
PERFORMANCE TRENDS	USA (1) 248 473 9230
RACELOGIC	01280 823803

DATA-ACQUISITION

ACTIVE SENSORS	Tel 01202 480620
	Fax 0120 2480664
ADVANCED AUTOMOTIVE	01753 642019
B&G RACING	USA (1) 602 274 2537
BOSCH	01895 834466
	Germany (49) 711 8111
	USA (1) 312 865 5200
COMPETITION DATA SYS	USA (1) 716 631 2880
COMPUTECH SYSTEMS	USA 800 870 8383
COMPUTERACE TIMING	01905 796090
CORSA INSTRUMENTS	USA (1) 313 761 1545
2D DEBUS	Germany (49) 721 944850
DATASPARES ACQUISITION	0208 463 9222
DATRON TECHNOLOGY	01908 261655
DIGICON ENGINEERING	Canada (1) 604 984 9437
FOREFRONT	USA (1) 404 448 9550

Intercomp

INTERCOMP — **USA Tel (1) 763 476 2531**
Fax (1) 763 476 2613
14465 23rd Avenue N, Minneapolis, MN 55447, USA

ISAAC INSTRUMENTS INC. — **Tel: (450) 658 7520**
Fax: (450) 658 3322
Email: isaac@isaac.ca
Website www.isaac.ca
25 Robert, Chamby, Quebec, Canada J3L 1S2

LONGACRE	USA (1) 425 485 0620
McCLAREN ELECTRONICS	01483 261400
MM COMPETITION SYSTEMS	08707 444666
MOTEC	Australia (61) 3 9761 5050
MOTEC (EUROPE)	UK 08700 119100
MOTEC JAPAN	Japan (81) 489 46 1734
MOTEC SYSTEMS USA	USA (1) 714 897 6804
MOTECH	USA (1) 804 973 1399
MOTOR SPORT ELEC	Australia (61) 7 3290 1309
MOTORSPORTS INTERFACE	01327 311011
MTS Powertrain Tech	**Tel 01932 351516**
	Fax 01932 351517
	7 Glen Court,Canada Road, Byfleet, Surrey KT14 7JL
NIPPON DENSO	Japan (81) 56 625 6951
PECTEL CONTROL SYSTEMS	+44 (0)1954 253610
PENNY & GILES	01202 409409
PERFORMANCE TRENDS	USA (1) 248 473 9230
PI RESEARCH	**01954 253600**
POLY LOGIC	01462 621066
QINETIQ	08700 100942
QUANTUM SUSPENSION	01243 865058
RACE DATA ENGINEERING	USA (1) 714 449 1445
SAKATA MOTORSPORT ELEC. INC.	(714) 446 9473
STACK	**Tel 01869 240404**
	Fax 01869 245500
	email: sales@stackltd.com
	Wedgewood Road, Bicester Oxfordshire, OX26 4UL
STEVE BUNKHALL	01223 303025
VARIOHM	01327 351004

ENGINE MANAGEMENT SYSTEMS

ADVANCED AUTOMOTIVE	01753 642019
ASNU	0208 420 4494
BOSCH	01895 834466
	Germany (49) 711 8111
	USA (1) 312 865 5200
CONNAUGHT	01795 843802
DATASPARES	0208 463 9229
SBD MOTORSPORT	0208 391 0121
McCLAREN ELECTRONICS	01483 261400
MM COMPETITION	08707 444666

MoTeC

MOTEC PTY LTD — **Aus Tel: 613 9761 5050**
Aus Fax: 613 9761 5051
Japan +81 489 461 734
121 Merringdale Drive
Croydon South Victoria Australia
UK: +44 8700 119100
USA +1 714 895 7001

PECTEL CONTROL SYSTEMS	+44 (0)1954 253610
PRECISION RACE SERVICES	USA (1) 248 844 1060
SAKATA MOTORSPORT ELEC. INC.	(714) 446 9473
STACK	**01869 240404**
SUPERCHIPS	01280 816781
TERRY SHEPHERD TUNING	01695 574454
WALBRO ENGINE MANAGEMENT	**USA (1)989 872 7091**
ZYTEK SYSTEMS	0121 323 2323

ENGINE SENSORS

ACTIVE SENSORS	Tel 01202 480620
	Fax 01202 480664
	Unit 12, Wilverley Rd, Christchurch, Dorset, BH23 3RU England
AVL DEUTSCHLAND Gmbh Germany	(49) 6134 7179-0
DATASPARES	0208 463 9229
ENTRAN	01923 893 999
KISTLER INSTRUMENTS	01420 544477

kulite

KULITE SENSORS — **Tel 01256 461646**
Kulite House, Stroudley Road, Basingstoke, RG24 8UG, England

MAGCANICA INC	USA 858 454 8950
McCLAREN ELECTRONICS	01483 261400
THE STRAIN GAUGING CO	**01256 320666**
VARIOHM	01327 351004

REV-LIMITERS

LUCAS ELECTRICAL	0121 536 5050
LUMENITION	020 7403 4344
MM COMPETITION	08707 444666

3.4 Transmission Components

CLUTCHES

alcon

ALCON — **Tel +44 (0) 1827 723700**
Fax +44 (0) 1827 723701
Email info@alcon.co.uk
www.alcon.co.uk
Apollo, Tamworth, Staffordshire B79 7TN

AP RACING

AP RACING — **(0)24 7663 9595**
Fax (0) 24 7663 9559
Wheler Road, Coventry, CV3 4LB

FICHTEL & SACHS	0208 654 8835
GOODRIDGE	01392 369090
LOLA	Tel 01480 451301
	Fax 01480 456722
QUARTER MASTER	USA (1) 847 540 8999
	Fax (1) 847 540 0526
	510 Telser Road, Lake Zurich, IL 60047, USA
SUPER CLUTCH	UK 01926 812136
RTRAC	Germany (49) 9725 5075

SACHS RACE ENGINEERING

SACHS RACE ENGINEERING GmbH — **Tel +49 9721-984300**
Fax +49 9721-984299
Email service.sre@sachs.de
Website www.sachs-race-engineering.de
Ernst-Sachs-Strasse 62, 97424 Schweinfurt, Germany

SACHS BOGE	UK 01788 822353
TILTON ENGINEERING	USA (1) 805 688 2353
	Fax (1) 805 688 2745
	25 Easy Street, Buellton, CA 93427 USA
WILWOOD ENGINEERING	Fax (1) 805 388 4938
	USA (1) 805 388 1188
	416 Calle San Pablo, Camarillo, CA 93012, USA

COMPLETE TRANSMISSIONS

RICARDO

RICARDO MIDLANDS TECHNICAL CENTRE — **Tel: 01926 447152**
Fax: 01926 319352
Email: iain.wight@ricardo.com
Website: www.ricardo.com
Southam Road, Radford Semele, Leamington Spa CV31 1FQ

CWP'S

DAVID BROWN	01484 422180
DTS	USA (1) 313 778 0540
JCM TRANSAXLES	USA (1) 303 695 6093
MARK BAILEY RACING	01380 850130
XTRAC LTD	**01635 293800**

DIFFERENTIALS

AJEC INDUSTRIES	01242 222739
GEARACE LIMITED	01869 277563
GKN AXLES	0207 930 2424
HEWLAND ENG	01628 827600
JCM TRANSAXLES	USA (1) 303 695 6093
MARK BAILEY RACING	01380 850130
QUAIFE ENGINEERING	01732 741144
RICARDO	01273 455611
RICARDO MIDLANDS TECHNICAL CENTRE	01926 319399
TOM'S DIFFERENTIALS	USA (1) 310 634 8431
TRAN-X GEARS LTD	02476 659061
XTRAC LTD	**01635 293800**
ZEXEL-GLEASON	USA (1) 716 464 5000

DRIVESHAFTS

TORQline CTG Composite Driveline Products

CTG — **Tel: +44 (0)1295 220130**
Fax: +44 (0)1295 220138
Email: motorsport@ctgltd.co.uk
www.ctgltd.co.uk
Thorpe Park, Thorpe Way, Banbury, Oxfordshire OX16 4SU United Kingdom

GKN Motor Sport

GKN MOTOR SPORT — **Tel 0121 313 1661**
Fax 0121 313 2074
Unit 5, Kingsbury Business Park, Kingsbury Road, Minworth, Sutton Coldfield, Birmingham B76 9DL, England

METALORE	USA (1) 310 643 0360
PANKL	0043 3862 33999
TEX RACING	USA (1) 910 428 9522
TRAN-X GEARS LTD	02476 659061

GEARS

B&M

B&M — **001 818 882 6422**
www.bmracing.com
Chatsworth CA 91311 USA

COLLEDGE & MORLEY	02476 462328
COMPTECH USA	USA (1) 916 933 1080
DAVID BROWN	01484 422180
GEARACE LIMITED	01869 277563
HEWLAND ENG	01628 827600
JCM TRANSAXLES	**USA (1) 303 695 6093**
KERSCHBAUMER	**Ger (49) 6074 47 663**
MARK BAILEY RACING	01380 850130
PANKL	0043 3862 33999
TEX RACING	USA (1) 910 428 9522
RICARDO MIDLANDS TECHNICAL CENTRE	01926 319399
TRAN-X GEARS LTD	02476 659061
XTRAC LTD	01635 293800

UNIVERSAL JOINTS

FLAMING RIVER	USA (1) 440 826 4488
GEARACE LIMITED	01869 277563

Database 4

FACTORY EQUIPMENT

4.1 Factory Hardware

AIR LINES & FITTINGS

A.N. MOTORSPORT DESIGN	01628 776320
EARL'S	**UK 01327 858221**
EXACT ENGINEERING	**01803 866464**
Fhs Motor Racing Ltd	**01753 513080**
GOODRIDGE UK	**01392 369090**
GOODRIDGE CA	USA (1) 310 533 1924
GOODRIDGE INDY	USA (1) 317 244 1000
GOODRIDGE EAST	USA(1) 704 662 9095
INGERSOLL RAND	01204 690690
JLS MOTORSPORT	**0121 525 7733**
KRONTEC	**Germany (49) 9401 703062**
REGENT	01908 612602
ROTOTEST	Sweden 46 8532 55890
THINK AUTOMOTIVE	0208 568 1172

AIR TOOLS

DESOUTTER AUTOMOTIVE	0208 205 4884

paoli AVVITATORI

DINO PAOLI S.R.L. — **Tel: +390 522 300828**
Fax: +390 522 304864
email: info@dinopaoli.com
Website: www.dinopaoli.com
Via Guido Dorso, 542100, Reggio Emilia, Italy

FACOM	01932 566099
INGERSOLL RAND	01204 690690
JLS MOTORSPORT	0121 525 7733

CNC MACHINING CENTRES

ABSOLUTE MACHINE TOOL	USA (1) 440 324 5133
BOSTON DIGITAL	USA (1) 508 473 4561
BRIDGEPORT MACHINE	USA (1) 248 299 1750
DEREK ROBINSON	0116 266 2222
DEWCO	USA (1) 765 962 7201
MACHINERY SALES	USA (1) 510 490 4000
MAKINO	USA (1) 800 552 3288
MEDDINGS MACHINES	01752 893277
MILLS ENGINEERING	01603 745531
MILLSITE ENGINEERING	USA (1) 304 273 5351
RGS PERFORMANCE	USA (1) 716 434 2509
RMT MECHATRONICS	01565 650411
SERDI	**01895 232215**
SOUTHWESTERN IND	USA (1) 310 608 4422
SPA AEROFOILS LTD	01827 260026
TGS	USA (1) 940 668 1002
TOYODA EUROPE	02476 547200

CRACK DETECTION

ABS PRODUCTS	USA (1) 714 671 0728
DCM TECH	USA (1) 800 533 5339
KRAUTKRAMER BRANSON	USA (1) 717 242 0327

CRYOGENIC TEMPERING

FROZEN SOLID	01449 674914

DUST EXTRACTION EQUIP

DENCER	01789 470198

DYNAMOMETERS: CHASSIS

FROUDE CONSINE	01905 856800
	International Dynamometers LTD/Dynapack
	USA 001 559 292 3800 New Zealand 64 4587 0484
LAND & SEA	USA (1) 603 329 5645
KISTLER Instruments Ltd	01420 544477
ROTOTEST	Sweden (46) 8 532 55890
SUPERFLOW	USA (1) 800 471 7701
	Belgium 3215 216300
UNICO (UK) LTD	01908 260000

DYNAMOMETERS: DAMPER

BEHRENTS SPEED CENTER	USA (1) 914 651 7389
CZECH MATE	USA (1) 800 819 7223
DYNAMIC SUSPENSIONS	**Can (1) 905 470 8778**
	UK 01842 755744
ND TECH SHOCK DYNOS	USA (1) 520 624 3907
SCHMITT EUROPE	UK 02476 697192
SPA DESIGN	**01827 260026**
SPA TECHNIQUE	**USA (1) 317 271 7941**
TAT	Germany (49) 7252 84258

DYNAMOMETERS: ENGINE

AVL	Germany (49) 61 34 71 790
DSP TECHNOLOGY	01932 351516
DYNAMIC TEST SYSTEMS	01842 755744
ENGINE & DYNAMOMETER	**01708 857108**
FROUDE CONSINE	01905 856800
JKM AUTOMOTIVE	USA (1) 508 966 2531
LAND & SEA	USA (1) 603 329 5645
LOTUS ENGINEERING	01953 608000
MOTORSPORTS INTERFACE	01788 890412
TAT	**Germany (49) 7252 84258**

DYNAMOMETER INSTRUMENTATION

AQUIRED DATA SYSTEMS	USA (1) 810 566 0131
DEPAC DYNO SYSTEMS	USA (1) 315 339 1265
DYNOLAB	USA (1) 206 243 8877
FROUDE CONSINE	01905 856800
LAND & SEA	USA (1) 603 329 5645
KISTLER Instruments Ltd	01420 544477
PERFORMANCE TRENDS	**USA (1) 248 473 9230**
QUADRANT SCIENTIFIC	**USA (1) 303 666 8414**
ROEHRIG ENGINEERING	**USA (1) 336 431 1827**
SUPERFLOW	USA (1) 800 471 7701
	Belgium 3215 216300
TAT	Germany (49) 7252 84258

ENGINE BALANCING EQUIP

ABS PRODUCTS	USA (1) 714 671 0728
BC GEROLAMY	USA (1) 916 638 9008
POWERHOUSE PRODUCTS	USA 800 872 7223
SCHMITT EUROPE	02476 697192
SUNNEN PRODUCTS	USA (1) 800 772 2878
WINONA VAN	Canada (1) 800 833 4870

ENGINE HOISTS

MR GASKET PERFORMANCE	USA (1) 216 398 8300
SILVER SEAL	USA (1) 800 521 2936

ENGINE STANDS

ABS PRODUCTS	USA (1) 714 671 0728
BLUEBIRD	USA (1) 800 808 2473
C-LINE	USA (1) 800 645 7267
DYNAMIC TEST SYSTEMS	USA (1) 800 243 3966
GOODSON	**USA (1) 507 452 1830**
JEGS	USA (1) 614 294 5451
MOROSO PERFORMANCE	USA (1) 203 453 6571
MR GASKET PERFORMANCE	USA (1) 216 398 8300
RACER COMPONENTS	USA (1) 903 581 5976
SCRIBNER	USA (1) 916 638 1515

FLOW BENCHES

ASNU	0208 420 4494
AUDIE TECHNOLOGY	USA (1) 610 630 5895
CV PRODUCTS	USA (1) 800 448 1223
CLO-FLOW	South Africa (27) 11 963128
DEPAC DYNO SYSTEMS	USA (1) 315 339 1265
FLOWDATA	USA (1) 714 632 7828
HODGE MFG	USA (1) 800 262 4634
PERFORMANCE TRENDS	USA (1) 248 473 9230
ROEHRIG ENGINEERING	USA (1) 336 431 1827
SUPERFLOW	USA (1) 800 471 7701
	Belgium 3215 216300
TAT	Germany (49) 7252 84258

GENERATORS: PORTABLE
- HANCO GENERATING — USA (1) 800 413 6688
- LINCOLN ELECTRIC — USA (1) 216 481 8100

HORIZONTAL/VERTICAL MACHINING CENTRES
- MAKINO — USA (1) 800 552 3288
- MILLS — 01603 745531
- MITSUBISHI-YAMAZEN — 0208 549 9161
- RGS PERFORMANCE — USA (1) 716 434 2509
- TOYODA — 02476 547200

LATHES
- RMT MECHATRONICS — 01565 650411
- LOCK-N-STITCH — USA (1) 800 736 8261
- MAGNAFLUX — USA (1) 847 657 5300
- **THE STRAIN GAUGING CO — 01256 320666**

RAPID PROTOTYPING
- CRP TECHNOLOGY — Italy (39) 059 821135
- 3D SYSTEMS — UK 01442 282600

TOOL CABINETS
- DURA — 01295 712800

GWS Systems Oy
Tel: 01403 276445
Fax: 01403 276434
Email: sales@gwssystems.co.uk
Website: gwssystems.co.uk
Units 10-12 Horsham Court, City Business Centre, 6 Brighton Road, Horsham, West Sussex RH13 5BA

- LISTA — 01908 222333
- MAC TOOLS — USA (1) 614 755 7000

WELDING EQUIPMENT
- AMILLER ELECTRIC MFG — USA (1) 800 426 4553

4.2 Factory Software

CAD & CAM SOFTWARE
- BRIDGEPORT MACHINE — USA (1) 248 299 1750
- DASSAULT SYSTEMES — USA (1) 818 673 2134
- DELCAM — 0121 766 5544
- EXA — USA (1) 781 676 8551
- MITUTOYO UK — 01264 353123
- PARAMETRIC TECHNOLOGY — 01252 817000
- QinetiQ — 08700 100942

PARTS USE LIFING
- ADVANCED RACING SYSTEMS — USA (1) 513 893 2773
- LIFECHECK — 01285 720665
- KINETIC RACING TECHNOLOGIES — USA (1) 248 245 2330
- NOSKECOMP — Australia 07 32 88 3895

PERF SIMULATION
- D.A.T.A.S — 01603 506526
- PI RESEARCH — 01954 253600
- PERFORMANCE TRENDS — USA (1) 248 473 9230
- RICARDO — USA (1) 734 397 6666
- SERVOTEST — 0208 707 1400
- VEHICLE DYNAMICS PERFORMANCE — USA (1) 512 450 1035

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CIRCUIT EQUIPMENT

5.1 Pits Equipment

AIR COMPRESSORS
- COMPAIR UK — 01494 465000
- COMPAIR UK — 01473 602222
- **ROTOTEST — Sweden 46 8532 55 890**

AIR LINES & FITTINGS
- **EXACT ENGINEERING — 01803 866464**
- **FASTENER FACTORY — 01327 311018**
- FHS Motor Racing Ltd — 01753 513080
- **GOODRIDGE — UK 01392 369090**
- **GOODRIDGE CA — USA (1) 310 533 1924**
- **GOODRIDGE INDY — USA (1) 317 244 1000**
- **GOODRIDGE EAST — USA (1) 704 662 9095**
- JLS MOTORSPORT — 0121 525 7733
- KRONTEC — Germany (49) 9401 703062, Fax (49) 9401 70 24 76, **Berliner Straße 31, 93073 Neutraubling, Germany**
- MOTORSPORTS NZ — NZ 0064 2596 5599
- THINK AUTOMOTIVE — 0208 568 1172

BATTERY CHARGERS
- **POWER TRANS SOLUTIONS — Tel 01722 332126, Fax 01722 333 522, www.wynall.com, Stephens Road, Church Fields, Salisbury, Wiltshire, FP2 7NX**
- TRIDENT — 01327 857822

CAMBER GAUGES
- **DEMON TWEEKS — 01978 664466**, 75 Ash Road South, Wrexham Industrial Estate, Wrexham, Clwyd LL13 9UG, Wales

- HARRISON AUTO — USA (1) 602 254 0024
- LONGACRE RACING — USA (1) 425 885 3823
- **OMS RACING — 0113 2575956**
- PACE PRODUCTS — 01284 850960

REDLINE MOTORSPORT — Tel 01606 737500
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk

- TRIDENT — 01327 857822

CHASSIS STANDS
- **DEMON TWEEKS — 01978 664466**
- SMR COMPONENTS — USA (1) 708 949 9100

COMPUTER HARDWARE
- ADVANCED AUTOMOTIVE — 01753 642019
- CALEX INSTRUMENTATION — 01525 373128
- **CRANFIELD — 01234 751361**
- DYNOLAB — USA (1) 206 243 8877
- FASTER SYSTEMS — USA (1) 415 332 6064
- FUELTRONICS — Australia (61) 0883632199
- FUJITSU — 0208 573 4444
- **GENESIS — 01635 582255**
- KISTLER — Switzerland (41) 52 224 1111
- NOVA — USA (1) 615 832 6355
- OLIVETTI — 0208 785 6666
- PERFORMANCE TRENDS — USA (1) 248 473 9230
- RACING CAR COMPUTERS — 01279 812496
- STACK — 01869 240404

CORNER SCALES
- **A.R.T. — USA (1) 914 889 4499**
- **DEMON TWEEKS — 01978 664466**
- **LONGACRE RACING — USA (1) 206 885 3823**
- NOVATECH — 01424 852744
- **REDLINE MOTORSPORT — Tel 01606 737500**
- ROLLCENTRE — 01480 464052

DAMPER DYNAMOMETERS (PORTABLE)
- DYNAMIC SUSPENSIONS — 01842 755744
- ROEHRIG ENGINEERING — USA (1) 313 344 8120
- **SERVOTEST LTD — 020 8707 1400**
- SPA DESIGN — 01827 288328
- SPA TECHNIQUE — USA (1) 317 271 7941

EAR DEFENDERS
- **DEMON TWEEKS — 01978 664466**
- FASTENER FACTORY — 01327 311018
- RACING RADIOS — USA (1) 404 366 3796
- **REDLINE MOTORSPORT — Tel 01606 737500**

ELECTRIC STARTERS
- **POWER TRANS SOLUTIONS — 01722 332126**

ENGINE HOISTS
- DUNLOP AUTOMOTIVE — 0121 384 4444
- FACOM — UK 01932 566099

ENGINE STANDS
- GUYON RACING — Canada (1) 403 277 6020
- TITAN MOTORSPORT — 01480 474402

FIRE EXTINGUISHERS
- CHUBB — 01932 785588

FEV — Tel 01243 555566 Fax 01234 555660
Email sales@f-e-v.co.uk
www.f-e-v.co.uk
Unit 10 Ford Lane Business Park, Ford, West Sussex BN18 0UZ

- FIREMASTER — 0208 852 8585
- **LIFELINE FIRE SYSTEMS — 02476 712999**
- Mardi Gras Motorsports — 01327 858 006
- OMP — 0208 656 7031, Italy (39) 10 680 851
- QINETIQ — 08700 100942
- SILVERSTONE RACE SERVICES — 01327 858441
- **SPA DESIGN — 01827 288328**
- **SPA TECHNIQUE — USA (1)317 271 7941**
- **TRIDENT — 01327 857822**

FLOOR CRANES
- ANRICK TRADING — NZ (04) 5899371
- FASTNER FACTORY — 01327 311018
- SLINGSBY — 01274 721591

FUME EXTRACTORS
- DENCER — 01789 470198
- INGERSOLL RAND — 01204 690690

HAND PUMPS
- EXACT ENGINEERING — 01803 866464
- FACOM — 01932 566099
- SILVERSTONE RACE SERVICES — 01327 858441
- SNAP-ON — USA (1) 414 656 5372, 0161 969 0126
- WURTH UK — 0208 310 6666

HAND TRUCKS
- OMS RACING — 0113 2575956
- SILVERSTONE RACE SERVICES — 01327 858441

HEAD TORCHES
- ESSEX RACING — USA (1) 404 889 4096
- HELLA — 01295 272233

JACKS
- ARGO MANUFACTURING — USA (1) 630 377 1750
- DEMON TWEEKS — 01978 664466
- DUNLOP AUTOMOTIVE — 02476 667738
- FACOM — UK 01932 566099
- FASTENER FACTORY — 01327 311018
- JLS MOTORSPORT — 0121 525 7733
- KS MOTORSPORT — Germany (49) 2271 44905
- PADDY HOPKIRK LTD — 01525 850800
- PERFORMANCE MACHINE — USA (1) 303 828 4546
- **REDLINE MOTORSPORT — Tel 01606 737500**
- SLINGSBY — 01274 721591
- DEMON TWEEKS — 01978 664466
- KS MOTORSPORT — Germany (49) 2271 44905
- MARDI GRAS MOTORSPORTS — 01327 858 006
- MECHANIX WEAR — USA (1) 661 257 0474
- RALLY DESIGN — 01795 531871
- SILVERSTONE RACE SERVICES — 01327 858441

NOISE METERS
- CIRRUS RESEARCH — 01723 891655

PIT BARRIERS
- KAISER & KRAFT — 01923 233312
- SLINGSBY — 01274 721591

PIT BOARDS
- ACTIVE ENGINEERING — USA 001 714 637 1155
- DEMON TWEEKS — 01978 664466
- GRAND PRIX RACEWEAR — 0208 987 5500
- KS MOTORSPORT — Germany (49) 2271 44905
- **REDLINE MOTORSPORT — Tel 01606 737500**
- TRIDENT — 01327 857822

PIT CANOPIES
- PIT BITS — 01727 858297

PIT LANE MARKERS
- KAISER & KRAFT — 01923 233312
- SLINGSBY — 01274 721591

PIT TROLLEYS
- CHAMPION — 01953 888664
- **DEMON TWEEKS — 01978 664466**
- GTC COMPETITION — 01483 272151
- LISTA — 01908 222333
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **OMS RACING — 0113 2575956**

PYROMETERS
- AP RACING — Tel 02476 639595, Fax 02476 639559, Wheler Road, Coventry, CV3 4LB

RADIO SCANNERS
- QINETIQ — 08700 100942
- RACING RADIOS — USA (1) 404 366 3796

RADIO SYSTEMS/INTERCOMS
- AUTOCOM — 01926 431249
- AUTOTEL RACE RADIO — 01508 528837
- MRTC — 0150 981 2610
- QINETIQ — 08700 100942
- STRODE SOUND — 01761 419248

RAIN SUITS
- **DEMON TWEEKS — 01978 664466**
- GRAND PRIX PROMOTIONS — 01474 879524
- JAYBRAND — 01733 68247
- **REDLINE MOTORSPORT — Tel 01606 737500**

REFUELLING LINES & VALVES
- DUNLOP — 01235 863863
- **EXACT ENGINEERING — 01803 866464**
- **GTC COMPETITION — 01483 272151**
- KRONTEC — Germany (49) 9401 703062
- PREMIER FUEL SYSTEMS — 01332 850515
- **THE STRAIN GAUGING CO — 01256 320666**

REFUELLING RIGS
- **DEMON TWEEKS — 01978 664466**
- GTC COMPETITION — 01483 272 151
- PREMIER FUEL SYSTEMS — 01332 850515
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **SPA DESIGN — 01827 288328**
- **THE STRAIN GAUGING CO — 01256 320666**

SCISSOR PLATFORMS
- SLINGSBY — 01274 721591

SETUP FLOORS
- **ACTIVE ENGINEERING — USA 001 714 637 1155**
- 4-PATCH — 01376 348246
- KS MOTORSPORT — Germany (49) 2271 44905
- ME MOTORSPORT — 01884 253070
- RML — 01933 402440
- **THE STRAIN GAUGING CO — 01256 320666**
- SPA AEROFOILS LTD — 01827 260026
- UNIVERSITY OF HERTFORDSHIRE — 01707 284270

SETUP GAUGES
- **A.R.T. — USA (1) 914 889 4499**
- **CYBER DYNAMICS — 01869 347812**
- **DEMON TWEEKS — 01978 664466**
- **ILONGACRE RACING — USA (1) 206 885 3823**
- ME MOTORSPORT — 01884 253070
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **THE STRAIN GAUGING CO — 01256 320666**

SPACE HEATERS
- FASTENER FACTORY — 01327 311018

STOPWATCHES
- CASIO — 0208 450 9131
- **DEMON TWEEKS — 01978 664466**
- **GRAND PRIX RACEWEAR — 020 8987 5500**
- KS MOTORSPORT — Germany (49) 2271 44905
- RACING RADIOS — USA (1) 404 366 3796
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **TRIDENT — 01327 857822**

STORAGE SYSTEMS
- KAISER & KRAFT — 01923 233312
- LISTA (UK) LTD — 01908 222333
- POLSTORE STORAGE — 01403 750000
- PRONALS — France (33) 3201 997510

TAPE
- **DEMON TWEEKS — 01978 664466**
- **CLARENDON — 01455 841200**
- DRC RACE CAR — USA (1) 609 397 4455
- FASTENER FACTORY — 01327 311018
- KS MOTORSPORT — Germany (49) 2271 44905
- RALLY DESIGN — 01795 531871
- **REDLINE MOTORSPORT — Tel 01606 737500**
- TRIDENT — 01327 857822

TIMING SYSTEMS
- CASIO — 0208 450 9131
- CONTINENTAL SPORT — USA (1) 513 459 8888
- ME MOTORSPORT — 01884 253070
- MOTEC — Australia (61) 3 9761 5050
- MOTEC (EUROPE) — UK 08700 119100
- MOTEC JAPAN — Japan (81) 489 46 1734
- MOTEC SYSTEMS USA — USA (1) 714 897 6804
- MST SPORTS TIMING — 01684 573479
- **PI RESEARCH — 01954 253600**
- PIT BITS — 01727 858297
- STACK — 01869 240404
- UNISYS — 0208 453 5562
- VULCAN ENTERPRISES — USA (1) 602 759 7926

TOOL CABINETS
- FACOM — UK 01932 566099
- KAISER & KRAFT — 01923 233312
- POLSTORE STORAGE — 01403 750000
- SLINGSBY — 01274 721591

TORQUE WRENCHES
- FACOM UK — 01932 566099
- NORBAR TORQUE TOOLS — 01295 270333
- RALLY DESIGN — 01795 531871

TRACKING GAUGES
- **A.R.T. — USA (1) 914 889 4499**
- **DEMON TWEEKS — 01978 664466**
- **GMD COMPUTRACK — Austra (61) 2 9644 1946**
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **THE STRAIN GAUGING CO — 01256 320666**

TYRE PRESSURE GAUGES
- BERU F1 SYSTEMS — 01379 646200
- GRAND PRIX RACEWEAR — 0208 987 5500
- **THE STRAIN GAUGING CO — 01256 320666**
- **TRIDENT — 01327 857822**

TYRE TEMPERATURE GAUGES
- **THE STRAIN GAUGING CO — 01256 320666**
- TRIDENT — 01327 857822

TYRE TROLLEYS
- **OMS RACING — 0113 2575956**

TYRE WARMERS
- **BANDIT — Australia (61) 3 9318 0644**
- **DEMON TWEEKS — 01978 664466**
- **GRAND PRIX RACEWEAR — 020 8987 5500**
- JAYBRAND — 01733 68247
- **REDLINE MOTORSPORT — Tel 01606 737500**
- **SEEKERS — 0151 524 0919**

5.2 Paddock Equipment

AWNINGS
- ALFRED BULL — 01483 575492
- ALRESFORD TECTONICS — 01962 736316
- AWNING COMPANY — 01204 363463
- **BARKERS — 020 8653 1988**
- DEANS AWNINGS — 01942 241399
- MAYFLOWER — 01494 712131
- PIT BITS — 01727 858297
- TOP MARQUEES — 01623 740777

MOTORHOME HIRE
- ATLANTIC COAST — 01297 552222
- DAVID WILSON'S TRAILERS — 01825 740696
- DUDLEYS — 01993 703774
- MIDLAND INTERNATIONAL — 02476 336411
- SPIRES OF OXFORD — 01865 875539
- **WESTCROFT AMERICAN — 01902 731324**

Database 6
COMPETITION CAR CHASSIS COMPONENTS

6.1 Driver's Equipment

ANTI MIST FLUIDS

DEMON TWEEKS Tel 01978 664466 / Fax 01978 664467
Hugmore Lane, Llan-y-Pwll, Wrexham, Clwyd LL13 9YE, Wales

GRAND PRIX RACEWEAR Tel 0208 987 5500
Fax 0208 742 8999
Power Road, Chiswick, London, W4 5PY, England

REDLINE MOTORSPORT Tel 01606 737500
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk

BOOTS & GLOVES

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	0208 987 5500
MECHANIXWEAR	USA (1) 805 257 0474
REDLINE MOTORSPORT	**Tel 01606 737500**

COOL CAPS & SUITS

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	020 8987 5500
REDLINE MOTORSPORT	**Tel 01606 737500**

DRIVING SUITS & ACCESSORIES

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	020 8987 5500
REDLINE MOTORSPORT	**Tel 01606 737500**

HELMETS & ACCESSORIES

QINETIQ Tel 44 (0) 8700 100942
www.QinetiQ.com
Cody Technology Park,
Ively Road , Farnborough, Hampshire, GU14 0LX

Database 7
CHASSIS ENGINEERING SERVICES

7.1 Chassis Services

BODYWORK SPECIALISTS

ABBEY PANELS	02476 644999
ADVANCED COMPOSITES	01773 763441
ANDY ROUSE ENGINEERING	02476 635182
AERO APPLICATIONS	USA (1) 562 597 0001
AERODINE COMPOSITES	**USA (1) 317 271 1207**
AERODYNAMIC CONSULTANTS	**(661) 729 5628**
APPLIED FIBREGLASS	01842 765339
ASQUITH BROTHERS	01924 402001
C&B CONSULTANTS AERODYNAMICS	(0) 1202 673666
CML GROUP	0151 647 5531
COMPOSITE DESIGN	USA (1) 727 539 0605
CRANFIELD UNIVERSITY	01234 754152
CROPREDY BRIDGE GARAGE	01295 758444
DEREK PALMER ENGINEERING	01555 893315
DON FOSTER	**France (33) 470 580308**
EARS MOTORSPORT	01625 433773
FIBRESPORTS	01268 527331
GRAHAM HATHAWAY RACING	01621 856956
GTC COMPETITION	01483 272151
GTI ENGINEERING	01280 700800
HAMLYN MOTOR SERVICES	01582 841284
HEDDINGTON COACHWORKS	01380 850198
INTAPORSCH	01273 834241
LOTUS ENGINEERING	01953 608000
LYNX MOTORS	01424 851277
MERLIN BODYCRAFT	01280 705156
MITCHELL	NZ (64) 78236188
PODIUM DESIGN	07000 763486
SPA COMPOSITES	01543 432904

COMPOSITES SPECIALISTS

Active engineering	USA 001 714 637 1155
ACTIVA TECHNOLOGY	**020 8974 1615**
ÆOLUS TECHNOLOGY	**USA (1) 970 472 1288**
AERODINE COMPOSITES	**USA (1) 317 271 1207**
APPLIED FIBREGLASS	01842 765339
ASTEC	01332 875451
BGK RESINS	0208 464 7734
C&B CONSULTANT AERODYNAMICS	(0) 1202 673666
CARBON FIBRE TECHNOLOGY	01508 488257
CARBONE INDUSTRIE	France (33) 14 972 2305
COMPOSITE AUTOMOTIVE TECH	01249 443438
COMPOSITE DESIGN	**USA (1) 727 539 0605**
COMPOSITE WINGS	**01953 885478**

CRANFIELD UNIVERSITY Tel 01234 754902
Fax 01234 751671
Cranfield, Bedfordshire, MK43 0AL
www.motorsport.cranfield.ac.uk
motorsport@cranfield.ac.uk

CROSBY GRP	01327 857042
CTG	+44 (0)1295 220130
CTS	**01480 459378**
DELTA COMPOSITES	01280 824498
DEREK BENNETT	**01565 777395**
ELAN COMPOSITES	USA (1) 706 658 2853
DU PONT	UK 01438 734000
	Switzerland (41) 22 717 5111
	USA (1) 302 774 1000
FIBREGLASS FABRICATIONS	0208 568 0293
G FORCE COMPOSITES	01243 544192
HEYES ENGINEERING	01453 750491
HITCO	USA (1) 213 516 5707
JANUS TECHNOLOGY	01753 869996

KOMPREX Tel 0191 416 8200 Fax 0191 415 5962
Website www.komprex.com
Email sales@komprex.com
58-59 Hutton Close, Crowther Ind Est,
Tyne & Wear NE38 0AH

LOTUS ENGINEERING	01953 608000
MICRO CRAFT	**USA (1) 909 947 1843**
MIRA	**0247 6355 000**
NERO	01254 202085
PANKL	Austria (43) 3862 512500
PODIUM DESIGN	07000 763486
PRONAL'S	France (33) 320 99 75 10
QINETIQ	08700 100942
RICHARD HINTON RACING	01279 771667
RMCS (CRANFIELD)	01793 785359
SAMCO sport	**01443 238 464**
SECART	USA (1) 203 798 6698
SCOTT BADER	01933 663100
SPA COMPOSITES	01543 432904
SQUARE ONE MOTORSPORT	01825 723425
STRAND GLASSFIBRE	0208 568 7191
TAG EQUIPMENT	01787 477790
TECHFLEX	USA (1) 201 729 6253
TECHNICAL RESIN BONDERS	01480 52381
TONY THOMPSON RACING	01664 812454
TURBO HEAT	**01535 664903**
UNIVERSITY OF HERTFORDSHIRE	01707 284270
VIN MALKIE RACING	01565 777395
ZEUS M/SPORT ENG LTD	01604 878101

DESIGN AND ANALYSIS

LOLA Tel 01480 451301
Fax 01480 456722

RICARDO MIDLANDS TECHNICAL CENTRE
Tel 01926 477152 Fax 01926 319352
Email: pmarkwick@mtc.ricardo.com
Website: www.ricardo.com
Southam Rd, Radford Semele, Leamington Spa CV31 1FQ

FABRICATION

ABBEY PANELS	02476 644999
A-MAC FABRICATION	USA (1) 408 727 9288
ANDY ROUSE ENGINEERING	02476 635182
ANEX SYSTEMS	01869 345038

AUTOMOTIVE FABRICATION Tel/Fax 001 214 745 1148
Email weld666@airmail.net
1027 Levee Street Dallas, Texas 75207

ASTEC	01332 875451
AZTEK	01509 261299
BBW	**01483 722 713**
BOB SPARSHOTT ENGINEERING	01908 618080
BRADY FABRICATIONS	01869 252750
BRISE ALLOY FABRICATIONS	01322 222343
BSS PARTS	01772 601602
CHEVRON RACING	01565 777395
CHIP GANASSI RACING	01243 544192
CML GROUP	0151 647 5531
COLMET PRECISION	01296 681658
COMPOSITE DESIGN	USA (1) 727 539 0605
COMPETITION FABRICATIONS	01953 454573
CRANFIELD UNIVERSITY	01234 754152
CTG RACING	01202 871102
DEREK BENNETT	**01565 777395**
DJ RACECARS	01663 734518
DOCKING ENGINEERING	01327 857164
EUROTECH MOTORSPORT	**0121 3314944**
FOXCRAFT ENGINEERING	01264 810110
B Y G.FORCE PRECISION ENG	01243 544192
GOMM METAL DEVELOPMENTS	01483 764876
GRAHAM HATHAWAY RACING	01621 856956
GTC COMPETITION	01483 272151
HAMLYN MOTOR SERVICES	01582 600745
HAUS OF PERFORMANCE	USA (1) 714 545 2755
JAGO DEVELOPMENTS	01243 789366
KRONTEC MASCHINENBAU	(49) 9401 700352
LOTUS ENGINEERING	01953 608000
LYNX MOTORS	01424 851277
MACDONALD RACE ENG	**0208 889 1633**
MATRIX ENGINEERING	USA (1) 888 249 0013
MASON ENGINEERING	USA (1) 805 527 6624
MICRO CRAFT	**USA (1) 909 947 1843**
MIKE TAYLOR DEVELOPMENTS	01609 780123
MIRKO RACING	USA (1) 408 776 0073
POLSON	01440 820371
PREMIER AEROSPACE	01332 850515
QinetiQ	08700 100942
RACEPREP 3001	01903 734499
RBS	01788 543094
RETRO TRACK & AIR UK	01453 545360
RICARDO MIDLANDS TECHNICAL CENTRE	
	Tel: 01926 477152
	Fax: 01926 319352
	Email: iain.wight@ricardo.com
RILEY & SCOTT	USA (1) 317 248 9470

Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate,
Wellingborough, Northants NN8 6TY England

SNAPDRAGON MOTORSPORTS	USA (1) 413 2560861
SPA AEROFOILS LTD	01827 260026
SOUTH CERNEY ENGINEERING	01285 860295
UNICLIP AUTOMOTIVE	01932 355277
VAN DYNE ENGINEERING	USA (1) 714 847 4417
VIN MALKIE RACING	01565 777395

MOULDING

ADVANCED COMPOSITES	01773 763441
AERODINE COMPOSITES	**USA (1) 317 271 1207**
ASTEC	01332 875451
BENTLEY CHEMICAL TRADING	01962 515121
BUTSER RUBBER	01730 894034
CML GROUP	0151 647 5531
COMPOSITE DESIGN	USA (1) 727 539 0605
COMPOSITE WINGS	01953 885478
CROSBY GRP	01327 857042
CROMPTON TECH GROUP	01295 220130
CTG	+44 (0)1295 220130
G FORCE COMPOSITES	01243 544192
GRIFFITHS ENGINEERING	01582 600629
JANUS TECHNOLOGY	01753 869996
MICRO CRAFT	**USA (1) 909 947 1843**

PROTECH COMPOSITES LTD Tel: +44(0) 1420 471 400
Fax: +44 (0) 1420 487 047
www.protechcomposites.co.uk
Unit 62, Woolmer Trading Estate
Bordon, Hampshire, GU35 9QF, UK

ROSS COURTNEY	01384 291919
STARTLINE UK LTD	01933 665752
SECART ENGINEERING	001 203 798 6698

SPACEFRAME DESIGN

ÆOLUS TECHNOLOGY	**USA (1) 970 472 1288**
ENABLING TECHNOLOGIES LTD	01983 550481
COSINE TECHNOLOGY	01706 378851
CRANFIELD UNIVERSITY	01234 754152
DAVID POTTER CONSULTING	0033(0) 494 339090
DEREK BENNETT ENGINEERING	**01565 777395**
MAGNUM CARS	01933 442861

Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate,
Wellingborough, Northants NN8 6TY England

STARTLINE UK LTD	01933 665752

Database 8
DRIVETRAIN & SUSPENSION ENGINEERING SERVICES

8.1 Engine Services

RACE PREPARATION

ALDON	01384 572553
ANDY ROUSE ENGINEERING	02476 635182
AUTOKRAFT	0121 777 2083
AZTEK	01509 261299
BJ MOTOR ENGINEERS	0161 748 8663
BR MOTORSPORT	01926 451545
DAVE CROSS MOTOR SERVICES	01246 477566
SBD MOTORSPORT	0208 391 0121
CLEM COMPETITION	USA (1) 214 503 8044
CONCEPT MOTORSPORT	0208 568 0293
CONTINENTAL M/SPORT	USA (1) 513 459 8888

DBR MotorSport Tel 0161 627 4189 Fax 0161 627 4189
Unit 4 Forge Ind Estate, Green Acres Road,
Oldham Lancashire, OL4 7LE

DJ RACECARS	01663 734518
DTM POWER	01865 407726
DUNNELL ENGINES	01449 677726
EARS MOTORSPORT	01625 433773
EDS	01708 857108
ELABORAZIONE COLASUNO	0207 738 8331
ENGINE DATA ANALYSIS	01977 516622
ENGINE SHOP	01280 812199
FISCHER ENGINEERING	USA (1) 818 767 8840
FORWARD ENGINEERING	01676 523526
GEMINI ENGINEERING	01474 534779
GEOFF RICHARDSON ENGINEERING	01480 861599
GF BECK MOTORSPORT PREPARATION	01646 621184
GOLDFLOW	01491 875554
GOODMAN RACING ENGINES	01327 300422
GRAHAM HATHAWAY RACING	01621 856956
GRIFFIN MOTORSPORT	01793 771802
HARPERS PERFORMANCE	01642 818188
HARTWELL	01202 556566
HAUS OF PERFORMANCE	USA (1) 714 545 2755
HT RACING	01474 872888
IRMSCHER	01543 414466
IVAN DUTTON	01923 816277
JANSPEED MOTORSPORT	01722 321833
J MATTIS ENGINETECH	Greece 003 019 512 761
JOHN WILCOX COMPETITION ENG	01455 230576
JONDEL	01933 411993
KENT AUTO DEVELOPMENTS	01303 874082
KREMER RACING	Germany (49) 221 171025
LE SPORT	France (33) 14 582 4400
LIGHTNING PERFORMANCE	USA (1) 904 439 5283
LINGENFELTER	**USA (1) 219 724 2552**
MARDI GRAS MOTORSPORTS	01327 858 006
MATHWALL ENGINEERING	01252 703191
MATRIX ENGINEERING	USA (1) 888 249 0013
MAXSYM ENGINE TECH	**01608 685155**
MERLIN DEVELOPMENTS	01283 511184
MILLINGTON	01746 789268
MINERVA MOTORSPORT	01509 233970
MINISTER RACING ENGINES	01634 682577
MIRKO RACING	USA (1) 408 776 0073
MIS M/SPORTTECHNIK GERMANY	(49)263680394
MOUNTUNE RACE ENGINES	01621 854029
NEIL BROWN ENGINEERING	01775 723052
PHIL JONES ENGINE DEV	01454 310936
PHIL MARKS ENGINE DEV	01564 824869
PRICE MOTORSPORT	USA (1) 812 546 4220
PRIMA RACING	0115 9491903
PRODRIVE	01295 273355
QUICKSILVER RACE	USA (1) 301698 9009
QUORN ENGINE DEVELOPMENTS	01509 412317
RACE ENGINE DEVELOPMENT	USA (1) 760 630 0450
RACESPEC	01925 636959
RACE TECHNIQUES	01242 245640
RACING BENT	USA (1) 714 779 8677
RANDLINGER	Germany (49) 761 16373
ROAD & STAGE MOTORSPORT	01524 844066
ROADSPEED PERFORMANCE	01453 750864
RPM FRANCE	(33) 3 86 66 00 08
SCARBOROUGH	Canada (1) 416 759 9309
SEARLE	0208 305 2250
STEVE CARBONE RACING	USA (1) 918 835 6596
SWAYMAR	01932 868377
SWINDON RACING ENGINES	01793 531321
TECNO	01268 764047
TERRY SHEPHERD TUNING	01695 574454

THINK AUTOMOTIVE Tel 0208 568 1172
Fax 0208 847 5338
Email matt@thinkauto.co.uk
292 Worton Road, Isleworth, Middlesex, TW7 6EI

THUNDERBIRD RACING INT LTD	01623 622848
VAN DYNE ENGINEERING	USA (1) 714 847 4417
WARRIOR	01825 764833
ZYTEK ENGINEERING	01332 48074

ZEUS MOTORSPORT ENGINEERING LIMITED
Tel 01604 878101 Fax 01604 878111
The Racing Stables, Blisworth Hill Farm,
Stoke Road, Blisworth, Northants NN7 3DB

8.2 Engine Services

REBUILDS

ANDREASON RACING	01300 348499
ANEX SYSTEMS	01869 345038
BTR PREPARATIONS	01977 522348
EARS MOTORSPORT	01625 433773
GTC COMPETITION	01483 272151
HAUS OF PERFORMANCE	USA (1) 714 545 2755

HEWLAND ENGINEERING Tel 01628 827600
Fax 01628 829706
Waltham Road, Maidenhead, Berks, SL6 3LR

JACK KNIGHT	01483 764326
JP RACE CENTRE	01327 858151
KREMSPEED EQUIPMENT INC. USA	(1)814 724 4086
MARK BAILEY RACING	01380 850130
MATRIX ENGINEERING	USA (1) 888 249 0013
ME MOTORSPORTS	01884 253070

QUAIFE ENGINEERING Tel 01732 741144
Fax 01732 741555
Email info@quaife.co.uk
www.quaife.co.uk
Vestry Road, Sevenoaks, Kent, TN14 5EL

ROADSPEED PERFORMANCE	01453 750864
TONY THOMPSON RACING	01664 812454d
ZF	Germany (49) 7541 77 2543
	UK 0115 9869211

8.3 Suspension Services

SETUP SPECIALISTS

ACTIVE ENGINEERING	USA (1) 714 637 1155
ANDREASON RACING	01300 348499
ATHON MOTORSPORT	0114 2490 272
AZTEK	01509 261299
BEAUFORT RESTORATION	01795 830288

DAVID POTTER CONSULTING 0033(0)494 339090
BRADY FABRICATIONS 01869 252750
CRANFIELD UNIVERSITY 01234 754152
DON FOSTER France (33) 470 580308
EARS MOTORSPORT 01625 433773
GEOSCAN (G.I.L. Design) 01225 790568
LOLA Tel 01480 451301
Fax 01480 456722
HAUS OF PERFORMANCE USA (1) 714 545 2755
INTERPRO ENGINEERING 01454 412777
LOTUS ENGINEERING 01953 608000
MARDI GRAS MOTORSPORT 01327 858006
MARK ORTIZ USA (1) 704 933 8876
PILBEAM RACING DESIGNS 01778 424838
PODIUM DESIGNS 07000 763 486
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
FSUSPENSION TECHNOLOGY 01327 858558

SHOCKBOX DAMPER SERVICES Tel: 07919 340550
Website: www.shockbox.co.uk
Email: ghbj@compuserve.com
67 Blackthorn Road, Attleborough, Norfolk, NR17 1YJ UK
THE STRAIN GAUGING CO 01256 320666
UNIVERSITY OF HERTFORDSHIRE 01707 284270

ENGINEERING SERVICES
RACING INDUSTRY TECHNICAL SERVICES USA (1) 248 645 1724

8.4 Metal Services

BEAD & SAND BLASTING
BLAST-IT-ALL USA (1) 800 353 2612
CAMCOAT PERFORMANCE COATINGS 01925 445003
COMPAIR AUTOPOWER 01494 465000
HANKOE MOTORSPORT 01753 522779
MACDONALD RACE ENG 0208 889 1633
SWAYMAR CASTING 01932 868377
AEROMET 01795 415000
GM DESIGN 0117 985 9964
GRIFFITHS ENGINEERING 01582 600629
HILLGARD Sweden (46) 300 60590
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
PANKL Austria (43) 3862 512500
QUAIFE ENGINEERING 01732 741144
QDF COMPONENTS 01332 760260
QUARTERMASTER USA (1) 847 540 8999
QINETIQ Tel 08700 100942
www.QinetiQ.com
Cody Technology Park, Ively Road, Farnborough, Hampshire, GU14 0LX
ZEUS ALUMINIUM 01384 482222

COATINGS
BALZERS LTD Tel 01908 377277 Fax 01908 361362
www.balzers.co.uk
Bradbourne Drive, Tilbrook, Milton Keynes, MK7 8AT, UK
CAMCOAT PERFORMANCE COATINGS 01925 445003

CTG Tel: +44 (0)1295 220130 Fax: +44 (0)1295 220138
E-mail: motorsport@ctgltd.co.uk
www.ctgltd.co.uk
Thorpe Park, Thorpe Way, Banbury, Oxfordshire OX16 4SU United Kingdom
LURO COTE USA (1) 909 885 3223
KENT MOTORSPORT CASTINGS 01795 662288
POETON 01452 300500
POLYMER DYNAMICS USA (1) 713 694 3296
QINETIQ 0 8700 100942
SWAIN TECH USA (1) 716 889 2786
WALLWARK HEAT TREATMENT 0161 7979111

ZIRCOTEC PERFORMANCE COATINGS
Tel: 0870 190 8480 Fax: 0870 190 8488
E-mail: enquiries@zircotek.co.uk
www. zircotek.com
528.10 Unit 2 Harwell business Centre, Didcot, Oxfordshire OX11 0QJ United Kingdom

FINISHING
ALUMINIUM SPECIAL 01384 291900
APPERLEY HONING 01242 525868
ARMORALL PRODUCTS 01799 513130
CML GROUP 0151 647 5531
GRIFFITHS ENGINEERING 01582 600629
HEPWORTH INTERNATIONAL 01484 711720
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
QUAIFE ENGINEERING 01732 741144
QINETIQ 0 8700 100942
RICHARD BARRETT MOULDS USA 353 282 9842
ZEUS ALUMINIUM PRODUCTS 01384 482222

FOUNDRIES
AEROMET 01795 415000
BA HARRISON 0116 2769351
GM DESIGN 0117 985 9964

FINECAST 01903 765821
H GRIFFITHS ENGINEERING 01582 600629
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
KENT MOTORSPORT CASTINGS 01795 662288
QUALCAST 01332 760260
UK RACING CASTINGS 01227 750877

HEAT TREATMENT
AR CORNELL 01245 268098
AUTOSPRINT 01675 464857
AVONBAR 01932 840058
BEAUFORT RESTORATION 01795 830288
JENVEY DYNAMICS 01746 768810
PANKL Austria (43) 3862 512500
QUANTUM HEAT TREATMENT 01908 642242
TECVAC 01954 233700
ZEUS MOTORSPORT 01604 878101

MACHINING
ABBEY PANELS 02476 644999
ACTIVE ENGINEERING USA (1) 714 637 1155
APPERLEY HONING 01242 525868
ATHENA MANUFACTURING LP USA (1)512 928 2693
AVONBAR 01932 840058
AZTEK 01509 261299
BEAUFORT RESTORATION 01795 830288
CML GROUP 0151 647 5531
COLEMAN MACHINE USA (1) 906 863 8945
DATUM ENGINEERING 02476 383032
FORMULA FABRICATIONS 01953 605490
DONCASTERS LTD 01332 864900
JENVEY DYNAMICS 01746 768810

KRONTEC GMBH Tel Germany (49) 9401 5253-0
Fax Germany (49) 9401 5253-10
Pommernstrabe 33, 93073 Neutraubling, Germany
LANGSTONE ENGINEERING LTD 02392 452430
LINGENFELTER USA (1) 219 724 2552
LOTUS ENGINEERING 01953 608000
MACDONALD RACE ENG 0208 889 1633
MASON ENGINEERING USA (1) 805 527 6624
METAL SPINNERS 0191 267 1011
MILSPEC PRODUCTS USA (1) 407 814 8997
QINETIQ 0 8700 100942
PANKL AUSTRIA (43) 386255122500
PERFORMANCE MACHINE USA (1) 303 828 4546
PREMIER AEROSPACE 01332 850515
PREMIER FUEL SYSTEMS 01332 850515
QUAIFE ENGINEERING 01732 741144
RICARDO INC USA (1) 734 397 6666
RICHARD BARRETT MOULDS USA 353 282 9842
TITAN MOTORSPORTS 01480 474402
TREVOR MORRIS ENGINES 015474 289
TRICK MACHINING 01493 751666
VIN MALKIE 01565 777395

METAL MATRIX COMPOSITES
BP METAL COMPOSITES 01252 37

CRANFIELD UNIVERSITY Tel 01234 754902
Fax 01234 751671
Email motorsport@cranfield.ac.uk
www.motorsport.cranfield.ac.uk
Motorsport Group, Cranfield University, Cranfield, Bedfordshire, MK43 0AL
GM DESIGN 0117 985 9964
MMCC USA (1) 617 893 4449
PANKL Austria (43) 3 8625 12500

METAL SUPPLIERS
ADVANCED METALS INTERNAT 01923 210250
AIRCO METALS LTD 0118 973 0509
ALUMINIUM SPECIAL 01384 291900
APPERLEY HONING 01242 525868
BRADY FABRICATIONS 01869 252750
BRITISH ALCAN ALUMINIUM 01753 887373
AVESTOPOLART LTD 0114 2443311
BYWORTH MATERIAL SERVICES 01453 821609
COLUMBIA METALS 01604 810191
CROMPTON TECH GROUP 01295 220130
MASON ENG USA (1) 805 527 6624
RICHARD BARRETT MOULDS USA 353 282 9842
RGB STAINLESS 0121 558 3111
SMITHS HIGH PERFORMANCE 01767 604708
SPA AEROFOILS LTD 01827 260026

SUPER ALLOYS INTERNATIONAL LIMITED
Tel: +44 (0) 1908 260707 Fax: +44 (0) 1908 260404
Email: sales@superalloys.co.uk
Number 1 Garamonde Drive, Wymbush Milton Keynes MK8 9DF UK.

TITANIUM SPECIALISTS
AIRCO METALS LTD 0118 973 0509
A.N. MOTORSPORT DESIGN 01628 776320
APPERLEY HONING 01242 525868
ATHENA MANUFACTURING LP USA (1)512 928 2693
CML GROUP 0151 647 5531
COAST FABRICATION USA (1) 714 842 2603
DATUM ENGINEERING 02476 383032
DONCASTERS LTD 01332 864900
PANKL Austria (43) 3 8625 12500
QINETIQ 0 8700 100942
SPA AEROFOILS LTD 01827 260026

ATI Titanium International
Allegheny Technologies
TITANIUM INTERNATIONAL Tel: 0121 789 5764
Fax: 0121 784 8054
Email: nhoskison@tiltd.co.uk
Keys House, Granby Avenue, Garretts Green, Birmingham B33 0SP

TUBE FORMING
CONTRACT MFG & ASM USA (1) 920 720 4225
MALVERN AIRCRAFT 01684 892600
SPA AEROFOILS LTD 01827 260026

8.5 Race Preparation

CHASSIS
ACTIVE ENGINEERING USA (1) 714 637 1155
AMS 01831 501363
AMT MOTORSPORT 01444 483477
ANEX SYSTEMS 01869 345038
AUTOMECH 0161 775 1851
AVONBAR 01932 840058
BARWELL MOTORSPORT 0208 397 4411
BR MOTORSPORT 01926 451545
BRR MOTORSPORT 01327 858055
CHRIS LEWIS MOTORSPORT 01677 422623
DEREK BENNET ENG 01565 777395
PRO MOTORSPORT 01555 893315
DOME CARS LTD Japan (81) 75 744 3131
DON FOSTER France (33) 470 580308
FOXCRAFT ENGINEERING 01264 810110
FRP RACING 01494 771609
GRAHAM WISEMAN 01278 685349
HAUS OF PERFORMANCE USA (1) 714 545 2755
HAWKINS RACING 0208 579 1438
INTERPRO ENGINEERING 01454 412777IVAN
JACK CRONE RACING USA (1) 909 371 6090
JOHN VILLAGE AUTOMOTIVE 01246 450580
K2 RACE ENGINEERING 01825 766728
MACDONALD RACE ENG 020 8889 1633
MARDI GRAS MOTORSPORT 01327 857246
MARK BAILEY RACING 01380 850130
MARK DUNHAM RACE ENG 01353 648922
MATRIX ENGINEERING USA (1) 888 249 0013
MELTUNE PX MOTORSPORT 01923 242536
MIRKO RACING Tel USA (1) 408 776 0073
Fax USA(1) 408 779 9319
16890 Church Street, Building no.14, Morgan Hill, CA 95037, USA
PLANET MOTORSPORT 01403 891553
PODIUM DESIGNS 07000 763486
QINETIQ 0 8700 100942
RACECRAFT INTERNATIONAL 01789 297000
RACE TEC DESIGN & ENGINEERING 01386 871292
RILEY & SCOTT USA (1) 317 248 9470
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
ROY KENNEDY RACING 01327 858055
SCHNITZER Germany (49) 8654 2034
SHENPAR PRODUCTS 01332 862901
STARTLINE UK LTD 01933 665752
STORM MOTORSPORT 01474 85 4367
TECH-CRAFT MOTORSPORT 01926 496075
TOLLBAR RACING 01433 631698
TT AUTOMOTIVE RACING 0147 485 3456
VIN MALKIE 01565 777395
ZAKSPEED Germany (49) 2636 87923

Database 9
TESTING SERVICES

9.1 Chassis Testing

CALIBRATION SERVICES
RICARDO INC USA 001 734 397 6666
THE STRAIN GAUGING CO 01256 320666
TORQUE FAST CALIBRATION 01782 744212
UNIVERSITY OF HERTFORDSHIRE 01707 284270

CRASH TESTING
CRANFIELD UNIVERSITY 01234 754152
CRANFIELD IMPACT CENTRE 01234 751361
KISTLER INSTRUMENTS LTD 01420 544477
MIRA LTD 0247 635 5000
QINETIQ 0 8700 100942
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
THE STRAIN GAUGING CO 01256 320666

MEASUREMENT EQUIPMENT
AUTOSPRINT 01675 464857
BEAUFORT RESTORATION 01795 83288
BERU F1 SYSTEMS 01379 646200
CCA DATA SYSTEMS 01525 378938
CRANFIELD INSTITUTE 01908 694134
GENESIS ELECTRONIC SYSTEMS 01923 893 999
INSTRON SCHENK 01494 456789
INTERCOMP USA -763 476 2531
KISTLER INSTRUMENTS LTD 01420 544477
LONGACRE USA (1) 425 485 0620
LOTUS ENGINEERING 01953 608000
MICROLEASE 0208 427 8822
MIRA LTD 0247 635 5000
MOTORSPORTS INTERFACE 01788 890412

QINETIQ 0 8700 100942
ROEHRIG ENGINEERING Tel USA (1) 336 431 1827
ROTO TEST AB Sweden (46) 85 325 5890
THE STRAIN GAUGING CO 01256 320666

ROLLING ROADS
ALDON AUTOMOTIVE 01384 78508
AUTOMECH 0161 775 1851
AUTOPOINT 01842 766226
AUTOSPRINT 01675 464857
BD ENGINEERING 01795 843980
PIT STOP 01993 850654
B&J MOTOR ENGINEERS 0161 748 8663
BOSCH 01895 834466
BBR GTI LTD 01280 702389
BRUNO HANSON Denmark (45) 65 99 1616
CARBURETTOR CENTRE 0208 340 5057
CHAMPION MOTORS 01621 857444
CRANFIELD INSTITUTE 01908 694134
DERBY AUTO ACCESSORIES 01332 671493
DTM CONSULTANTS (UK) 01865 407726
ELABORAZIONE COLASUNO 0207 738 8331
FGR 01885 400639
FROUDE CONSINE 01905 856800
INTERPRO ENGINEERING 01454 412777
JANSPEED MOTORSPORT 01722 321833
MACHTECH 01923 269788
MATRIX ENGINEERING USA (1) 888 249 0013
MIRA LTD 0247 635 5000
MOTORSCOPE 01609 780155
OHIO STATE UNIVERSITY USA (1) 614 292 5491
OSELLI ENGINEERING 01865 248100
RE PERFORMANCE CENTRE 0161 761 1177
RICHARD LONGMAN RACING 01202 486569
ROADSPEED PERFORMANCE 01453 750864
SARDOU France (33) 16 00 10 367
SCHENCK 01869 321111
SOUTHAMPTON UNIVERSITY 01703 585044
TIM STILES RACING 01278 453036
TIPTON GARAGE 01404 812091

STRESS ANALYSIS
COSINE TECHNOLOGY 01706 378851
LOLA Tel 01480 451301
Fax 01480 456722

WELD TESTING
C&B CONSULTANTS AERODYNAMICS LTD
C & B CONSULTANTS, AERODYNAMICS LTD
Tel +44 (0) 1202 673666 / Fax +44 (0) 1202 671776
Email candbaero.uk@candbconsultants.com
www.candbconsultants.com
194 Stanley Green Road, Poole, Dorset BH15 3AH
C & B INTERNATIONAL INC
Tel +1 317 291 0978 / Fax +1 317 536 0656
email candbaero_indy@msn.com
6210 La Pas Trail, Indianapolis, Indiana 46268
KISTLER INSTRUMENTS LTD 01420 544477
WIND TUNNELS ACTIVA TECH 0208 974 1615
AIOLOS ENG Canada (1) 416 674 3017
CRANFIELD INSTITUTE 01908 694134
CRANFIELD UNIVERSITY 01234 754152
DOME CARS LTD Japan (81) 75 744 3131
IMPERIAL COLLEGE LONDON 0207 589 5111
LANGLEY FULL-SCALE USA (1) 757 766 2266
MARCH 01280 704160
MICRO CRAFT USA (1) 909 947 1843
MIRA LTD 0247 635 5000
OHIO STATE UNIVERSITY USA (1) 614 292 5491
RMCS (CRANFIELD) 01793 785359
QINETIQ 0 8700 100942
SARDOU SA France (33) 16 00 10 367
UNIVERSITY OF MARYLAND USA(1) 301 405 6861
WESTLAND HELICOPTERS 01935 702190

WIND TUNNEL MODELS
ADVANCED COMPOSITES 01773 763441
AERODINE COMPOSITES USA (1) 317 271 1207
CAPITAL PATTERNS 0208 777 9276
COMPOSITE DESIGN USA (1) 727 539 0605
DOME CARS LTD Japan (81) 75 744 3131
MARTIN FELDWICK 01603 712611
MICRO CRAFT USA (1) 909 947 1843
MIRA 0247 635 5000
SARDOU SA France (33) 16 00 10 367
THE STRAIN GAUGING CO 01256 320666

9.2 Engine Testing

COMBUSTION ANALYSIS
AM TEST SYSTEMS 01253 780780
AUTOSPRINT 0121 236 5133

AVL DEUTSCHLAND
AVL DEUTSCHLAND Gmbh GERMANY (49) 6134 7179-0
CRANFIELD INSTITUTE 01908 694134
CRANFIELD UNIVERSITY 01234 754152
INTEGRAL POWERTRAIN 01908 278600
KISTLER Instruments Ltd 01420 544477
LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788
MIRA LTD 0247 635 5000
MOTORSPORTS INTERFACE 01788 890412
MTS Powertrain Tech Tel 01932 351516
PETROCHEM CARLESS LTD 01372 360000
PRECISION AUTOMOTIVE USA (1) 708 766 4402
RICARDO 01273 794144

RICARDO INC	USA (1) 734 397 6666
QINETIQ	0 8700 100942
RICARDO	01273 45561
TREVOR MORRIS ENGINES	0154 74289

DYNAMOMETER SUPPLIERS

AVL DEUTSCHLAND Gmbh GERMANY	**(49) 6134 7179-0**
BEAUFORT RESTORATION	01795 83288
CRANFIELD UNIVERSITY	01234 754152
DEPAC DYNO	USA (1) 315 339 1265
DYNAMIC TEST	USA (1) 800 243 3966
DYNOMITE	USA (1) 603 329 5645
ENGINE & DYNAMOMETER	**01708 857108**
FROUDE CONSINE	01905 856800
LOTUS ENGINEERING	01953 608000
MACHTECH	01923 269788
MIS M/SPORTTECHNIK Germany	(49)263680394
MOTORSPORTS INTERFACE	01788 890412
Ricardo Inc	USA (1) 734 397 6666
ROTOTEST	Sweden (46) 8 532 55890
SUPERFLOW	USA (1) 719 471 1746
BELGIUM	32 15 216300
TAT	Germany (49) 7252 84258

DYNAMOMETER SERVICES

ACCURATE ENGINEERING	USA (1) 216 232 1156
CELTIC PERFORMANCE ENG	01362 696729
AIRFLOW RESEARCH	USA (1) 818 890 0616
ALDON AUTOMOTIVE	01384 78508
AMG MOTORENBAU	Germany (49) 7144 3020
ANDY ROUSE ENGINEERING	02476 635182
ARIAS	01403 784022
ATKINSONS MOTORSPORT	01539 732500
AUTOKRAFT	0121 777 2083
AUTOMECH	0161 7751851
AUTO SPECIALISTS	USA (1) 704 786 0187
AVONBAR	01932 840058
EVOLUTION ENGINEERING	0207 703 2225
BERTILS ENGINES	USA (1) 708 395 4244
BJ MOTOR ENGINEERS	0161 748 8663
BOB WIRTH RACING	USA (1) 510 487 3279
BRAYTON ENGINEERING	USA (1) 517 279 8458
BR MOTORSPORT	01926 451545
BRODIE BRITTAIN (BBR)	01280 702389
CAMBRIDGESHIRE SPORTS	01954 210248
CARBONE RACING	USA (1) 918 835 6596
CENTRAL AUTO TECH	0121 4558392
COMPETITION ENGINE	01296 435389
CONCEPT MOTORSPORT	0208 568 0293
CONNAUGHT	01795 843802
DAVE CROFTS	01246 477566
DAWSON AUTO DEVELOPMENT	01327 857729
DESIGN & DEVELOPMENT	01695 574454
DRAGON PROJECT RACING	**TEL 0118 974 4175**
DUNNELL ENGINES	01449 677726
DYNOMITE	USA (1) 603 329 5645
EAGLE ENGINE CO	USA (1) 805 373 6806
ELABORAZIONE COLASUNO	0207 738 8331
ELLIOTT & SON	01306 711275
EDS	**01708 857108**
ENGINE DATA ANALYSIS	01977 516622
FAST CAR CLINIC	01274 579564
FISCHER ENGINEERING	USA (1) 818 504 0300
FONTANA AUTOMOTIVE	USA (1) 310 538 2505
FROUDE CONSINE	01905 856800
GAERTE ENGINES	USA (1) 219 223 3016
GEMINI ENGINEERING	01474 534779
GEOFF RICHARDSON ENG	01480 861599
GMH ENGINEERING	USA (1) 801 225 8970
GOODMAN RACING ENGINES	01327 300422
GRAHAM HATHAWAY RACING	01621 856956
HARPERS PERFORMANCE	01642 818188
GEORGE HARTWELL	01202 556566
HASSELGREN ENGINES	USA (1) 510 524 2485
HAUS OF PERFORMANCE	USA (1) 714 545 2755
HIGHGATE ENGINEERING	0208 951 4923
HODSON ENGINEERINBG	01732 463658
HOLBAY RACE ENGINES	01473 623000
HOLMAN AUTOMOTIVE	USA (1) 704 394 2151
HUDDART	01270 665405
INTEGRAL POWERTRAIN	01908 278600
INTERPRO ENGINEERING	01454 412777
INTER-TUNING	Belgium (32) 473 652 216
IVAN DUTTON	01923 816277
JANSPEED ENGINEERING	01722 321833
JENNETTS ENGINES	01993 891776
JF ENGINES	01491 680719
JOHN BROWN ENGINEERING	01903 773022
KREMER RACING	Germany (49) 221 17 1025
LANGFORD & PECK	01933 441661
LINGENFELTER	**USA (1) 219 724 2552**
LISTER CARS	01372 377474
LOTUS ENGINEERING	01953 608000
LYNX MOTORS	01424 851277
MRE	**0208 889 1633**
MAXSYM ENGINE TECHNOLOGY	**01608 685155**
MACHTECH	01923 269788
MATHWALL ENGINEERING	01252 703191
MERLIN DEVELOPMENTS	01283 511184
MICKEY MAROLLO	USA (1) 607 734 2148
MINERVA MOTORSPORT	01509 233970
MINISTER RACING ENGINES	01634 682577
MOUNTUNE	01621 854029
NEIL BROWN ENGINEERING	01775 723052
NELSON ENGINE SERVICES	01249 815929
OSELLI ENGINEERING	01865 248100
PAUL PFAFF RACE	USA (1) 714 894 7573
PHIL JONES ENGINE DEVELOPMENTS	01454 310 936 / 01564 824869
PIPER FM	01233 7327377
PRICE MOTORSPORT	USA (1) 812 546 4220
PRIMA RACING	0115 9491903
PRO/CAM	USA (1) 616 847 5000
PRODRIVE	01295 273355
QUAIFE ENGINEERING	01732 741144
QUICKSILVER	USA (1) 301 698 9009
QUORN ENGINE DEVELOPMENTS	01509 412317
RACING BENT	USA (1) 714 779 8677
RICARDO INC	USA (1) 734 397 6666
RICARDO	01273 794144
ROAD & STAGE MOTORSPORT	01524 844066
ROTO TEST	**Sweden (46) 8 532 55890**
SCARBOROUGH	Canada (1) 416 759 9309
SEARLE	0208 305 2250
SCHENCK PEGASUS	USA (1) 248 689 9000
SOUTH CERNEY ENGINEERING	01285 860295
SPECIALISED ENGINES	01375 378606
STERLING ENGINES	USA (1)209 267 5081
SWIFT MOTORSPORT	0191 5867311
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AEROBYTES

With Simon McBeath

Underbody details

Examining pressures and flows in a Champ Car underbody

2001 Reynard 01I Champ Car shown here in pre-season testing

LAT

Continuing with the aerodynamics of an entire single seater, this month we look at pressure patterns in the underbody of a 2001 Reynard Champ Car. Regulations restrict underbody design in this category, making it even more peculiar than other restricted categories. But some of the effects hint at the generalities.

Figure 1 shows the distinctive underbody. Essentially the sidepod undersides are flat, with 'scalloped' areas in the underfloor entries. Curved 'vortex generators' are attached in these scalloped areas. Beneath the engine is a narrow diffuser either side of a tapering cowl. There is also a transverse 'bump' under the transmission.

Figure 2 shows underbody static pressures in plan view. In this plot, zero is indicated by orange, so red is positive, yellow through to blue show negative static pressures. As such, the majority of the underbody is at moderately reduced pressure, but integrated over the large plan area this contributes around half the car's downforce in road-course configuration.

To build a more three-dimensional picture we'll use transverse 'slices' through the air and the racecar, looking rearwards. Figures 3 to 7, slices at various stations along the underbody, show two different properties. To briefly recap, on the left is 'total pressure' – a measure of the energy in the airflow. As air passes over the body surfaces it loses energy due to skin friction, viscous shear forces and flow separations. Total pressure therefore remains high where these effects have not 'stolen' energy. But where energy losses have occurred, total pressure decreases. These plots use red for maximum total pressure (total pressure coefficient, CpT = 1), through yellows, greens and blues (CpT = 0) showing decreasing total pressure.

On the right is static pressure, the form of pressure that exerts forces on the racecar surfaces. In conditions where Bernoulli's equation applies, static pressure decreases as flow velocity increases (and vice versa). Positive static pressures are shown as red and orange and negative static pressures are shown by green and blue.

Figure 3 is a slice at X = 1500mm, that is 1500mm back from the front face of the chassis (approximately 300mm along the left hand sidepod). The static pressure is high in the radiator inlet duct (red), but outboard and above the sidepod static pressure is more or less zero. Beneath the →

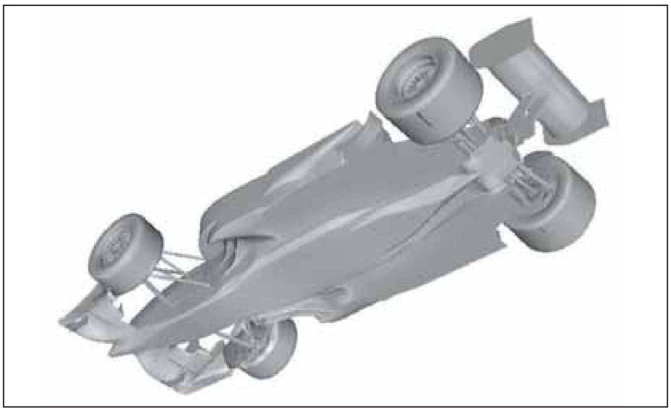

Figure 1: the Reynard 01I model, underside view

Illustrations courtesy: Advantage CFD

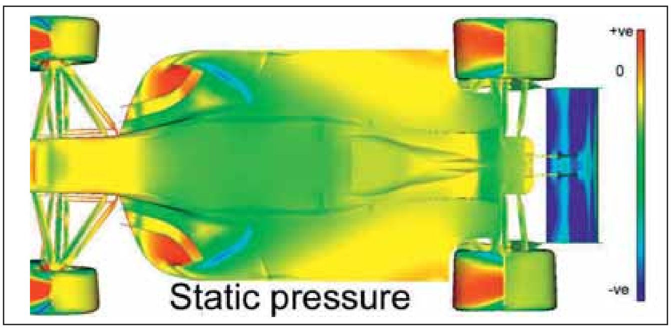

Figure 2: modest reductions in static pressure over the underbody area generate approximately half this car's total downforce

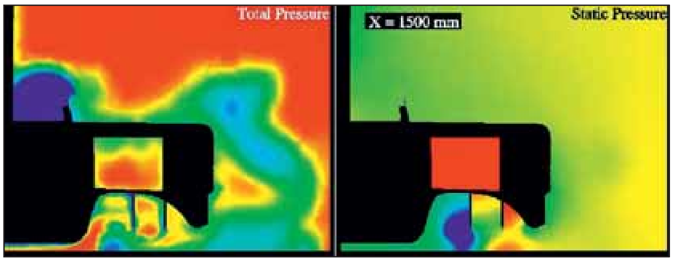

Figure 3: cross section of the car, looking rearwards, 300mm back from the leading edge of the sidepod, showing total (right) and static pressures

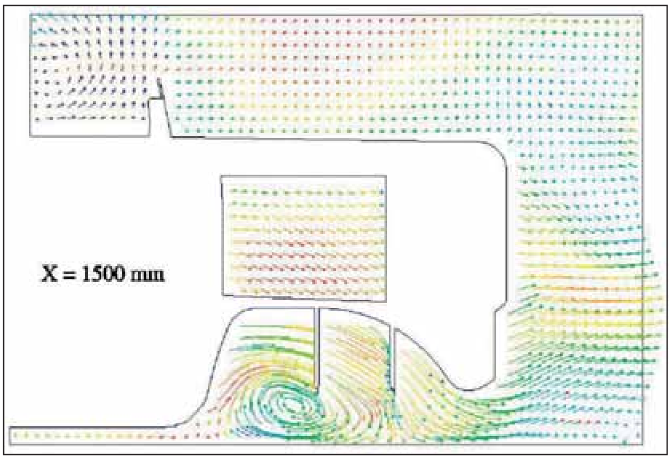

Figure 3a: in-plane velocity vectors showing the vortex 300mm back from the sidepod leading edge

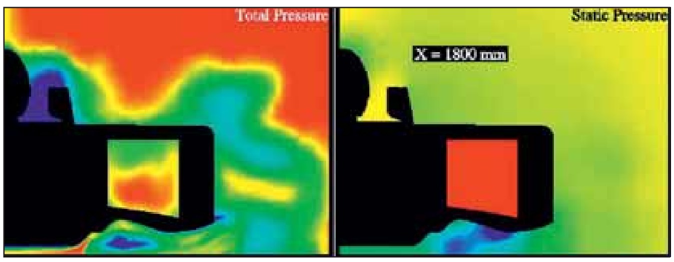

Figure 4: cross section roughly 600mm back from the sidepod leading edge

sidepod things are more complex. Outboard of the outer vortex generator (VG) static pressure is raised, but inboard of the inner VG it is markedly reduced (as shown in blue).

Looking at total pressure, outboard of the sidepod the large region of reduced total pressure reveals the wake of the front wheel. In the inlet region to the underbody however is a region of mixed high and low energy air. Figure 3a shows in-plane velocity vectors at this station, and shows a clear rotating pattern. The vortex generators trigger this by turning the airflow. Since static pressure is higher ahead of the upstream face of the vanes than downstream (see figure 2), some air is induced to flow around the lower edge but, because of the sharpness of the edge, it cannot remain attached. Nevertheless, the attempt at making the turn adds an angular component to its velocity that results in rotating flow – a vortex – being established. The additional velocity component in the vortex causes a reduction in static pressure.

Moving 300mm downstream, figure 4 at X = 1800mm shows pressure in line with the rearward portion of the underbody scallop. The aforementioned vortex now has a reduced total pressure in its core – due to viscous losses – and static pressure is still low here. However, looking at the static pressure plot, just outboard of this 'tiring' vortex there is another region of reduced static pressure, in the transition from scallop to flat underbody. This arises from the airflow accelerating through this narrowing gap, creating a Bernoulli-style static pressure drop. The combination of these two effects

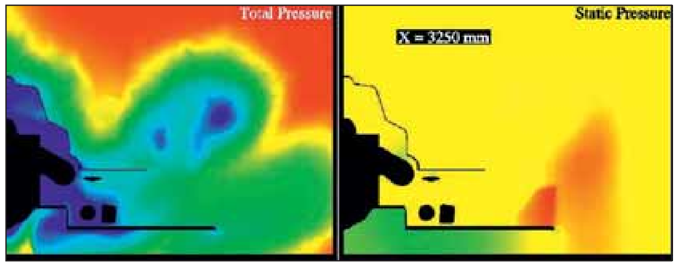

Figure 6: cross section just in front of the rear tyres

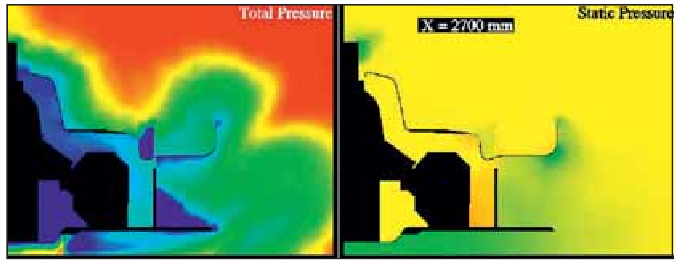

Figure 5: cross section approximately 600mm aft of the roll hoop

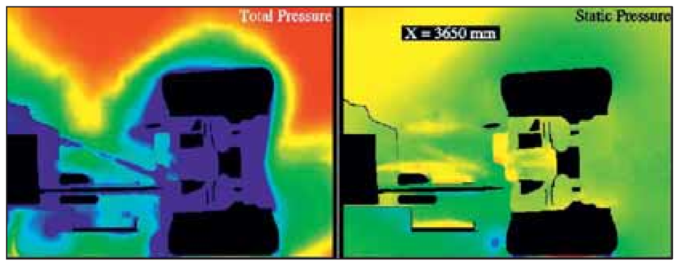

Figure 7: cross section in line with the rear underbody extremity, rear axle line

sees the marked drop in static pressure in this area of the underbody, and indeed across the whole car width.

Figure 5 at X = 2700mm still shows a static pressure differential above and below the car, but the static pressure reduction in the underbody is of lower magnitude than further forwards. The total pressure is now quite low in the underbody, showing that the flow here has lost further energy. The static pressure plot also shows raised pressure above the 'flip up' ahead of the rear tyre, and slightly reduced pressure beneath it, adding an increment of downforce.

Figure 6 at X = 3250mm is 100mm in front of the rear tyres. The red area to the right of the static pressure plot shows the increase in pressure ahead of the tyre. The outer portion of the skirt Gurney causes the trapezoid-shaped area of increased static pressure (bottom centre) above the outboard edge of the horizontal 'skirt', adding another increment of downforce. Meanwhile, in the underbody and the narrow diffuser – which began at X = 2775mm and can be seen on the left of each plot – the static pressure is moderately low, and importantly, lower than the static pressure above the skirt.

Figure 7 is taken at the rearmost edge of the main underfloor, at X = 3650mm, virtually on the rear axle line. The inboard portion of the rear skirt Gurney increases the static pressure ahead of itself, apparent from the yellow band on the top surface of the skirt. Also, the static pressure in this rear section of the underbody and diffuser is lower than it was further forward. This is partly due to interaction with the low pressure in the lee of the skirt Gurney but is also down to the transverse 'bump' mentioned earlier, which accelerates the airflow here. And there may also be interaction with the rear wing. The total pressure plot hints at the vortex triggered further forward by the inwards flow across the edge of the diffuser.

Restrictions may have produced unconventional underfloor design, but clever details enable Champ Car underbodies to generate significant levels of downforce. RE


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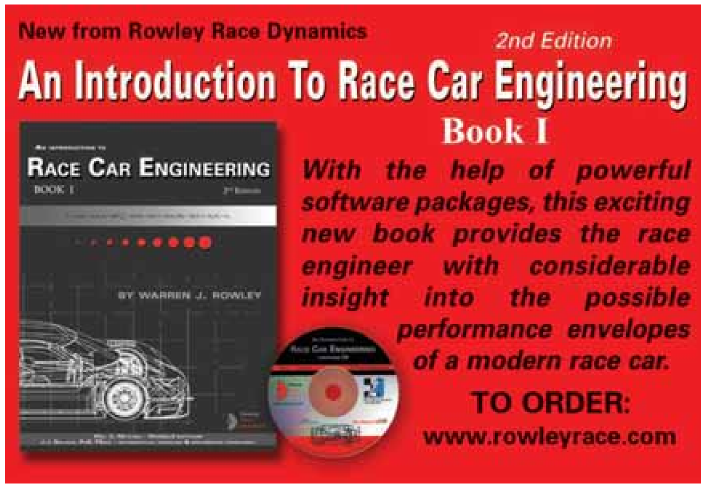
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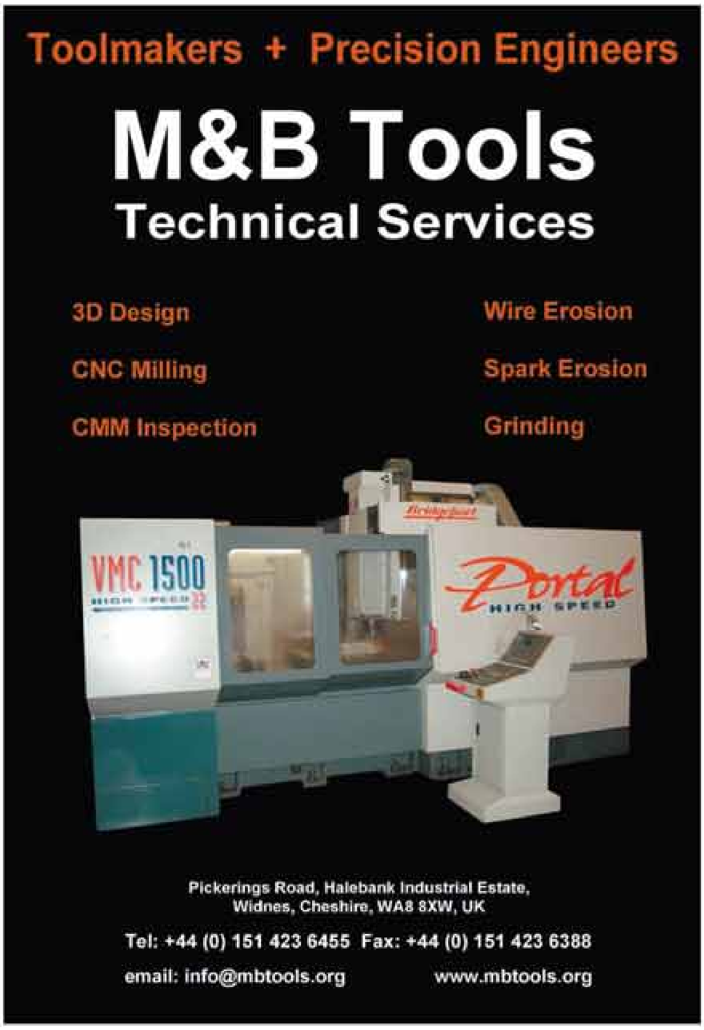
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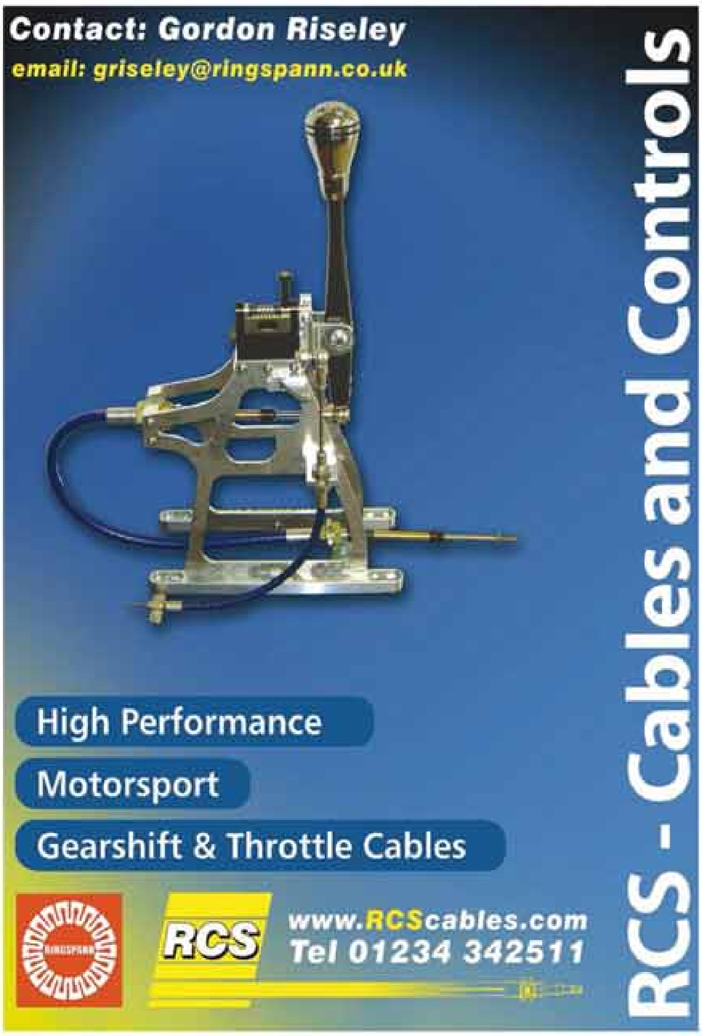
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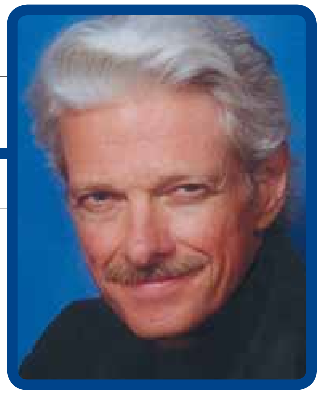

Roll axis inclination

Rear-engined cars, such as the Hillman Imp, traditionally have a nose-up roll axis with a higher front roll centre

CCC archive

Q What is the influence of a roll axis inclination biased to the front suspension; ie a front roll centre closer to the ground than the rear? At least in passenger cars, the roll axis is always inclined down to the front except in some special cases, for example the BMW 1 Series, which is reported by BMW to have the roll axis parallel to the ground.

My understanding of this concept was based on the idea that the more the roll axis is inclined toward the front, the more load transfer there will be at the front axle and the more understeer the vehicle will have. However, I have put into an Excel spreadsheet the formulation found in Milliken, *Race Car Vehicle Dynamics*, and find to my surprise that the higher the front roll centre, the greater the load transfer at that end. Can you explain this?

A Short answer: higher roll centre at the front implies more geometric roll resistance at the front, hence more load transfer at the front, other things being equal. So the typical nose-down roll axis inclination does not increase front load transfer.

There are also cars that have a nose-up roll axis, all of which are rear engined. Probably the most extreme example is the Hillman Imp, which had a front roll centre near hub height and a rear roll centre near ground level.

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. In these pages Mark answers your queries on chassis set-up and handling. If you have a question to put to him, email to **markortiz@vnet.net**, call **704-933-8876** or write to **Mark Ortiz, 155 Wankel Dr., Kannapolis, NC 28083-8200 USA**

Like many things, the subject of roll resistance and load transfer is fairly simple once you understand it, but will drive you crazy until you do. When discussing this subject, I am always quick to plug my video, *Minding Your Anti*, which covers the subject at length. It costs US$50.00, shipping included, payable by cheque or money order to me at the address opposite.

In steady-state cornering (constant speed, on a constant radius), on an unbanked road surface, the total load transfer from the inside wheels to the outside wheels depends entirely on the height of the whole vehicle's centre of mass (centre of gravity, or c of g.) and the track width at the c of g.

“NOSE DOWN ROLL AXIS INCLINATION DOES NOT INCREASE FRONT LOAD TRANSFER”

Suspension design and tuning have almost no effect on the magnitude of the total load transfer. What we mainly do with these aspects is control the distribution of that total, between the front and rear wheel pairs. →

We customarily consider the car to be a rigid object, supported by a single compliant structure at each end. The sprung structure is the rigid object, the front and rear suspension systems are the compliant structures.

As an analogy, imagine that you and a friend are carrying a sailboard (as used for windsurfing) along the beach. Each of you is carrying one end of the sailboard. The sail is up, and there is a breeze blowing. The force of the wind on the sail tries to overturn the sailboard. The overturning force depends entirely on the design of the sailboard and the amount of wind. The total counterforce that you and your friend together need to exert to balance this does not depend on you and your friend. However, the amount of counterforce that you individually need to exert depends on the amount exerted by your friend, and the amount of counterforce he has to exert depends on you. You and your friend are like the front and rear suspension systems. The sailboard is like the sprung mass.

There are portions of the load transfer that come from the unsprung components, and there are portions that come from the dampers if the car is rolling upon corner entry or de-rolling on exit. However, for simplicity in answering the present question, let's look just at the components of the load transfer that come from the inertia force (centrifugal force) of the sprung mass acting through the suspension, in steady-state cornering. There are only two such components: elastic load transfer and geometric load transfer. Elastic load transfer comes from elastic roll resistance: the roll resistance supplied by the springs and anti-roll bars. Geometric load transfer comes from the properties of the structural components attaching the wheels to the sprung mass, which can be arranged to generate forces opposing roll, or geometric roll resistance.

With independent suspension, these two components influence each other more than is commonly recognised. The load distribution on an independently suspended wheel pair affects how much geometric roll resistance the wheel pair has, for any given suspension geometry. To illustrate with an extreme case, if the inside wheel is off the ground, the geometry of its suspension linkage is irrelevant and only the geometry of the outside wheel has any effect on the car. My video deals with these effects in detail. For simplicity, I will ignore them here, but I do want to note in passing that they exist.

When we speak of roll centre height, we are speaking of an imaginary point whose height represents the amount of geometric roll resistance for the front or rear wheel pair. If this point is assigned properly, we can approximate the geometric load transfer at one end of the car as:

$$\frac{\text{roll centre height x sprung mass centrifugal force at that end of the car}}{\text{track width at that end of the car}}$$

When the suspension is symmetrical, the point you generally see in the chassis books – the force line intersection – is a good approximation. When the suspension is not symmetrical, using the force line intersection as the roll centre can lead to major mis-predictions of car behaviour. Sometimes the force lines may be parallel, in which case there is no intersection.

We may define a line connecting the front and rear roll centres, called the roll axis. The car doesn't really roll about this line, but as a crude approximation we can reasonably think of it as doing so. If we raise the roll axis at both ends, the geometric roll resistance is greater at both ends. If we raise one end of the roll axis and lower the other, leaving its height at the c of g unchanged, the total geometric roll resistance is unchanged, but we increase the geometric roll resistance at one end and lower it at the other. The elastic elements – springs and anti-roll bars – are not affected by this.

So the end where we lowered the roll centre has less geometric load transfer and the same elastic load transfer as before – hence less load transfer overall. This will make that tyre pair grip better, because they will be sharing the work more equally. At the opposite end, the elastic component will likewise be unchanged, but the geometric component will be increased – hence more load transfer overall.

Okay, so if we want understeer for most drivers, why have a nose-down roll axis? There are a number of explanations. The most obvious is that when the car has independent suspension in front and a beam axle in back, we don't have much choice. Independent suspensions with roll centres much above four inches generally jack excessively. Front suspensions with high roll centres generate lateral contact patch motion over bumps, which creates kick at the steering wheel. It is possible to build a beam axle suspension with a roll centre below any component of the suspension, but the linkage required is somewhat complex. Consequently, beam axles on cars with enough ground clearance to be practical on the street generally have roll centres at least six inches high, and usually at least 10in. Of course, with independent rear suspension, the roll centre is usually much lower, but most often still a bit above the front one.

The next most obvious reason is that passenger cars are generally too nose heavy to have balanced handling, and the front suspension doesn't control camber when cornering nearly as well as the rear suspension. Consequently, we need to kill understeer, not increase it.

"PASSENGER CARS ARE GENERALLY TOO NOSE HEAVY TO HAVE BALANCED HANDLING"

BMW's 1 series – unusually for a passenger car, is reputed to have a roll axis parallel to the ground

A somewhat less obvious reason has to do with driver-perceived car behaviour in abrupt transient manoeuvres, such as the lane-change test commonly used in passenger car testing. With a nose-down roll axis, there is a small yaw component with roll. The nose points out of the turn slightly, relative to the four contact patches. This makes the car feel steady to the driver, rather than twitchy.

Another reason sometimes cited is that when a car is abruptly steered into a turn, the geometric component of the load transfer is the first to act on the car. If this component is greater at the rear, we will momentarily have less understeer and the car will turn in more responsively. Note that this explanation is somewhat at odds with the one immediately preceding it.

There are somewhat logical variations on both of these two explanations. We could say that if the main mass of the car is yawing out of the turn relative to the four contact patches, that steers the contact patches into the turn, or steers the rear wheels out of the turn, momentarily adding oversteer! Some people also believe that tyre load sensitivity momentarily works backwards until the tyres start heating. I personally don't believe this, but if so it means that if there is initially more rear load transfer, that adds understeer rather than oversteer, and makes the car feel stable.

Isn't this fun? If it weren't for vehicle dynamics, I'd have to do something sane for a living. RE