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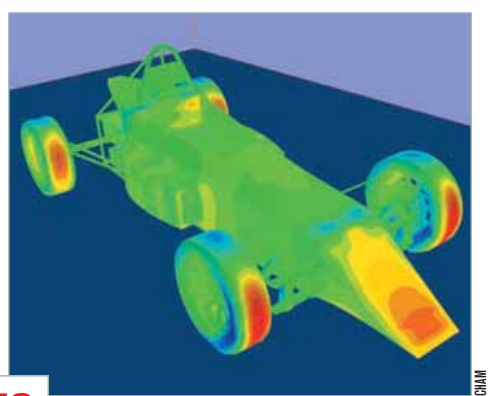
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Write Line

Depending on which direction you thumb your copy of Racecar Engineering, you will either have just seen or will be about to see a wealth of recently unveiled new racecars. I view this state of affairs with enthusiasm, not least because, as the editor of this title, it makes my life much easier. In contrast, 2004 was probably the most barren season in decades for new cars. As someone tasked with filling this magazine with new developments in motorsport, I'm sure that absence contributed more than a few of my grey hairs. Be sure we'll make hay while the sun shines.

Interestingly the explosion has been in sportscars, both prototypes and GTs. On the one hand the initial promise of the LMP categories seems to be finally paying off particularly with a crop of LMP2s. Also the notional LMP3 class seems to be gelling with new cars and a move to aligning the class' regional series under an internationally recognised set of rules. On the other hand, SRO's creation of a GT3 category has inspired teams and manufacturers to dust off virtually every suitable coupé as a potential candidate.

It's all great stuff and feeds these pages, but is there really a market for all this thoroughbred hardware? Just because people are building cars, it doesn't mean there is anyone willing to buy them. Indeed motorsport has a long history of duping otherwise rational individuals into putting enthusiasm over good business sense. For once, I think this is not a case of hopeless optimism over commercial realities. Think about where the money to run these cars is likely to come from. We are not talking highly funded but famously tricky works budgets here. Nor are we talking about the capital behind pressured, young Formula 1 hopefuls desperate to make an impact that will get them to the top. All these cars are aimed at the self-funded amateur. That is drivers without work's backing on any genuine sponsorship deals.

> "THIS IS THE AGE OF ARRIVE AND DRIVE"

So what? I hear you ask. Is a bunch of 'hobbyists' really going to sustain motorsport in the future and see it through to a new dawn? I would urge you not to be too dismissive. A not inconsiderable proportion of international racing these days is populated by 'gentleman drivers'. Get away from the heavily manufacturer-backed series like touring cars or the single-seater learning Formulae and there are plenty of drivers doing it 'just for fun'. And their annual spend on their hobby is far from insignificant. For the new GT3 category, SRO expects teams to be working on budgets of up to £200,000 a season. Yes, I know it wouldn't pay the tea and biscuits budget of an F1 team, but there are only 11 of those. Add up the spend of all the amateur, international level drivers and it amounts to a very worthwhile spend on parts and staff. That means jobs all round. Much, like we discovered when we analysed historic motorsport, it adds up to much more than a cottage industry.

The important thing to remember is this is the age of arrive and drive. There's no point offering customers a chassis and expecting them to get on with it. Service is the key, taking care of all their needs; while charging them for the privilege of course.

There are plenty of glamorous sports for the world's wealthy to indulge in from ocean racing to polo. But is any more exciting or glamorous than motorsport. It is up to us to make sure there is no competition.

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Charles Armstrong-Wilson

The International Journal
Racecar engineering

Pit Crew

Vol 16 **No.5**

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New sportscar season sees

Sam Collins

ProTran's Reynard 2KQ based hybrid, the RS06/H, was unveiled to the press at Brooklands in February this year, the all-English team is aiming for Le Mans

The Prototype racing boom is showing no signs of slowing down as there seems to be more teams than available cars in all series from LMP1 to LMP3. 'We have sold 24 cars since September last year,' enthused C/D sports specialist Lee Stohr. 'We have had to expand our capabilities with the addition of a new composites oven.'

Juno Racing has also been forced to expand by moving to a new factory in the north of England to accommodate the demand for the popular SSV6 and new VdeV series car, the TR220. Juno founder Ewan Baldry continues to eye Le Mans, but will wait until he has the finances to mount a serious campaign. The recent success of the firm could accelerate this.

Meanwhile Racing for Holland has taken delivery of the ex-Jim Gainer Dome S101 hybrid to use at Le Mans this year. Last year the team pioneered the usage of Creuat's innovative suspension system (see V15N10), yet this year it will return to more conventional spring damper units. 'It's an experimental system and as such is still under development,' explained a Dome source. 'It suffers problems at speeds in excess of 300kph. The hybrid LMP1 Dome S101-Hb produces more downforce than the S101 the team used last year, and the suspension has not been developed for the higher aero loads.'

Looking to the 2007 season Dome is assessing its options; neither LMP1 or 2 has been ruled out.

Yet Dome is not currently looking to sell customer cars. It would mainly like to work with a car manufacturer helping its racing car development.

'We tried to sell our cars in the market around 2000, however there always used to be financial problems with the customer and conditions were not right to do the race, even though we developed the car specially. As a result,

LMP production booming

Creation

Another hybrid with its roots in a Reynard is the Creation C60-H. As *Racecar* closed for press only this rendering (above) was available

Radical

Radical's first Le Mans racer, the SR9 (right), is nearing completion, and it has been described as looking like a cross between Giger's alien and Darth Vader

explosion of prototypes

our president Hayashi's frustration got really high and now seems to hate selling cars in the market,' explained Dome's head of R&D Hiroshi Yuchi.

Hoping to race against the Dutch Dome is the very English ProTran RS06/H owned by the very patriotic Paul Cope. The car is a development of the Reynard 2KQ with hybridisation done by Kieran Salter. 'From the roll hoop back this is a new car, but the front is just modified Reynard, like the Nasamax,' explained ProTran's Lester Ray. 'We did as much as we could with the front of the car without having to redo the crash test.' There are disadvantages to running an older car such as the Reynard, 'the double roll hoop could be a disadvantage aerodynamically, but we are hoping that the switch to LMP1 will give us the power to overcome that.'

Originally ProTran had wanted to run in GT2 but there were no suitable (read English) cars available for the right money, so the RS06 was created. It was initially intended to be an LMP2 but AER released its twin turbo V8 LMP1 power plant early in the car's development. 'It was decided that we could go to LMP1 for similar money and it may be easier to get an entry in that class as there are so many LMP2's around at the moment' stated team founder Paul Cope.

With hybrids being outlawed everywhere, except the ALMS in 2007, ProTran is seriously considering developing an all new car with KWM for next season. The team has lodged an entry for the full LMS season and also the Le Mans 24 Hours.

Courage competition has also entered the LMP1 fray with the LC70, which is to be used by a new team called Swiss Spirit as well as by the factory itself. The new cars bear a strong resemblance to the LC75 LMP2, but under the bodywork things are somewhat different. Power is supplied by Judd's 5-litre V10 driving through Courage's own TLSE six-speed gearbox. A curious feature on the car's bodywork is the chain of lumps and blisters on the nose.

In previous years the Sebring 12 hours has been seen as the qualifying race for Le Mans. But this year many European teams have been told the opening round of the LMS at Istanbul in Turkey is the event to go, to causing some dark murmuring. One team principal told *Racecar*: 'It's ridiculous to have a race so far away and force teams to go, it's not even in Europe. My staff will be away for a month and that's very expensive.' Another senior figure said: 'The teams don't like it, the fans don't like it and the media don't like it but for some reason the ACO do'.

Swiss Spirit

Courage's new LC70 was unveiled in the colours of Swiss Spirit in Geneva

Y-Car

New French prototype constructor Y car has issued these renderings of its forthcoming CN chassis

INTERCOM

MIKE BRESLIN

You know why soccer is so popular across the globe? It's because it's simple. A boy in Mali can kick a tin can between two oil drums and we understand. Similarly, you can watch a game with an Arabic commentary and still know what's going on. Soccer is almost instantly understandable; even the offside rule isn't that complicated. The game's goals are simple, and its terminology is simple – the 'goal' is the goal.

But there are even simpler sports. Racing has to be the most natural competition known to man, for instance. Everyone knows that the first one to get to the woolly mammoth gets the choicest morsels, and I guess it grew out of that. Man against man, simple. Horse against horse, again it's simple. Car against car, oh dear...

Where have we gone wrong? How come, with F1 in particular, we've managed to turn something as natural as racing into an event that Wittgenstein would struggle to understand?

At a recent F1 press event I was talking to a non-motorsport journalist about F1 racing. He told me that this was not the first time he'd come into contact with this strange world of ours. Just a few years ago he'd been whisked into Silverstone by chopper, enjoyed the slap up Paddock Club fare, and then he was in turn impressed-then-confused-then bored by the racing. In fact, once the first round of pit stops had happened he had no idea what was going on, or why. Nor did he really care.

And that's the problem. Unnecessary complication. It's okay for us dyed-in-the-wool fans, but can we really expect to compete with other sports when it comes to viewing figures if the man on the couch simply doesn't know what's actually happening?

All right, stay with it for long enough and the commentator will explain, but I'm not sure that the average viewer's patience is up to that. After all, he has that ultimate weapon of mass distraction at his finger tips – the remote.

What makes it worse, of course, is that as soon as someone gets a handle on what is going on, the FIA comes along and changes the rules again: 'One set of tyres? No that was last year... Single lap qualifying you say? Oh, haven't you been paying attention?

Which brings me to the new qualifying format. Hardly kids' stuff, is it? Let's just hope they haven't scored yet another own goal.

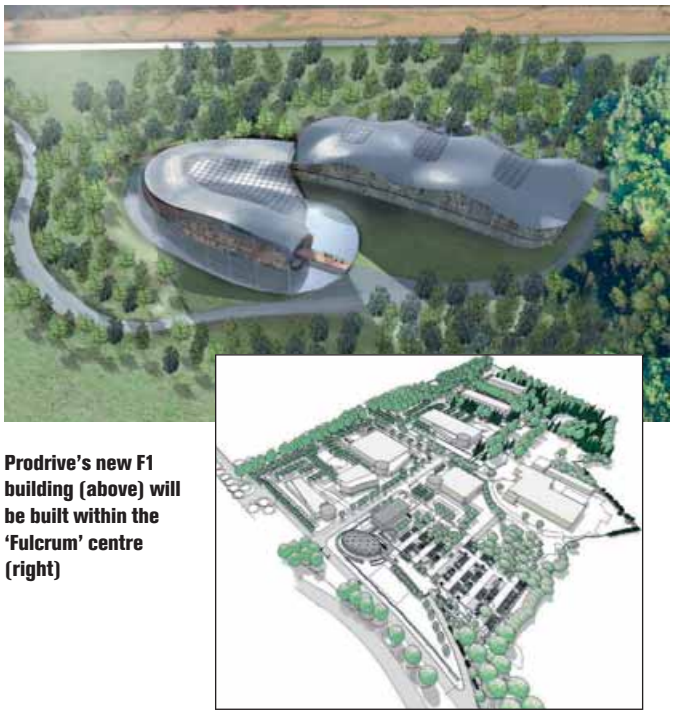
Prodrive eyes F1, while Dome says no

Prodrive is evaluating a return to Formula 1 with its own team in 2008, it has been revealed. The English firm who is behind the Aston Martin racing programme and Subaru WRC team was last involved in grand prix racing with BAR-Honda in 2004.

Prodrive head man, David Richards, first hinted at a return to F1 in an interview with *Racecar* in V15 N8 when, in reference to the new, lower cost regulations that will come into force for the 2008 season, he stated, 'In the current environment F1 is not a viable business proposition, but in the next couple of years it is quite likely to be.' When that comment was made the rules were not finalised but they since have been.

A new team would bring F1 to its maximum entry of 12 teams, which should cause the value of all teams to rise significantly as any new team wanting to enter F1 would have to buy an existing outfit. An established organisation like Prodrive would be exactly what the other teams want.

If the firm does decide to undertake a F1 project then it would be housed in a facility at a new research and development centre in Warwickshire, England. A group known as the Fulcrum Partnership has applied for permission to develop a 200-acre site adjacent to the Prodrive test track. The new centre would house offices, design studios, R&D laboratories and a conference centre. Currently the site, which is a former military airfield, houses Marcos cars, TRW and a Prodrive facility. If plans are approved construction will start early in 2007.



Prodrive's new F1 building (above) will be built within the 'Fulcrum' centre (right)

Meanwhile in Japan, motorsport R&D specialist and racecar manufacturer Dome has completed its new factory, which was scheduled to open in April. In the mid-to-late '90s Dome was very keen to enter F1, even going as far as building and testing a prototype car, and with the new 'low cost' F1 of 2008 there have been rumours that the Japanese firm, like Prodrive, is planning a return. But head of R&D at Dome, Hiroshi Yuchi, pours cold water on them: 'No we will not do that, as Minoru Hayashi – who is the president of Dome – lost the passion for F1 completely.' Talk of Dome being involved with the Honda-backed Super Aguri F1 programme is also thought to be wide of the mark.

However, a new LMP project is being considered, and the Formula 3 F107 is already competing with some success in Japan, though there are no plans as yet to bring it to Europe.

Super Aguri reworks Arrows

Super Aguri's re-worked Arrows chassis made its competition debut at the Bahrain Grand Prix. Initially the test car appeared with 2002-spec aerodynamics (centre) then with an update kit for the Bahrain Grand Prix (right). The car has evolved from the Sergio Rinland-designed A23 of 2002 (left). The arrival of the all new Aguri has been delayed.

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Caparo goes motorsport

Caparo Vehicle Technologies is to create an advanced vehicle technology, engineering and design wing. Caparo will supply to the OE, Motorsport and aerospace markets as it aims to accelerate the use of lightweight materials in vehicle structures.

Two former McLaren engineers Ben Scott-Geddes and Graham Halstead, who were behind the Freestream high performance road car project, have been appointed to positions within the new firm. Geddes is to become Design Director with Halstead becoming Engineering Director. Former Ricardo head of CAE Mark Findlay has been appointed MD of Caparo VT and will be hiring a team of around 30 top engineers in the coming months. Caparo group chief executive Angad Paul will take the position of chairman while fellow main board director Richard Butler will also take a seat on the Caparo Vehicle Technologies' board. Sean Butcher who identified the commercial opportunity and brought the two parties together will become commercial director.

'We will use our vehicle technology company to add new materials know-how to our existing aluminium and steel structural capabilities' enthused a Caparo spokesman. 'To us, advanced composites represent an important development in delivering to our customers better vehicle efficiency with less environmental impact.'

LMP constructors association

A number of racing sportscar manufacturers have already signed up to the new International Sports Car Manufacturers Association. Early members include Radical, Chiron, Saker and Diasio. The body has been set up as a result of the recent rapid growth in the sportscar market and aims to 'address the issues facing the industry on a global scale'. Out of these issues, the first must be the establishment of common regulations for safety and car construction and an official press release from the new body states as much. Such a move would open up the global market and allow EU and US firms to trade within the same rule structures.

ISCMA hopes to be able to broker block deals with suppliers for all of its members on common parts such as rod ends and electrical connectors. Research partnerships will be setup with government and other bodies with a code of ethics applying to all members plus a membership fee. The next few months will see if the association is a viable proposition although the growth in the market suggests that it is. ISCMA will need to break into the lucrative continental European market, which may be a challenge for an organisation based in Indianapolis.

BMW's latest 'ringer

BMW Motorsport has unveiled a new motorsport version of its Z4 coupe, aimed directly at the Nürburgring 24 Hours, run on the 14-mile Nordschliefe circuit. Power comes from a 3.2-litre, in-line six, which produces around 400bhp. The kit to make a Motorsport spec Z4 costs around €250,000 plus VAT (£172,325).

Jacer's new Vee

Jacer

Australian firm Jacer has unveiled its new F2K6 Formula Vee, which has greatly improved cooling and aerodynamics. Turn to page 52 for more on F Vee

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Global Motorsport Congress

Vieweg Verlag's Global Motorsport Congress is set to return this year on 6–7 November. The event has moved to a new venue in Cologne after two very successful years in Frankfurt. Toyota Motorsport has agreed to support the event which will include a tour of the Toyota factory. *Racecar Engineering* will be supporting the event (see V16N2). For more information see www.globalmotorsportcongress.com

New Suzuki WRC

At the end of February Suzuki ended prolonged speculation with the announcement of its plans to join the World Rally Championship with a World Rally Car version of its forthcoming SX4 model. Company president Hiroshi Tsuda and Suzuki Sport president Nobuhiro 'Monster' Tajima unveiled the SX4 WRC at the Geneva Motor Show. The car will begin testing almost straight away and the Japanese firm will join the WRC as a full manufacturer in August 2007.

Much of the early development work on Suzuki's new WRC has already been undertaken in Tajima's Milton Keynes-based operation. Any later development will be carried out in Japan before the cars return to Milton Keynes for the final preparation for the WRC. Bodyshells will come from the firm's Hungary factory where the road-going RX4 is being built.

Suzuki

Suzuki's new WRC the SX4 will compete next year

Additionally, WRC commercial boss David Richards is extremely confident that another manufacturer will join the series next season, in addition to Suzuki, and that other manufacturers are ready to step into world rallying. 'It just shows that these things are cyclical,' said Richards. 'People do come and go in this sport and I know for a fact that there are two other manufacturers waiting in the wings – they are quietly going about homologating their cars. One of them will come to WRC at the same time as Suzuki, but I'm not sure when the other will join.'

Next season's WRC will be split into two championships, with the first eight rallies – from January to June – counting as a six month series. The second half of the season and the first half of 2008 will then count for the next title. Suzuki will contest all rounds of the first 07/08 series. The RX4 WRC will also be used in competition in the first half of 2007, but only for testing.

Skoda's S2000 hopes?

Having revealed increased profits of £189m, the Skoda Auto board has confirmed that it is not ruling out an official return to the World Rally Championship. It warned that such a move would depend on FIA decisions over rules. This may indicate a Skoda Super 2000 car, based on the Fabia replacement, will replace the Fabia WRC

Meanwhile, the Red Bull Skoda team has further delayed its decision on a lead driver for the gravel rounds of this year's WRC. Sporting advisor Armin Schwarz hoped to be able to reveal the name of Austrian Andreas Aigner's team partner before Rally Mexico, but pointed out that there was still time for the appointment.

Schwarz visited Skoda HQ after Rally Mexico, and the Red Bull team's first gravel test was scheduled for end March/beginning April. Its first dirt event is set to be the Rally d'Italia Sardinia in the middle of May.

Altitude sickness

Group N cars suffered on rally Mexico due to the high altitude

World Rally Car engines drop some 10 per cent of their power for every 1000m of altitude meaning drivers were 20 per cent down on power even in the service park in Leon; HQ town for Rally Mexico.

Subaru engineer Pierre Genon estimated that on the highest stages cars lose some 27 per cent of their available output. In terms of top speed, a potential 220kph is reduced to about 200kph. Acceleration also suffers with at least half a second being added to the 0-100kph time.

The cars' cooling suffers from going slower as less air gets to the engine and brakes due to the altitude. Air that does get in is thinner and less effective.

Brake effectiveness also suffers because the comparative lack of power means drivers adjust their styles, tending to apply the brakes later and for shorter periods.

Fiat Super 2000 problems continue

A row is brewing over Fiat's all-new Super-2000 Grande Punto.

Sources close to the FIA said that the car was not granted its homologation papers on the set date of March 1st. It was expected that Fiat would re-present the car with answers to the FIA enquiries within the one week of the originally scheduled homologation date.

The all-new Super 2000 formula is for four-wheel drive, normally-aspirated cars producing about 280bhp and is designed to cut costs by using a common transmission and differential developed by French company Sadev.

Strict limits on the amount of technology that can be incorporated into the car mean there will be a rigid price cap of €150,000 (£103,439) per car. This is to curtail expensive driver aids and materials.

It would appear that Fiat has incorporated a number of materials and technologies that go against the spirit of the rules, even though the Italian car giant has indicated that it would be willing to sell at the agreed price.

An insider commented: 'The rules are intended to make sure that the cars are actually worth €150,000 rather than just sold for €150,000. Fiat has got problems because it is obvious that the car is worth at least €20,000 more; maybe a lot more.' As increasing costs appear to be the biggest problem currently facing rallying, the FIA is under tremendous pressure to take a hard line on the Punto, which is the first car built to the newly introduced Super 2000 rally rules.

500 costs $25,000

Nextel Cup crew chief Chad Knaus was fined $25,000 by NASCAR, barred from attending four races and placed on probation until the end of the year for illegally changing the shape of the rear window during qualifying for the Daytona 500.

Knaus had tampered with the sway bar adjuster, which is accessed through the rear window to help push the window outwards, thus aiding aerodynamics. Some in the garage indicated Knaus was hoping to get caught so he could be released from his contract with Hendrick Motorsports.

Knaus started his NASCAR career working with previous crew chief Ray Evernham on the Jeff Gordon Hendrick Chevy team. He left to work for Evernham's self-owned Dodge team only to return to Hendrick in 2002 as crew chief for Johnson. Knaus has had more victories since 2002 (19) than any other crew chief and apparently Evernham has been trying to court him back. But Knaus has a contract in place with Hendrick and after the latest fiasco it's obvious they're intent on keeping him.

LAT

Knaus (left) in discussion with driver Jimmie Johnson at Daytona

NASCAR has also penalised Terry Labonte's crew chief Phillipe Lopez at the new Hall of Fame Racing the same amount but docked the team 25 points for an illegal carburettor. NASCAR's Robin Pemberton commented that points are only taken away if it's a part they can physically put their hands on.

All the rule infringements didn't bother the fans at all. The Daytona 500 attracted 37.2 million TV viewers making it the most watched Daytona 500 ever as well as the highest rated NASCAR event in history, according to information released by NBC Sports based on data from Nielsen Media Research. There were also seven million listeners on the Motor Racing Network radio broadcast.

Hall of fame for Charlotte

After a yearlong decision, NASCAR weeded out six other contenders to reveal that the city centre of Charlotte, North Carolina will be home to the new NASCAR Hall of Fame. 'To NASCAR fans everywhere, it is my distinct honour to announce that NASCAR has selected Charlotte, NC to be the home of the NASCAR Hall of Fame,' said NASCAR Chairman and CEO Brian France. 'The City of Charlotte will welcome fans from around the country and even the world to the NASCAR Hall of Fame.'

The $154.5 million project will be funded by a two per cent increase in Charlotte hotel taxes that will bring in $102.5 million, plus private sponsorships and under market bank loans. The city of Charlotte will own and operate the facility giving NASCAR percentage cuts ranging from 5 per cent of restaurant sales, 7.5 per cent for items like catering and admission and up to 10 per cent in merchandise revenues, plus $100,000 per year to NASCAR charities.

Charlotte is projecting 800,000 visitors in its first year of operation, dropping and stabilising to half that in 2016 and beyond. Charlotte is seen as the hub of the NASCAR industry with 82 per cent of NASCAR NEXTEL Cup teams, 72 per cent of NASCAR Busch Series teams and 55 per cent of NASCAR Craftsman Truck teams based in the Charlotte region.

The industry's current annual statewide economic contribution is estimated to be $5 billion. Although it will continue to be headquartered in Daytona Beach, NASCAR has exercised the right build a 300,000sq ft office tower at its own expense as part of the project that will house licensing and merchandising offices for example. The hall, which will open no later than spring 2010, is expected to include exhibit space, induction halls, interactive entertainment restaurants, retail outlets and a state-of-the-art media centre. It is designed by architecture firm Pei Cobb Freed & Partners, responsible for iconic buildings worldwide including the Javits Convention Centre in New York City and the expanded Louvre in Paris.

■ Following the March Las Vegas Motor Speedway race a $300 million construction was started, the track will be narrowed in the turns from 70 to 52ft and the banking will change from 12 degrees to 20.

Nelson goes it alone

After being responsible for the creation of the NASCAR 'Car of Tomorrow', former crew chief and NASCAR research and development safety guru Gary Nelson resigned from his post during February to form his own racing safety and technology consulting company working with NASCAR and other racing organisations. 'Nelson & Associates will be open for business right away and I'm delighted that NASCAR will be my first client,' commented Nelson.

With NASCAR as a client, Nelson will continue his efforts on the 'Car of Tomorrow' and other safety initiatives for the racing industry.

Meanwhile NASCAR has delivered blueprint copies of the 'Car of Tomorrow' that will debut at Bristol, Tennessee in 2007. The blueprints contain finalised safety, body and chassis requirements with the exception of the front splitter style spoiler and the rear spoiler or possible wing configuration, which will be determined following further team testing. The cars were again due to be tested during March and April at the Bristol and Martinsville short tracks.

LAT

Gary Nelson is going it alone

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DKE

Historic successes

Ian Williamson's International Historic Motorsport show was once again a success attracting 20,000 visitors over the three days and 450 exhibitors.

The continued success of the show is proving that the growth in the historic sector continues unabated. As a result, numbers of established engineering firms exhibited including Pi Research, ATL and Lola, who were all within sight of Racecar Engineering's stand.

Amongst the exhibitors was RML who recently announced the formation of RML Historic in response to the market demand. This new division of the Wellingborough, England company is to offer a number of services from restoration to race support. It is not an entirely new departure for the firm who has been actively involved with the preparation of historic cars for some time. Ray Mallock, RML's Chief Executive, who is a keen historic racer commented, 'there is a growing need for regulated maintenance and controlled regimes within the historic motorsport industry. These cars require the special understanding and attention that can only come from an organisation with design, build and race experience from the early '80s to present day. Many of the cars now racing in historic Group C, such as the Ecurie Ecosse C2 and Aston Martin AMR1, started life at RML.' The division will be headed up by Phil Barker who is also responsible for RML's current Le Mans race programme. Barker's experience in motorsport dates back to the early '80s when he was involved with a number of successful Group C race programmes.

IH MGS

Lola Cars (with the T70) and Racecar Engineering shared a stand at the show

NEWS IN BRIEF

- An increasingly severe worldwide carbon fibre shortage is beginning to affect a number of racecar constructors.
- Ligier's Formula 3 chassis has been testing in Germany, more next month.
- Cosworth's 2.4-litre V8 saw 20,700rpm in the run up to the Bahrain grand prix in March.
- There was discussion over the legality of Ferrari's rear wing in Bahrain.
- DAMS won the A1GP title with A1 team France at Laguna Seca. The Le Mans outfit dominated the series with others speculating this was down to it finding something in the tyres, adjusting the setup to optimise it.
- Ferrari GT outfit Scuderia Ecosse has stepped up to the FIA GT championship from the British series.
- Mitsubishi is being linked to a return to the WRC in the next two years.

ON THE GAS...

HIROSHI YUCHI
Manager, R&D Department, Dome Co, Ltd

Project leader for sportscars (LMP) and Formula 3

Dome

How did you first get involved in motorsport?
I started my career as a part time employee of Dome when I was a third year student at University in 1 7 and then started working full time after I graduated in 1998.

What's the most interesting project you've ever worked on?
I think it is sportscars, especially our LMP which I am still working on. Le Mans is such an exciting and challenging race with long history. Our F3 project, which I took responsibility for earlier this year, is also looking interesting. I worked in the IRL in 2004 and 2005 on the aero development of the G-Force Honda cars, and that year I was involved with cars in the Indy 500 and Le Mans 24 Hours so I have done two of the 'big three'. But the best is Le Mans.

What achievements are you most proud of?
IRL in 2004 was the first year for me and Dome to do Indy Car development. However, we won three races in 2004 with Adrian Fernandez and established a good relationship with the team. It was a nice moment I am proud of as we just started at the end of 2003 and won the race in the summer of 2004. Such an achievement!

Can you name your favourite racing car of all time?
Williams FW14 and Leyton House CG901

Who do you most admire in racecar engineering and why?
Adrian Newey, because he is a great aerodynamicist and a great race car designer. In addition, his cars always look good.

What racing era/formula would you have liked to work in and why?
I think Formula 1 in the 1990s when there seemed to be so much more freedom on the design of the car under the regulations.

What tool/instrument could you not work without?
Our wind tunnel! Also CAD and data acquisition system and analysis software.

What engineering innovation do you most admire?
To build the new wind tunnel in Toyota which is a copy of the existing one. Whilst it may not be pure innovation, it is a very smart way to spend the money to increase aero development capacity without losing the stability.

Is motorsport about engineering or entertainment?
Engineering with gambles! You have to take engineering risks to win the race sometimes for the better performance than your competitors.

What new technologies in motorsport are you most excited about?
Lightweight materials technology like carbon composite's for monocoque and gearbox construction. Especially the carbon composite gearbox casing by BAR Honda with the seamless shifting system.

Is there a future for high technology in motorsport?
As long as there is a competitor we have to invent something new. Sometimes that can be really high technology with huge cost if budget allows us to do it.


LAT

Murray Walker


LAT

Daniel Audetto


LAT

Chris Gorne


LAT

Rocky Rocquelin

● Red Bull Racing's head of vehicle design **Rob Taylor** is to join McLaren as 'Senior Design Team Leader'.

● **Ross Brawn** has been awarded a doctorate in engineering by Brunel University in the UK at an event to celebrate the 200th anniversary of the birth of Isambard Kingdom Brunel.

● Legendary British motor racing commentator **Murray Walker** has joined Honda Racing F1 as a special ambassador.

● Former Jaguar Racing team boss **David Pitchforth** has been recruited by helicopter manufacturer AgustaWestland.

● **Daniel Audetto** and **Mick Ainsley-Cowlinshaw** are joined at Super Aguri F1 by **Phil Spencer**, **Gerry Hughes**, **Graham Taylor** and **Antonio Cuquerella**.

● The United States Rally Championship has appointed its officers for the 2006 season; **Micheal Taylor**, **Olga Orise** and **Donna Hocker** will fill the roles of President, Vice President and Series Administrator respectively.

● Formula One and the WRC have appointed permanent stewards who will officiate at every round. Briton **Tony Scott Andrews** has been selected for F1 and for WRC India's **Nazir Hoosein** fills the role.

● Red Bull Racing engineer **Gunther Steiner** has joined the energy drink firm's NASCAR team.

Prodrive

Subaru performance director **David Lapworth** has been moved sideways to a new venture thought to be an F1 project within Prodrive. Operations director **Paul Howarth** has now taken more overall control of the team on events, while sporting director and former world champion co-driver **Luis Moya** will also have increased responsibilities.

Prodrive has also hired highly-regarded French engineer **François-Xavier Demaison**, to step in as **Petter Solberg's** chief engineer. **Pierre Genon**, formerly Solberg's race engineer and then chief engineer, will also move but stays with the team on the engineering side of test and development.

Another major change for the team was the departure of **Ed Wood**, who designed the last three Impreza WRCs.

● Nextel Cup engineer **Darian Grubb** stood in for **Chad Knaus** at the four events he was banned from after he was caught in breach of the rules at Daytona.

● **Gary Nelson**, the man behind NASCAR's car of tomorrow, has left the organisation to form his own safety consultancy firm.

● Briton **Chris Gorne** is to oversee Fortec Motorsports British F3 project as well as continuing his roles with DPR in GP2 and DAMS in A1GP.

● **Tom Smith** has been appointed as lead engineer on one of Newman-Haas's Champ Car entries. Smith replaces **Rocky Rocquelin** who has returned to Europe.

● **Phil Barker**, current head of RML's MG Le Mans programme, will head up the firm's new historic division in addition to his LMP duties.

● Team Dynamics designer **Alex Somerset** has joined rivals VX Racing as Chief Engineer.

● Grand Prix motorcycle preparation expert **Dick Smart**, who has worked with **Valentino Rossi**, has joined Paul Morris Motorsports as a Crew Chief in the Gold Coast based outfit's V8 Supercar team.

● **Robin Knight** (750MC), **John Wood** (MIRA), **Dennis Carter** (BARC) and **Alan Gow** have been appointed to sit on the board of directors of the UK's ASN the MSA. **Ronnie Trouton** and **Bill Troughear** have stepped down.

● **Pim van Baarsen** has left the Motorsport Industry Association to join Xtrac, after five years at the MIA.


Super Aguri

Gerry Hughes


Super Aguri

Mick Ainsley-Cowlinshaw

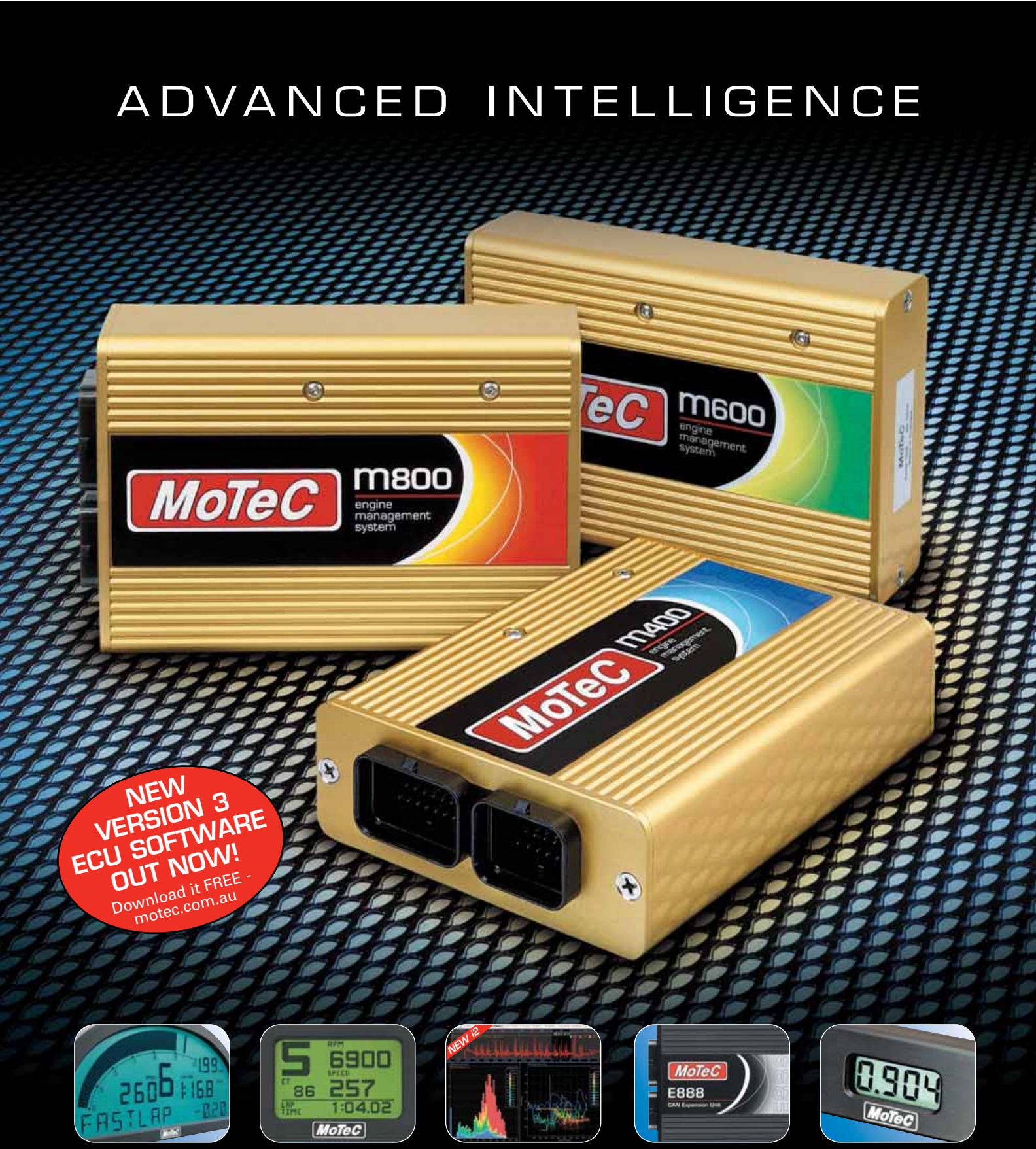

LAT

Luis Moya


LAT

David Pitchforth

ADVANCED INTELLIGENCE



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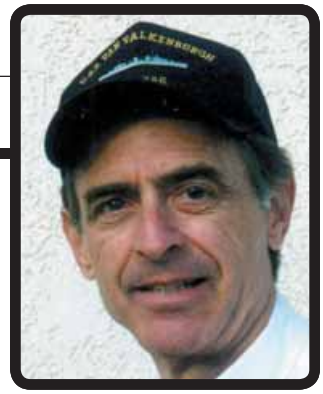
By Paul Van Valkenburgh



Engineering connections

With knowledge becoming ever more specialised, a good contacts book is now more important than ever

Maybe I've been wrong all these years. Maybe racing really isn't all about engineering and technology after all. Everyone is always saying, 'It's not *what* you know, but *who* you know.' Let's re-think that. Maybe instead of it meaning, 'who can do you a favour,' you should think, 'who already has the knowledge you need?' When I was starting out in amateur road racing in the '60s, so little was known about the science of racing that one person could build, engineer, and drive his own car, even in professional racing – Bruce McLaren and Mark Donohue, for example. Now... well, how many racers today have you even heard of who can effectively drive and develop and also engineer – in all the necessary disciplines, from electronics to aerodynamics?

I bitch about the lack of innovative technology at PRI and SAE, but recently I've been finding important discoveries coming from serendipitous connections and contacts with people who had basic knowledge that I could use. Suddenly I realised that at trade and engineering shows, often the interpersonal connections are more important to attendees than the products are. Even though I don't know all the answers, I usually know how to find the person who does. In fact, I often bump into them at just these events.

'Six Degrees of Separation' is a semi-scientific concept (and movie, and game) that suggests that through all your acquaintances, you are that closely connected with everyone else on the planet. Within any profession or scientific field, there are even fewer degrees separating you from the 'right person.' And given the ability to 'Google' search names and references, you can find the shortest path more quickly. There may only be three or four 'friends of friends' separating you from Adrian Newey.

On the other hand, the sociological downside of having the 'right connections' is that it can easily lead to 'cronyism', especially in the entertainment industry, especially in moviemaking and publishing. When you see a real dog of a movie, and say, 'what were they *thinking*?,' it's probably that they were thinking of helping out their friends, instead of searching for the real talent they needed.

It's not necessarily famous or wealthy people you need to connect with, but those who have information you need. How do you form a complete team of associates with complimentary talents? Who has the expertise? Who will be a real asset to your racing? Or who do you know that knows who does? The first →

> "THERE MAY ONLY BE THREE OR FOUR 'FRIENDS OF FRIENDS' SEPARATING YOU FROM ADRIAN NEWEY"

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problem is not knowing what you need to know – what is missing. I define arrogance as not realising what you don't know, because 'a man has got to know his limitations.'

College Formula SAE teams are inherently personal connection matrices, with a lot of interaction, even between competing colleges. Beyond focusing on good grades in textbook classes, you look for people who concentrate on labs and 'special projects', people who say, 'how can this apply to racing?' Or 'on my own, I want to find out...' Watch for students who apply that philosophy to classes such as: computers – how they can be used for chassis design, simulations of vehicles, and analysing track data; materials – properties of aerospace composites, stiffness, and failure analysis; thermodynamics – optimising combustion and heat dissipation, fluid dynamics – properties of airflow in engines and over wings, wind tunnel procedures; electronics – protecting circuitry in the racing environment and the design of control systems; chemical engineering – tyre compounds and fuel characteristics; ergonomics – the man-machine interface and optimising feedbacks; and management – logistics and critical paths.

> "TO RISE ABOVE YOUR POSITION, YOU NEED A WORKING KNOWLEDGE OF ALL AREAS"

Connect with people who get their hands dirty, and who know all the hand tools intimately, people who study tool catalogues and know the right tool for the job. Find the generalist, who may be a passable machinist, and does some composite lay-up, and even knows how to test tyres – even spec tyres – to learn how to optimise them. Finding someone experienced at actual race driving is also strongly recommended – especially in a 'do-it-yourself' class such as Formula SAE, or solar/electric vehicle competitions at the university level.

It's also good to know people with unique talents, or rare and valuable experience. Not many pro teams can start you out as an overall manager. Recent sought-out positions have included data acquisition specialists, suspension dynamics engineers and computational fluid dynamicists. It's hard to say what the next hot area might be, but if you can find a foremost expert in it, it could help. Once they get in the door, then they tend to generalise again (in their spare time) by observing what all the other specialists are doing. Because to rise above your position, you need a working knowledge of all areas, since it all has to go together and fit tight and light.

You need to remember that there are three categories of racecar engineers: design, development and trackside, which may depend a lot on personal traits. For example, if someone is drawn to the glamour, has a lot of hands-on experience and is a quick problem solver, they would probably prefer trackside. But if they are slow but methodical, pensive, take time to optimise everything and read a lot about technology, they are probably a better designer. The manager is empathetic, with a natural gift for understanding people as well as machines, and can manage them without obvious MBA techniques.

Just a fraction of a per cent of all the equally trained students actually make it into racing and, based on what I've seen, the following might be the deciding factors: street smarts – the ability to know a weak part by looking at it, or to be able to tell when something 'just doesn't look right.' Common sense – the ability to see what is most important at any instant, and focus on that, instead of what is more fun or more interesting. Extraordinary spatial visualisation – the ability to mentally iterate dozens of designs or solution options simultaneously, possibly subconsciously, and reduce them to the optimum almost intuitively. The kind of mind that goes to sleep mulling over an impossible problem, and wakes up in the middle of the night with the answer. Someone driven to search out and solve problems just for the fun of it. After they've done their own job, they look for other things that should be done, and do them. They can say, 'I may have made a mistake, but I'll never make it again,' or 'I don't know, but I know how to find out,' 'what's your opinion?' and 'maybe you're right.' A high level of confidence that stops just short of arrogance. Driven, organised, high energy, curious, almost obsessive. These traits are just what it takes to be successful in any field. But since you can't be all these things yourself, identify people like this, and nurture your networks. Have lots of friends and contacts in the game and interact with them a lot. Never make an enemy and never forget a friend.

Incidentally, all this may have sounded very personal – between you and me – but be careful about including me in your connection links. I may be able to guide you to the knowledge you need, but not to important potential employers. In that regard, I claim editorial immunity. RE

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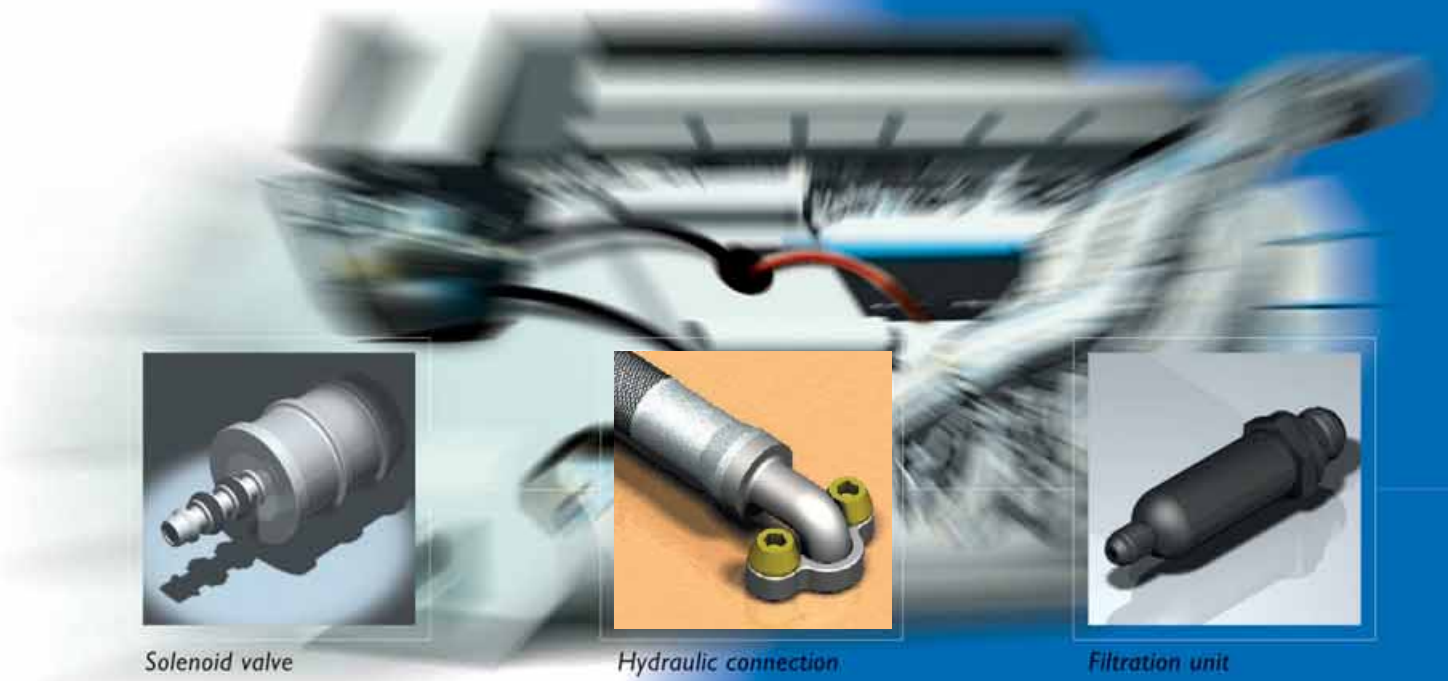

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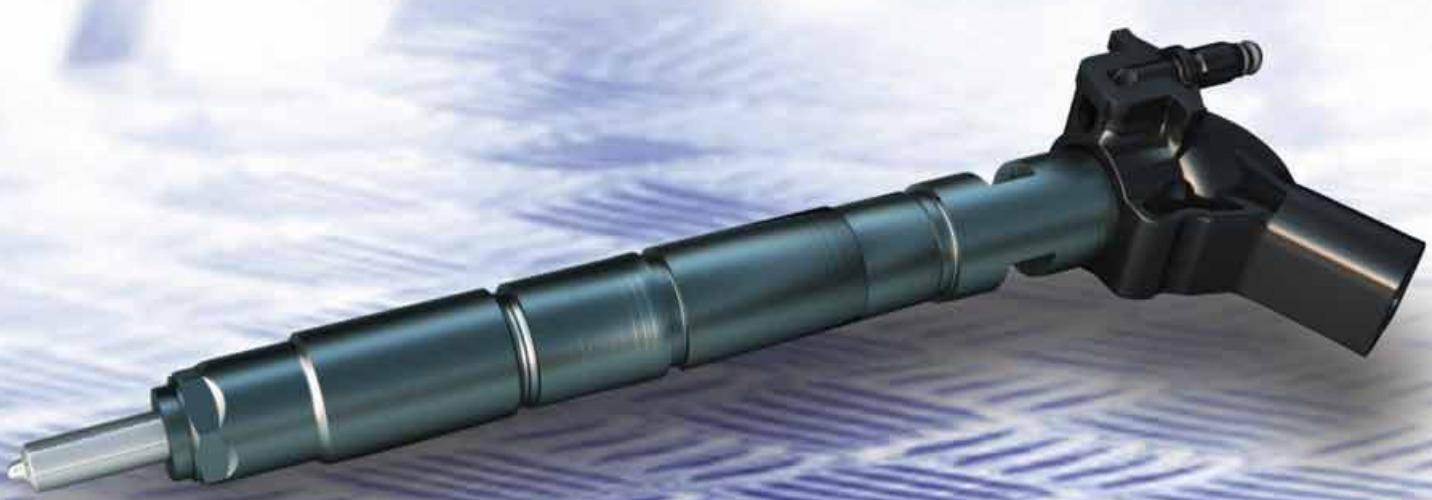

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Data interpretation

Having read your 'Both Barrels' article (*Racecar Engineering* April 2006), I had to email to tell you about a piece of software I wrote after testing an LMP2 car with linear potentiometers. When you looked at the trace of all four plots using the MoTeC Interpreter the data is very hard to decipher. As a result of this I have produced a simple piece of software that you can use to visualise how all four corners of the car are moving in relation to each other from a lap's worth of data. The corners' height above the ground is also factored in. This software has a gain (or zoom) control as you mentioned so you can see even subtle movements clearly.

I think that my software illustrates the points you made in your article perfectly. If you take a look at my website – www.linpotsim.com – you will see the full demo.

Peter Harris, via email

Aero information

I would like to say thank you for publishing Simon McBeath's very interesting article on wing selection in V16N3. It provided lots of good information for someone like me who has been interested in wing design for years. As a small comment I would like to direct readers to MSelig's website, which contains aerofoil programmes as well as profiles. The address is; www.ae.uiuc.edu/m-selig/

Bastian Loeffler
Ditzingen, Germany

Email the Editor: racecar@ipcmedia.com
or send your letters to: The Editor, Racecar Engineering, IPC Media, Leon House, 233 High Street, Croydon, CR9 1HZ, England Fax: +44 (0)20 8726 8399
Visit www.racecar-engineering.com and submit your project for a feature online

Has Formula 1 become self obsessed and irrelevant?

Viva Italia

I work for the Italian Automotive Technical Association (ATA) and we are organising the second running of Formula ATA 2006. The event includes both Formula SAE Italy and also Formula Tech. I presume your readership already know all about Formula SAE, but Formula Tech is a 'new entry', having been conceived by ATA in 2005 to promote alternative propulsion culture among students. As with FSAE and FSUK, FTech is a competition between teams of students from all over the world. It is dedicated to alternative propulsion vehicles including, but not limited to, fuel cell, hybrid and electric.

On our website you can find a brochure which explains more about the two competitions. It gives some information about the 2005 event and highlights on the 2006 one. The event will take place at the Fiat Auto Proving Ground (Balocco, Vercelli) from 7 to 10 September.

I hope you and your readers are interested in our event. The web address is www.ata.it/formulaata/

D Vignetta, Italy

Formula irrelevant?

I've been away from motorsport for a while and so I was shocked to see what has happened to international motor racing. When I looked at your April issue (V16 N4) it was with some amazement – what has happened to the self-styled pinnacle of motorsport that is Formula 1? Control parts on the way in 2008, only one option on engine configuration, daft split rear wings... Has F1 regulated itself into irrelevance? Surely F1 should relate to something other than some very complex regulations. If Formula 1 was all about 'entertaining racing' then wouldn't we have some sort of cross breed between NASCAR and the Indy Racing League? Formula 1 has lost its way and become self obsessed, openly ignoring the wider world of motorsport. Fans can't get near the drivers or cars and have to watch everything on television. And because of the rules the cars all look the same. Grooved tyres and those horrible looking T-bar cameras make the cars look stupid and these new twin rear wings will make it worse. I think we are just lucky the new circuits have such giant escape areas, because it means the cars are too far away for you to look too closely!

Jurgen Stiftschraube
Düsseldorf, Germany

Data entry

Some original thought and the application of DATAS simulation software looks to have provided the answer to a successful, cost-effective, new GT series

Words	Charles Armstrong-Wilson
Photos	Lotus; SRO

Does motorsport really need another category of racing? In the case of GT3 the answer could well be a resounding yes. This latest championship organised by SRO brings a number of new ideas to racing that, if successful, could make it succeed when so many others in the past have failed. With its original approach, it promises to attract more drivers with more money funding more teams while, at the same time, supporting a field with a broader range on manufacturers' products than has been seen in many years. It plans to achieve this by two methods – through the way the rules of eligibility are framed and through the innovative way they are policed.

SRO's initial intention was to create a championship that fills the gap between one-make 'cup' series and full-blown international GT racing. It was felt that the jump from the former to the latter was too big for the drivers and the teams, resulting in a lack of entrants for the premier GT1 and GT2 classes of the FIA GT championship. 'We were regularly asked by manufacturers to consider a one-make series,' explains Stephane Ratel of SRO. His organisation had previously been successful with single-make championships for Venturi and Lamborghini, but to establish such a series takes enormous investment, which was not forthcoming for any of these other proposed series.

"WE CAN GENERALLY GET THEM TO WITHIN A QUARTER OF A SECOND OF EACH OTHER"

Considering the problem, Ratel postulated the idea of running several one-make fields together in one race and awarding cups to the winners of each marque. It was a radical idea and would only need a few of each type of car to make up a field. In fact, the aim is to limit each marque to a maximum of six cars to prevent one model becoming dominant. In this way, even with as few as six marques the series will enjoy 36 cars on the grid.

However, the big challenge was to frame a set of rules that would allow different marques to run against each other on a level playing field and keep costs down. How can you match a powerful, yet heavy car with a lighter, less powerful competitor? Matching power through capacity or with a restrictor would not be fair, as the lighter car would have a big advantage. Alternatively, a common minimum weight would be impossible as the heavy cars could never match it, while the lighter ones would be carrying crippling amounts of ballast. But, by working with the FIA, SRO found a solution. →

Early GT3 tests have attracted cars from Ascari KZR, Aston Martin and Dodge

The man with the plan – Stephane Ratel of SRO (left) and GT driver Christophe Bouchut at Paul Ricard for the inaugural GT3 test day

Left to right, GT3 contenders from Maserati, Ferrari, Nissan and Lamborghini

It stems from pioneering work carried out last year controlling the performance of the GT1 cars taking part in the FIA European GT Championship. Maserati's MC12 had threatened to upset the balance of power in this series due to its superior inherent dynamic advantages. Were it allowed to race unchecked then it would have been so dominant that the only way anyone else could be competitive would be to build race-bred homologation specials. To tackle the problem, SRO turned to the FIA and its technical consultant Peter Wright. He had experienced this problem some years earlier recalling, 'I was involved in GT1 and I got fed up sitting in the technical working group listening to the arguments about the rules. I said there has to be a better way of doing this.' It took until 2004 for his solution to be taken up, but what he had come up with seemed the perfect solution to the problem of the MC12. Wright called on the help of Steffen Kosuch of DATAS and, using the company's simulation software and data from the Maserati, they set about modeling its performance, working out how to restrict it fairly.

> **"ANALYSIS TECHNIQUES THAT ALLOW ANOMALIES TO BE HIGHLIGHTED"**

For 2005 they rolled this technique out to the entire GT1 field using simulation to assess the performance of the cars and real track data to validate the result. Then it was possible to adjust the models to equalise the performance and then impose those changes onto the cars. As a base line they used the Prodrive-developed Ferrari 550 and then matched the other cars to that. Mostly the corrections were made with weight adjustments although it was possible to use aerodynamics and engine restrictor changes if necessary.

'If over two races we see anything more than a half second difference between the cars we then act,' explains Wright. 'We can generally get them

Lotus Sport Exige GT3

If the new GT3 rules are able to achieve their intentions then a GT3 Lotus will be the proof. Previously GT regulations have dictated a minimum weight limit that would have required a racing version of the Elise or Exige to carry between 200 and 300kg of ballast. Not only would this be an enormous challenge technically, but it would also swamp the power available, even from the supercharged four-cylinder engine of the new Exige S. As the new rules police a performance level rather than any single physical attribute of the car then Lotus can use its products' light weight to the full in pursuit of competitiveness. This is an attraction that the Norfolk company quickly recognised and inspired the launch of its Sport Exige GT3 programme.

Lotus GT3 car is based on Sport Exige and uses a production car chassis and supercharged Toyota engine from the Exige S. The aim is to exploit the car's agility against more powerful machinery

No limits

Chris Arnold explains: 'In theory there are no limits for Lotus. There are no limits on power and no limit on minimum mass.' With its 1.8-litre engine developing 285bhp, Lotus is going to be less concerned with having its performance restricted, rather it will be working to match the benchmark of a GT Porsche chosen by the FIA. That is not to say the Exige will forever be struggling to catch up. Rather Arnold feels that with a different performance profile to the more powerful but heavier GTs, it will have a significant advantage in some areas. 'We wouldn't be doing it if we didn't feel we had a good chance. Some of it will be circuit specific. If you go to an out and out power circuit, Monza say, we are always going to have a tough time,' he admits. 'But if you go to a more technical circuit, I truly believe that we can be very strong. We can carry more speed through the corners, we have more responsiveness and our cornering ability ought to be better.'

With the various track and race versions of the Elise/Exige concept the company has produced over the years, developing the GT3 meant it

to within a quarter of a second of each other.' All the time their objective was to equalise performance. 'The whole idea is don't spend money. Because if you spend money on developing the car we are going to add weight.' Initially the teams found this hard to grasp and were quick to complain when they felt unfairly penalised. But Wright was unfazed, 'I'd have George [Howard-Chappell of Aston Martin] in one ear and Georgio [Ascanelli of Maserati] in the other and it was very simple. When the volume was the same I'd got it about right.'

To monitor the cars Peter and Steffen were receiving data every time they ran, which amounted to an enormous amount of information. However, Kosuch has analysis techniques that allow anomalies to be highlighted.

'What we are looking for is the basic performance built into the car rather than the way it's set up and driven,' explains Wright. 'So we are looking at steady state corning speeds, acceleration and top speed. We are not looking so much at how late the driver can leave the braking which is really more to do with how brave he is and how stable the car is. You can do an analysis of the race taking out fuel effects, tyre degradation, looking at trends, and if we see laps which don't look right, then we get the individual data for that lap. Then we can look at where they have an advantage. You don't have to process all the data. You apply human intelligence to it then go and look at the bits you want.'

> **"THE PORSCHE IS TAKEN AS A BENCHMARK FOR PERFORMANCE"**

Occasionally, teams tried special tyres or engines but it was quickly identified. We go through it and review the model and when we see the parameters in the model are changing, we plot trends and if we see a distinct trend we say hang on they've done some development. We usually accuse them of it and then they admit it. Also, if the Aston suddenly goes quicker Giorgio will ➔

was covering mostly well-charted territory. Arnold: 'The chassis is completely standard as we take it off the production line. We use the same chassis pick-up points but all the corners are new. We run at a much lower ride height and obviously we have joints locking out so we had to re-design and re-format all the wishbones, brakes and uprights.'

The AP Racing discs are the biggest that could be fitted into the 16 and 17-inch wheels which are, in turn, limited by the bodywork. Keeping a close affinity with the road car the dampers are a development of those used on the Exige S, only three way rather than two-way adjustable. The big challenge though is tyres, with the car needing very different rubber to the rest of the GT field. 'Tyres are critical for our type of car,' confirms Arnold. 'We need a well optimised tyre as we are not relying on raw power, we are relying on cornering power and tyres are a big part of that.'

Powering the Sport Exige GT3 is the same Toyota engine as all the company's road cars, fitted with the same supercharger as the Exige S but geared faster to increase the boost. For its racing application the unit is dry-sumped and fitted with different induction and exhaust systems. But, remarkably, the internals remain untouched and even with power now up to 285bhp there have been no problems. 'You have to take your hat off to those Toyota guys who designed this engine,' says Arnold, 'it really has got fantastic potential.' For the electrics the car continues the relationship with EFI for management but the dash is from AIM and is able to interface with the car's CAN system.

The transmission, however, was deemed unsuitable for a couple of reasons. Firstly it was felt the extra torque from the blown motor would exceed the transmission's limits and, with an H-gate change, the time loss would be unacceptable. So, it was replaced with a Hewland PCT Touring Car gearbox, which suits the transverse installation. The new GT3 rules do not mandate a production gearbox and Arnold sees the choice as more of a cost and performance consideration.

'We wouldn't be doing it if we didn't think we had a good chance' – Chris Arnold, Lotus.

Aero efficiency

Aerodynamically, the car was originally designed using previous experience with the production body shape. Most of the panels come from the road car but are now made in carbon, while the roof panel is the design incorporating a scoop taken from the one-off V6 Exige GT [RE V15N9]. This conveniently feeds air to an air-to-air intercooler, which Lotus feels brings worthwhile weight benefits over a water-cooled version. ➔

tell me. If the Maserati goes quick George will tell me.'

Despite some dissent during the season, by the end it was accepted it had worked, not least thanks to the results. Maserati managed four wins, Ferrari three, then Aston Martin and Corvette took two each. Also, the drivers' title was so close it ended up in the court of appeal arguing over a third of a litre of fuel. It was such a success that it seemed the perfect answer to matching a diverse field of cars for the proposed GT3.

Starting with the GT2 rules for construction and safety the Porsche is taken as a benchmark for performance. Manufacturers are then invited to submit cars to the FIA, which are then assessed at a series of pre-season tests in the hands of a professional driver. From the results of these the specifications for each model is fixed and documented in an FIA passport that scrutineers can refer to at each round.

However, the assessment process does not stop there and throughout the season Wright and Kosuch will be taking data from all the teams although it shouldn't need to happen as frequently as GT1. With a fixed specification for the cars and a single tyre supplier preventing a tyre war there is no reason for their capabilities to change. 'If we see a make of car that suddenly appears to have a step in performance then we are going to go and rip the car apart,' warns Wright.

Another advantage is that with the incentive to find more power removed, the need for strangling restrictors on the engines is taken away. So the cars can run freer breathing engines in a lower state of tune with a much longer life between rebuilds.

> "CARS CAN RUN IN A LOWER STATE OF TUNE WITH A MUCH LONGER LIFE"

With all the cars matched in performance and no benefit from development budget, SRO hopes it has achieved stable and affordable budgets for the series. This, it feels, will make the package attractive to wealthy amateur drivers. In fact, the rules have been framed to exclude anyone but amateur drivers by barring anyone with an overly accomplished driving record. In addition, while manufacturers are encouraged to develop cars to compete in the series, they are specifically prevented from entering works teams. That way no marque will become too dominant and fields will remain varied which is good for attracting spectators. With the vast majority of the money expected to come from the drivers rather than big sponsors, the actions of one party will be unlikely to destabilise the whole series.

Already a leading GT1 contender, Chevrolet is developing a GT3 Corvette Z06R

It certainly is an original idea and, if it gets off the ground, could provide a long-running series with a varied field and good racing for both those in the cars and in the grandstands. RE

Lotus Sport Exige GT3 contd.

In the rush to get the car ready for the first test at Paul Ricard there was no time to put it in the wind tunnel, but before Christmas it had a spell in the MIRA full-scale facility.

'We used the standard body shape so we know roughly that that had balanced downforce front and rear,' says Gavan Kershaw, principle vehicle dynamics engineer at Lotus Cars. However, it was found that 60 per cent of the downforce was on the rear. 'Obviously the rear wing was far more efficient than we imagined so we had to make the front create some downforce. We were careful how we did that, just making sure that radiator exits and things were properly done, some extra vents for trying to get the air out of the wheelarches and really just trying to maximise the rear diffuser. It shows, even on the road car, that the cars are sensitive to the diffuser shape. Even at club level, guys put 50mm on and they are quicker round Snetterton and the high-speed circuits.'

A lower ride height meant the uprights and wishbones had to be developed from the road version. Only the gearbox needed a total re-think, the designers opting for a Hewland PCT touring car 'box in the GT3

As an experienced GT racer, Kershaw has been doing most of the testing and gives some interesting feedback. 'The car is similar to the original Lotus. It is agile, and you can actually feel the corner speeds are high.' He particularly likes the car's low weight. 'It's just enjoyment and the accuracy you can get. That was what I missed in the Mosler a little bit. You couldn't be pinch-up accurate every time you approached a chicane. With this it's like millimetre perfect every time.'

GT3 has generated much enthusiasm at Lotus and Arnold is still pragmatic. 'The whole GT3 is a voyage of discovery. It might end up staying with the European FIA and the British GT allowing it, in which case it's going to be fairly limited. But, if other national GT championships around the world start adopting a GT3 class, then potentially there is quite a large market for them.'

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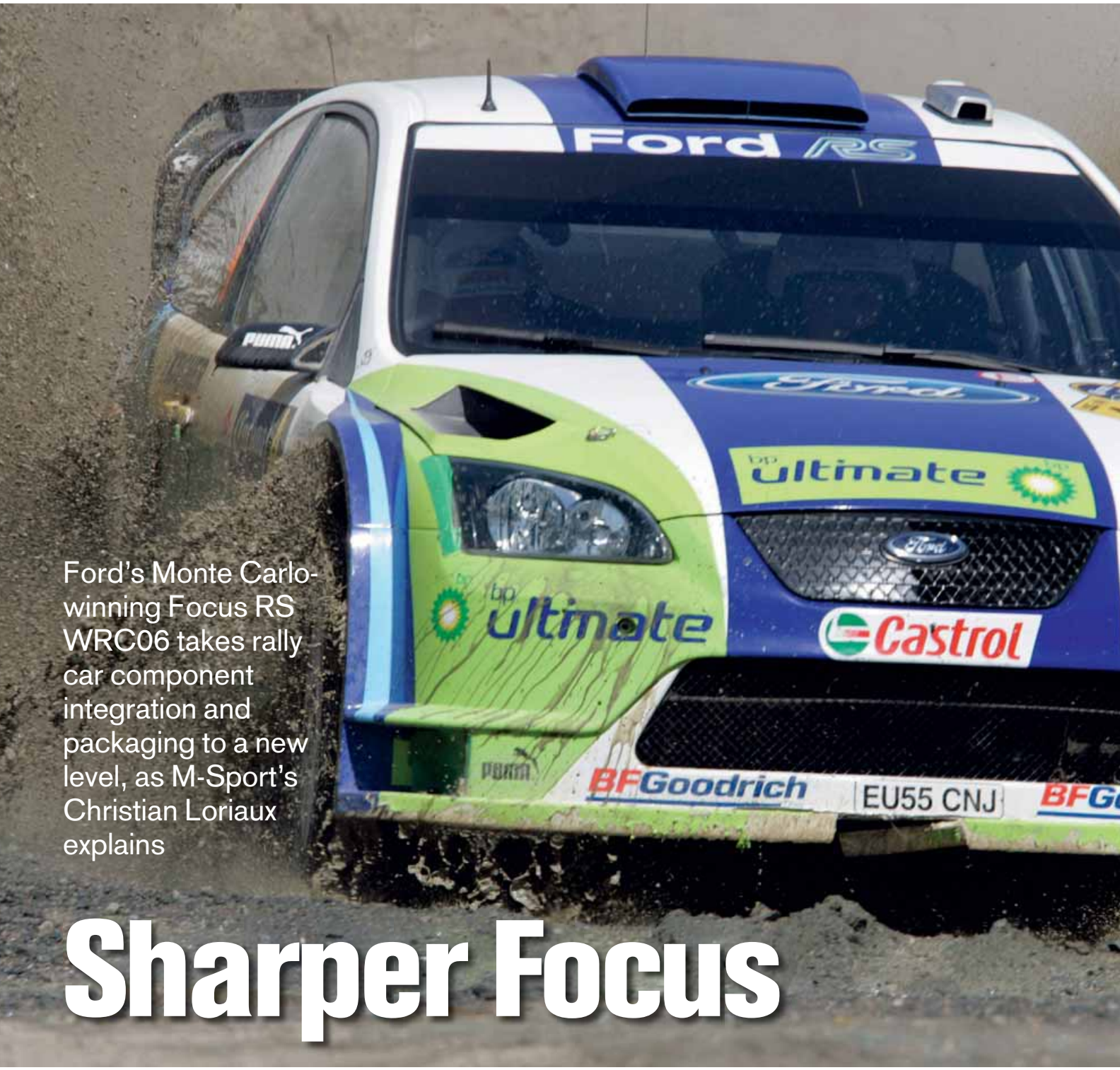

Ford's Monte Carlo-winning Focus RS WRC06 takes rally car component integration and packaging to a new level, as M-Sport's Christian Loriaux explains

Sharper Focus

Monte Carlo, 22 January 2006 and Marcus Gronholm takes a sensational overall victory in the all-new Focus RS WRC06, Ford's first victory on this legendary event since 1994 with François Delecour. It was a remarkable result considering that it was the ex-World Champion's debut rally for his new team, plus it was the first time the new Focus had competed in anger on tarmac. And while to the general press the result was a shock, the omens had been good prior to the start of 2006, as the new Focus had already set fastest stage times during Rally Australia (the final event of 2005 season) and had completed over 2000km in testing. When you consider that the WRC06 project began a mere 12 months previously, it's a remarkable achievement and the vindication of a punishing, compressed development programme.

"IT'S LIKE AN ARMCO BARRIER IN THERE FOR SIDE IMPACT PROTECTION"

The engineering responsibility for the project rests with Christian Loriaux, technical director of Ford's UK-based rally preparation partners, M-Sport Ltd, run by ex-British Rally Champion Malcolm Wilson. Loriaux is highly rated as a designer whose attention to detail and logical approach produces results, as proven in his dramatic and successful re-design of the 'Mk1' Focus for the 2003 season. This, and subsequent Focus WRC cars, all benefited from Loriaux's technical abilities, producing a brace of rally wins and fastest stage times. But 2005 proved to be something of a dip in form in light of an

Words | Peter Knivett
Photos | LAT; Martin Sharp

The Focus WRC's are prepared at M-Sport's Dovenby Hall HQ in the North West of England county, Cumbria

M-Sports designers have situated as much equipment as possible on the floor of the car to lower the centre of gravity, including the crew. Note mechanical and semi automatic shifters

Christian Loriaux (far left); Malcolm Wilson

unstoppable Citroën WRC steamroller that scooped not only the Drivers title but Manufacturers' title also.

Unconventionally, the goal was to debut the new 2006 car at the final rally of 2005 and understandably, from a PR perspective at least, Ford was reluctant to do this. But there was method to Loriaux's madness as it would give M-Sport vital breathing space to solve any potential problems over the only substantial break in the WRC calendar. As Loriaux explains, 'the only time in the year when you've got a bit of time is between the last rally – Australia – and Monte Carlo, when you have two months. So I knew that if we went to Australia and we got dramas and the engine shit itself or the gearbox shit itself then we've got two months to try to fix it and start the season in a half decent position. But if we waited until Monte Carlo and we had a problem then, with a schedule like WRC, it could take six months to fix it.'

Loriaux also had one eye on the revised technical regulations for 2006, particularly the requirement for some components, including transmissions, to be sealed to ensure use across two events. 'They sneaked that on us,' he says. 'I was a bit gutted really, because it was a good political move from the other teams to screw us.' Clearly, getting stage miles on the car as early as possible was crucial to a successful 2006 season.

With a debut on Rally Australia the goal, it →

"WEIGHT DISTRIBUTION IS BETTER WITH A TRANSVERSE GEARBOX"

meant having the car testing by mid-October last year. As Ford only re-committed to the WRC in November 2004 and M-Sport received its first CAD files from Ford for the new base car the following month, that gave Loriaux's 13 person technical team just over nine months to hit its build deadline, from scratch. So given the timescale, what priorities drove the design?

Philosophy of design

With an FIA-regulated 1230kg minimum car weight, shaving overall mass wouldn't seem a priority for WRC designers, but the key to success is the location of that weight. Produce an underweight car and teams can ballast it up to the minimum figure and, even better, they can place that ballast on the car in an advantageous position that produces real advantages for weight distribution and overall handling. Loriaux's design philosophy seeks to maximise this factor, but then takes it a stage further. 'Integration is the key,' he says, 'which means before you can design anything you have to design everything. When you look at the new car – and there are things here that I don't want to say – we've integrated further areas. Why? Because if out of two parts we can make one part, first you've saved money and second you've saved weight because two parts have to be glued or welded or joined together and that joint costs you weight.'

Applying that philosophy to the Mk1 Focus yielded real results in 2003 and 2004, but designing the all-new car represented even more of a challenge because the second generation Focus offered no clear advantages as a base car. Bigger, heavier and higher than the Mk1 Focus 'shell, in many senses the old car was a better base to work from. However, there were advantages – the new bodyshell is better aerodynamically, particularly at the rear, plus the engine in the Mk2 road car is mounted lower and is now all aluminium.

2006 Focus WRC's engine is based on the Mazda Duratec in-line four and is prepared by Pipo in France

A full design concept, including rollcage, started early on with a production line Focus ST220 'shell arriving in March. Reducing weight, improving impact protection and increasing stiffness were high up the agenda, with M-sport aiming to exploit the FIA's 320kg minimum 'shell mass rule as much as possible. 'We didn't get the 'shell to 320kg,' says Loriaux, 'we got it to 340kg because we left reinforcement in the sill and added extra. It's like an Armco barrier in there for side impact protection and, because the weight is low down, it doesn't give anything away.'

Interestingly, Loriaux's approach to rollcage design is pragmatic and hands-on, avoiding excessive computer-based finite element analysis. He explains: 'We build a lot of rollcage variants and then twist the car using hydraulic actuators and measure using dial test gauges. Then we can tell the guys 'cut this tube, weld that one, let's do it with bigger gauge tubes, smaller gauge tubes, this and that. We can test five iterations of rollcage in one day this way... It's a lot quicker than running it through a computer for two days.'

Bearing in mind the awful events on Rally GB last year, M-Sport's aim with the new, wider car was to move the occupants further inboard, relatively speaking, to improve side impact protection. In turn, this meant reducing the width of the transmission tunnel. Despite this modification though, the team has still managed to package the propshaft and exhaust within the standard Ford production structure from the front-wheel drive ST220.

All alloy engine

Although the high performance Focus road car

Technical specification: Ford Focus RS WRC 06

Engine:	Ford 1998cc, Pipo-built, I4 Duratec WRC engine. Four cylinders, 16 valves. Bore 85mm. Stroke 88mm. Pi electronic engine management system. Garrett turbocharger (with FIA required 34 mm inlet restrictor). Air intercooler. Catalytic converter.
Power:	320 bhp at 6000 rpm
Torque:	550 Nm at 4000 rpm
Transmission:	Permanent four-wheel drive with M-Sport designed active, centre differential. Pi electronic differential control units. M-Sport/Ricardo five speed sequential gearbox with electrohydraulically controlled shift. M-Sport/Sachs multi disc carbon clutch.
Suspension:	**Front and rear:** MacPherson struts (front) and Trailing-Arm (rear) with Reiger external reservoir dampers, adjustable in bump and rebound. Fully adjustable fabricated steel links. Front and rear anti-roll bars. Cast steel uprights. Ceramic wheel bearings.
Wheels:	**Gravel:** 7in × 15in (magnesium) wheels with BF Goodrich 650mm tyres. **Asphalt:** 8in × 18in (magnesium) wheels with BF Goodrich 650mm tyres.
Bodyshell:	Unitary construction. Unique composite side panels. Welded T45 steel safety roll cage. Aerodynamic rear wing. Unique front 'bumper' treatment.
Electronics:	Full Pi chassis and engine data acquisition for on-event diagnostics and performance development.
Fuel tank:	FIA FT3 tank, 94-litre capacity, located centrally.
Dimensions:	**Length:** 4362mm. **Width:** 1800mm. **Wheelbase:** 2640mm. **Weight:** 1230kg minimum.

The engine bay was originally designed for the road going Focus ST220's 2.5-litre Volvo five-cylinder unit

donated its bodyshell for the rally car, the ST's turbocharged 2.5-litre, five cylinder Volvo engine was regrettably unsuitable for the WRC. Therefore, as a result, M-Sport chose to use the all alloy, 2.0-litre, Mazda-designed Duratec powerplant from the more humble Mk2 Focus road car instead. This again meant starting from scratch as there was zero component carry-over from the previous Zetec motor.

Engine development initially began in February 2005 and, rather than undertake this in-house, M-Sport successfully benefited from Peugeot's withdrawal from the WRC by quickly snapping up the services of its French motor builders, Pipo. 'We knew that the 307 engine was very good, so I contacted Pipo straight away after Peugeot announced its pull out and came to an agreement. The first engine was running on the dyno in May, developing good power,' Loriaux grins. 'But that gives you a false sense of security, because you've still got to package the turbo and you haven't done a sump. From having an engine running in a 'bodge-up' state to having it running it in the car is a massive job.'

Even so, M-Sport's technical director is a big fan of the new Duratec engine, not least because its lightweight block is used in standard un-machined form, whereas the 'old' cast iron Zetec block underwent £5000 ($8,683) worth of machining to reach a WRC-style fighting weight. Internally, it's a strong base, featuring good combustion chamber and port shapes, which greatly assisted Pipo in developing it into a turbocharged WRC motor. Running on Pi electronics, using a Garrett turbocharger and breathing through the mandatory FIA 34mm inlet restrictor, the unit produces around 320bhp and 'well over 500Nm of torque,' according to Loriaux. More importantly, it offers a good spread of progressive power in the important 3-6000rpm range, which allowed the team to exercise its integrated thinking brief when it came to the new car's transmission package. As did the engine position within the under-bonnet area, which is dictated by the FIA.

These rules state that the engine position reference point is the production car's position of the end of the crankshaft at the gearbox/block interface. However, because the team had placed a four-cylinder transverse engine where a five cylinder used to be, they had a large space on the right hand side of the engine bay where the fifth cylinder on the road car should have been. In turn, this meant less space for the gearbox package, so creative thinking was required, and here Loriaux exploited the blank paper approach to his advantage.

> **"M-SPORT CHOSE THE ALL ALLOY, 2.0-LITRE, DURATEC POWERPLANT"**

To re-cap – all previous Focus WRC cars used a longitudinal gearbox, positioned behind the engine. A complex, tortuous solution, this was deemed necessary to position this bulky component further rearwards and towards the centreline of the car to assist in overall balance and handling. These were logical design goals but, surprisingly, Loriaux was never a fan of this transmission layout that he'd been forced to carry over on his 2003-2005 WRC cars on cost grounds.

So for the new Focus he's opted for a transverse gearbox design, which runs contrary to current WRC thinking as it's positioned further forward in the car and to one side. Surely that's a retrograde step in weight distribution terms? Well, follow Loriaux's train of logic through and you realise this simply isn't the case. 'If you do a longitudinal gearbox it weighs 90kg and you can get the weight 0.5m further back down the car than with a transverse unit. If you do a transverse gearbox you save 30kg and, if you want to put that 30kg as ballast, you can put it behind the rear wheels. That means you move it 2.5m further back down the car, so effectively the offset is much bigger. So the weight distribution is better with a transverse gearbox, plus you've made the car 30kg lighter,' Loriaux enthuses.

He's also very positive about the decision to swap from Xtrac to Ricardo as M-Sport's transmission partner which, again, runs contrary to perceived opinion, even within the team itself. 'When I said to Malcolm [Wilson] "we go with Ricardo" he said to me, "I reserve the right to change that decision." It's the first time ever he hasn't trusted me... Two days later he came back and he went for it, but then he had more to gain because he was saving £20,000 ($35,000) per gearbox!' The resultant semi-automatic unit is a true joint venture between M-Sport and Ricardo, with the bulk of the design work carried out at M-Sport and Ricardo finalising the details. As with the previous gearbox the gears are shifted via an electro-hydraulic mechanism, but on the new car there are only five forward ratios, as Loriaux deemed six to be superfluous. Why? Well the spread of power on an inlet-restricted WRC engine is such that between 3-6000rpm the delivery is quite flat, which offers a 3000rpm power band. Given that a six-speed unit offers typical rev drops of 900rpm between ratios, whereas a five-speed unit stretches this to 1200rpm, it's clear that five ratios are all that's required to keep the Focus's engine within that 3000rpm zone. In addition, 'you change gear less often, there's one less gear to go wrong, it's lighter, narrower and easier to package,' reckons Loriaux, which was highly relevant when considering the under bonnet space issues caused by the engine choice.

This gearbox also acts as the centre housing for the centre differential which, thanks to the 'cost-cutting' FIA rule changes for 2006, is the only remaining 'active' computer controlled diff' left on the car. Designed and manufactured by M-Sport, it uses Pi electronic controllers and works in concert with the mechanical plate-style differentials in the front and rear axles on the →

new Focus. Aside from meaning that driver set-up changes now require mechanical, rather than electronic, alterations Loriaux reckons that the transmission rule changes didn't upset the design too much. However, the same cannot be said for the new car's suspension.

Integrating the regulations

Titanium is banned from WRC cars in 2006, which meant that after years of fabricating the rear suspension from this exotic alloy, M-Sport had to design the suspension for the new Focus in more mundane materials. Physically, little has changed from the old Focus WRC car, which makes sense because the independent rear suspension was always a strong point. At present however the material specification has not been fixed with the new version. 'We currently have an aluminium version of the trailing arm and upright, and we've also got a stainless version,' says Loriaux. 'The test car always ran with aluminium on one side and steel on the other, so we can learn and put the mileage on the two designs. That way we spread the risk and it speeds up the learning.' Fabricated steel links complete the rear suspension, which is fully adjustable, as are the Reiger remote reservoir dampers.

Up front, the FIA rules that restrict relocating the pick-up points more than 20mm (when compared to the road car) defines the suspension package on the new Focus. Loriaux admits that the front geometry is a compromise, but confirms that 'we have over 250mm of travel all round, but I'm not going to say how much!' Meanwhile, passive front and rear anti-roll bars complete the suspension picture on the new machine.

Similarly, the braking system is conventional and changed little from the previous WRC car. This sees the Focus running on 300mm Brembo four-piston calipers in gravel specification, switching to larger 370mm items with eight-piston calipers in tarmac trim.

A look inside the new Focus reveals that Loriaux's emphasis on weight reduction and re-positioning has been refined further, as everything of use is sited on the floor and, where possible, between the drivers. 'We have lost a little bit of weight with the switch panel but, if you can imagine with the tunnel being from a front-wheel drive car, it's now very low.' As are the drivers, with Gronholm in particular commenting how much lower his seat is compared to the Peugeot 307.

And he sits just behind a control that Loriaux would rather not have on his car – a spare, back-up mechanical gear lever designed to take over should the steering column-mounted paddle shift fail. Previously the handbrake converted into a back-up gearchange, simply by removing a pin. But it meant the handbrake was lost. Risky, but ingenious, it backfired on Rally Deutschland when the paddle shift failed on one of the twistiest stages of the WRC, where a handbrake was crucial. The result was poor stage times. So Loriaux reluctantly relented: 'I've put a proper back-up gearchange in this one, because everyone gave me so much stick about it.'

Clearly this grates with his central design philosophy and you cannot argue with his logical point of view. 'If we need to work on something, let's work on making it reliable – why work on doing a back-up gearchange? Instead put that work into a reliable gearbox. I hate those bloody back-ups! And for me that original back-up system [from the old car] was the secret for improving the car, through true integration.'

> **"WE HAVE OVER 250MM OF TRAVEL ALL ROUND, BUT I'M NOT GOING TO SAY HOW MUCH!"**

Certainly it seems that Loriaux's talented M-Sport technical team have taken a significant leap forward through pursuing this philosophy on the Focus WRC06, but it's not been a painless enterprise. Viewing the car as a complete entity, where every single component has a knock-on effect on another, is a challenging undertaking for any team, particularly one facing tight deadlines. For example, the spare wheel on the Focus WRC06 lives below the boot floor, accessed via a quick-release section of the rear bumper. Shifting over 20kg of wheel and tyre 250mm lower in the rear of the car was the main goal, but this also meant re-designing the rear differential, propshaft and gearbox drop gears to gain a fractional, but vital, advantage.

So does this design method require weighty budgets and manpower? Not according to Loriaux. 'I think that's there no need for tons of people, what's more important is using people that get on well. More of the credit needs to go to those guys because we worked like bastards and no-one complained about the 12-hour days.' It's undoubtedly painstaking work but, as the Monte Carlo result proved, Loriaux's and M-Sport's ends more than justify the means. RE

Brembo ventilated discs and eight piston calipers provide stopping power on asphalt and four piston units on gravel. Note Reiger remote reservoir shocks and McPherson strut arrangement

The Spare wheel is located inside a cavity under the back of the car, shifting 20kg 250mm lower in the car

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Words	Paul J Weighell
Photos	LAT YYePG Proudly Presents, Thx for Support

Entering the FIA Formula 1 World Championship is not a simple matter. The time taken to bring a new team to the grid from acquiring initial investment capital depends on the team's longer term prospects and goals. Deep-pocketed teams can afford to set up several years before they race such as Toyota, for example, who spent a whole year just shadowing the real season in order to learn the process. A small new team, however, cannot afford to spend more than a single preparation year before racing, if that.

Although racing commences during March it is the previous November that contains the most important deadline. The 15th is the date by which a team's FIA entry must have been submitted unless unanimous agreement can be reached with the rest of the grid to allow a late entry, such as happened with Super Aguri F1 for 2006.

FIA acceptance

The official entry form must be accompanied by a $48m deposit. The deposit money is cashed by the FIA and then returned to the team as twelve equal payments throughout the season. The deposit requirement is there to encourage teams to

> "THE OFFICIAL ENTRY FORM MUST BE ACCOMPANIED BY A $48M DEPOSIT"

ensure that their finances are robust enough to last the season. A sensible team therefore needs to ensure it has enough money to last from its start point the previous year until the end of its first racing season, a practical minimum of two years. To be prudent, that money should be in the bank at the start of the pre-year build-up, and any team that has not sufficient capital at start-up is at serious risk of losing part or all of its $48m.

Whilst sponsors may be happy to see their brands advertised on television in conjunction with F1 racing, the risk of possibly losing up to $48m is too much for most of them and, as a result, they are unlikely to lend the team the deposit. The advertisers are not the primary business managers and are understandably loath to accept the risk inherent in a management team whose staff they have neither chosen nor can directly control. A new team may sign up all the sponsorship it needs and still be short of deposit.

Borrowing from a bank is a non-starter unless one is prepared to lodge an appropriate amount of collateral. Even if one secures such a loan the interest charges alone could cost $1m or more, being maybe two per cent of one's first annual budget. The FIA will pay interest on the $48m it holds on the teams' behalf but, naturally, a bank's

Super Aguri is the latest team to join the F1 circus, using an old Arrows design

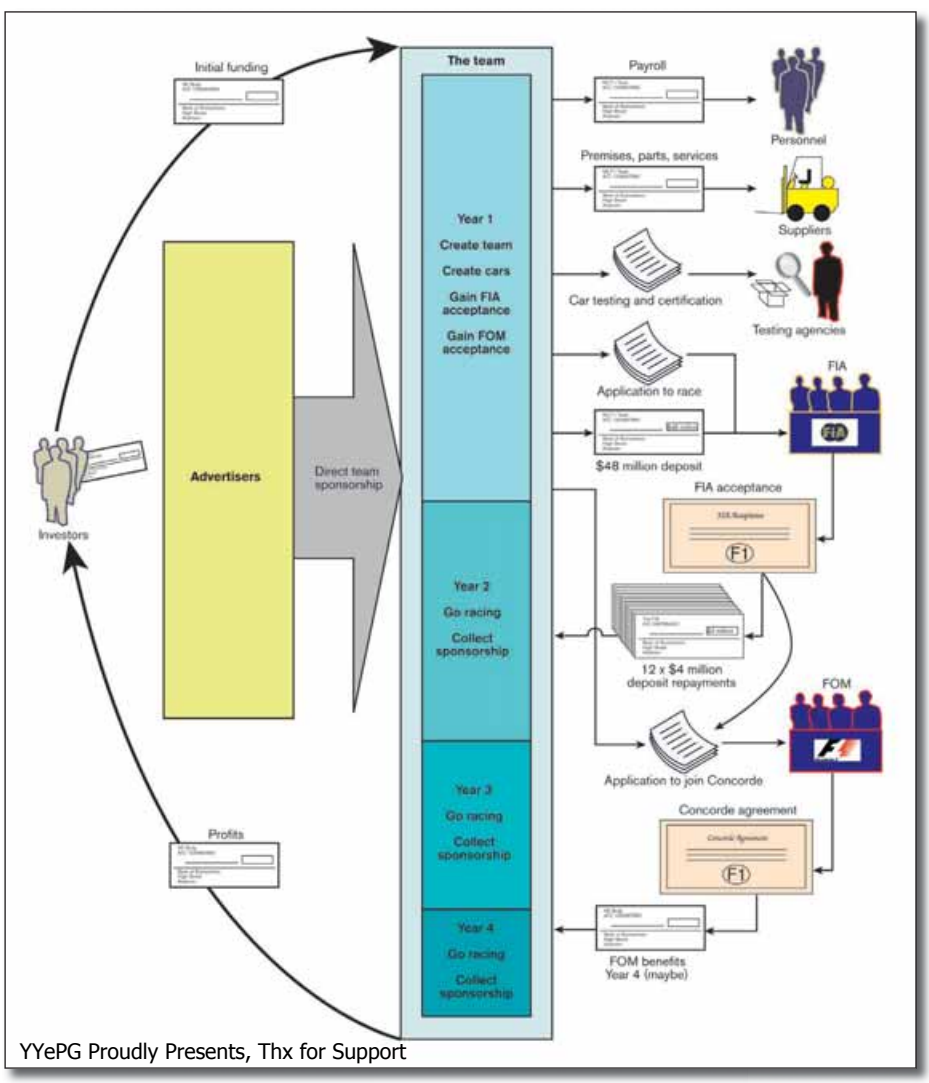
borrowing rate will always be lower than its lending rate and the team will lose money. However difficult it may be, the bond money must be found, under the current FIA rules at least.

> 'If you wish to enter the FIA Formula 1 World Championship and your entry is accepted, you will be offered the opportunity to sign a Concorde Agreement with Formula 1 Management and the FIA. As far as the current Concorde terms are concerned, this is between Formula 1 Management and the respective team that is a signatory to the current agreement.'
>
> **Bernie Ecclestone**

The Concorde Agreement details are mostly hidden until after one has gained FIA approval, including lodgement of the deposit, and one is already committed to race at that point. Having spent $100m or so to get that far it is less likely that one will quibble over the Concorde terms. A very neat arrangement that seems not to be illegal under EU law. In theory, one can race without being a Concorde signatory, but no team takes that route. →

"THE ADVERTISERS ARE NOT THE PRIMARY BUSINESS MANAGERS"

New team business cycle



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2006 team types

Grid	Team	Status	Brand
1	Renault	Tied	Renault
2	McLaren	Tied	Daimler-Chrysler
3	Ferrari	Tied	FIAT
4	Toyota	Tied	Toyota
5	Williams	Independent	
6	Honda	Tied	Honda
7	Red Bull	Tied	Red Bull
8	BMW	Tied	BMW
9	MF1	Independent	
10	Toro Rosso	Tied Junior	Red Bull
11	Super Aguri	Tied Junior (Unconfirmed)	Honda (Unconfirmed)
12	None	None	None

The only two truly independent teams competing in Formula 1 today – Midland F1 (top) and Williams

Profit share

Only two teams can currently be considered truly independent, with the rest being more realistically described as departmental offshoots of mainstream car manufacturers (with the single exception being a vendor of soft drinks).

Wholly owned, or tied, teams can run at a financial loss as their costs are largely met by their parent's advertising budgets, with some contribution from other departments such as R&D perhaps. Independent teams must make their own income and their own profits.

One independent team filed corporate accounts showing a profit before tax of exactly five per cent of gross income. Such a neat figure points to a decision that five per cent was to be the profit margin, and that amount was then taken off the top of the sponsors' money. The practice of spending only 95 per cent of sponsors' money necessarily puts an independent team at a disadvantage compared to the tied team that can spend 100 per cent. If one takes too much out of any business then it cannot grow, and it may be that 5 per cent was too much for that particular team, which fell into difficulty and was sold.

The wholly owned Renault team reported that it had made $5m profit during its 2004 financial year. Exactly on what basis that had been calculated, and what real meaning it had, must be open to question for any corporate division, in this case of the Renault Group. Taking an informed estimate of the team's 2004 gross

> "THE REAL COST PER POINT IS APPRECIABLY MORE THAN $4M"

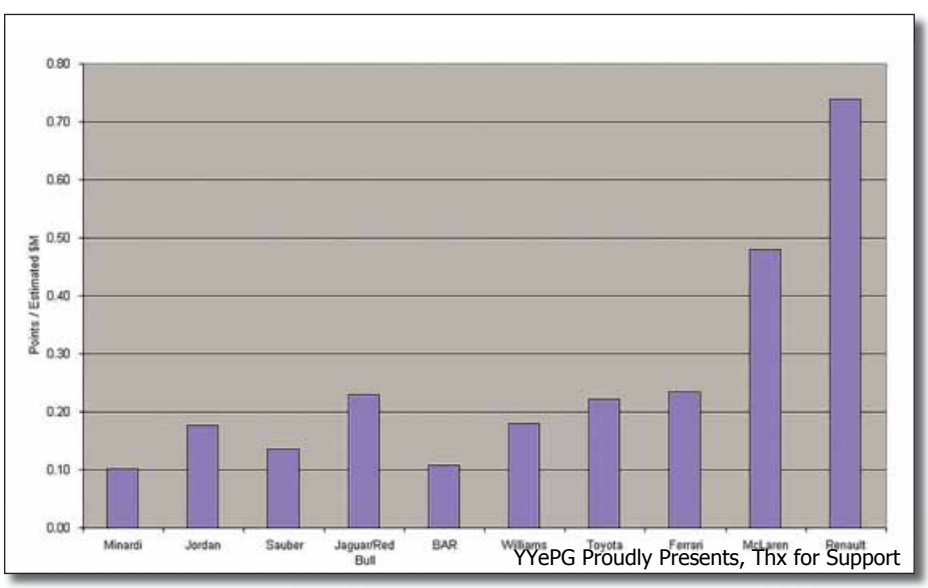
income at between $225m-$250m, the claimed $5m is still only 2-2.5 per cent profit. Most businesses would prefer to see a larger profit as 2.5 per cent is little more than European inflation, depending on which official figure you happen to believe! One can get better than 2.5 per cent from a local, risk free deposit account and if Renault Group were not in fact getting an incalculable amount of positive advertising from their Formula 1 presence, then F1 for profit alone is unlikely to be a business that they would choose to start.

F1 teams spent an average estimated $250m to achieve about 70 championship points during 2005, yielding a cost per point of some $4m. The expenditure quoted is only annual spending and does not include the accumulated value of property, capital plant and equipment or the skill and knowledge of staff. The real cost per point is therefore appreciably more than $4m.

Spending whatever it costs to win a championship may not necessarily result in a team that can return much income to its original investors, or perhaps FIAT for one would not be in so much trouble. If a team runs for five years spending enough money to win a championship for a single year and then declines in subsequent years, the overall return on the original investment may not be as healthy as the team that spends less on performance and is able to distribute more of its income to shareholders. Or, as Max Mosley put it, 'One manufacturer is spending a sum greater than half of its total annual dividend. This is unsustainable and sooner or later the shareholders will notice.'

A new and independent team cannot immediately, or realistically, be run as a team destined to be world champions, nor can it run as the loss making advertising department of a larger company. It must instead be structured as a normal new business and seek to make a profit. That means it should run on its own money from as early as possible and then show a profit from each and every racing year.

Value for money



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Battery charger

If battery power doesn't spring to mind as a *competitive* power source for a racecar, think again...

Words	Simon McBeath
Images	McBeath; Ogilvie

There are some commonly held negative perceptions surrounding battery technology as a viable, competitive power source – low power-to-weight ratio, short range and long 'refuelling' times are but three areas where 'traditionally' fuelled cars are pretty hard to beat. But *Racecar Engineering* has been privileged to look in on an ambitious electric racecar project that on paper – and on the strength of the test mule's performance – looks to have genuine potential to mix it with the internal combustion engines.

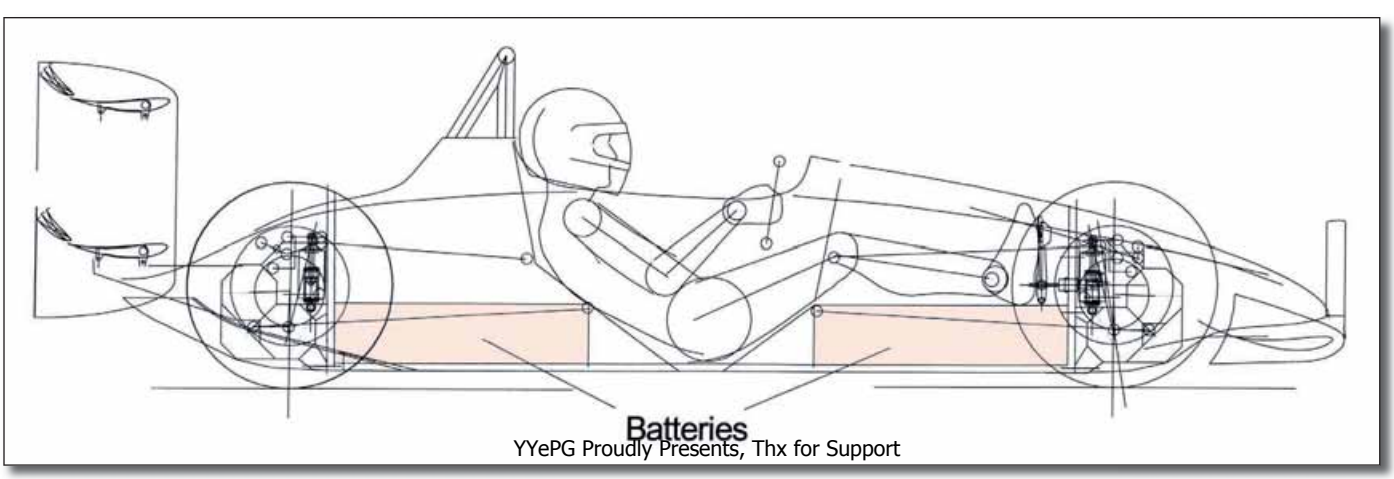
There are already various forms of electric-powered motorsport. Electric drag racing in the USA is administered and run by the National Electric Drag Racing Association, with classes and 'voltage divisions' (www.nedra.com). 'Current Eliminator' holds the record for the fastest standing quarter mile at 8.801secs (terminal speed 137.65mph). And two-wheeled 'Kill-a-cycle' (electric puns seem unavoidable) ran the quarter mile in 9.450secs, but hit a terminal speed of 152.07mph. So performance is respectable, but well short of conventionally powered vehicles.

At the other end of the scale is Formula Lightning. This is a 'spec series' for engineering colleges in the USA who obtain identical rolling chassis, around which students have to design and build an electric drive system. Races of 15 to 30 minutes duration, run at well-known racing venues and events, and speeds over 140mph are attained. But the cars weigh around 2750lb (1257kg), of which the battery pack alone weighs 1200lb (545kg), and power outputs are up to around 150kW (equivalent to 201bhp). So weight is high and power is modest. Furthermore, longer duration races require pit stops in which the 1200lb lead-acid battery packs are replaced in around 30 seconds. This may be physically impressive, but is less so in terms of what it says about energy density – that after such a short duration and with modest power output, battery replacement is required. Consider too that

> **"PERFECT STARTS ARE POSSIBLE EVERY TIME"**

Right: Martin Ogilvie demonstrates 'WISPER' – Westfield In Structural Plastics Electrical Roadster

Below: layout of the planned 4WD electrically powered hillclimb single seater (M. Ogilvie)



battery *charging* takes considerably longer than battery replacement, and compare that with a typical liquid fuel refuelling time. The level of technology means the power sources are just not comparable at present in this type of application.

However, one man is convinced he can make a competitive, high performance, electric racecar that can compete on the conventionally fuelled stage, and he has chosen a category traditionally free of technical restrictions in which to stake his claim – British Speed Hillclimbing. That man is Martin Ogilvie, former Team Lotus chief designer turned freelance who is responsible for (probably) the world's lightest hillclimb car – the 208kg, 1100cc Suzuki-powered PCD Saxon (profiled in V11N7) that went on to become a class record holder. Ogilvie's next hillclimber, the Arrows Hart V10-powered GWR Predator (profiled in V15N11), narrowly missed an outright win in the final event of its 2005 debut season.

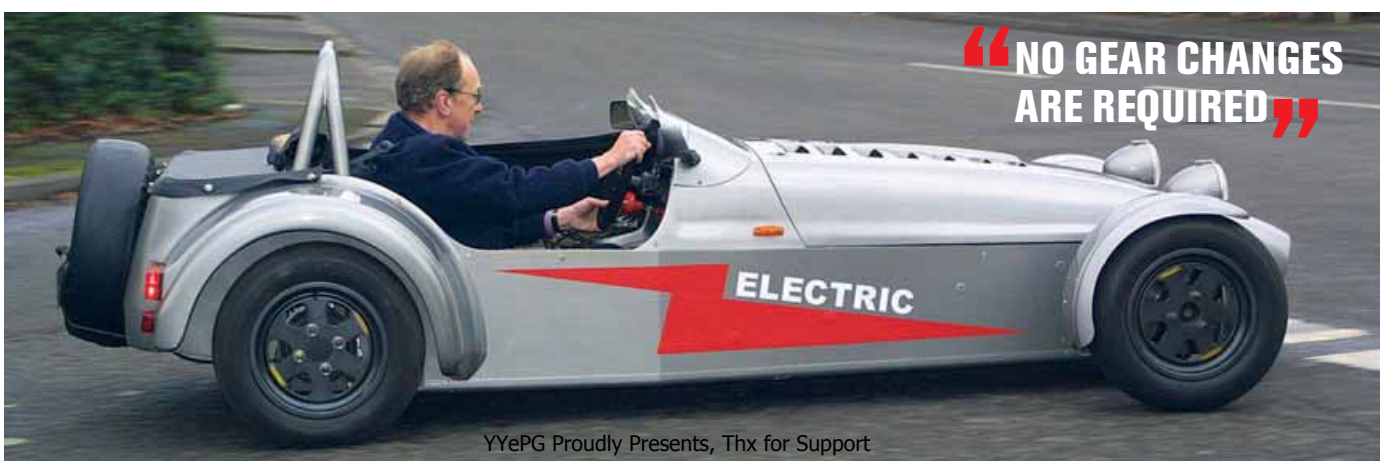
Achievable target?

The Saxon's power-to-weight ratio approached 1000bhp/tonne and the Predator's was probably in excess of 1500bhp/tonne. Could electric power really be competitive among such machinery? Martin Ogilvie's stated aim, subject to acceptance from within the sport and construction to as yet unwritten safety regulations, is to produce a car capable of scoring in British Hillclimb Championship Top 12 Run Offs. These are the climactic, single-run, points scoring shootouts, two of which take place at every championship event, involving the fastest 12 registered contenders from the qualifying class runs. The front runners generally use single seaters weighing in the region of 450kg, usually powered by V6 or V8 engines of 2.5 to 4.0 litres capacity and producing between 500 and 650bhp. However, some of the lighter, smaller-engined cars of 2.0 litres, or even 1.6 litres capacity, are capable of qualifying and scoring in Top 12 Run Offs, especially on the slower courses where sure-footedness partially offsets power deficit over the 25 to 50 seconds run durations.

Those 1.6-litre cars may generate 250bhp at best and weigh around 300kg. Ogilvie anticipates that an achievable target is a four-wheel-drive, battery-powered, single seater producing 200kW (approximately 268bhp) and weighing 300kg. 240kW (322bhp) may be available in due course.

Half of the 20 batteries are located in the former engine bay, the other half beneath the passenger space

So on this simple comparative basis, the sums stack up positively – the car should be competitive with and, with the right driver, capable of beating the best 1600cc cars. It should therefore be able to score British Hillclimb →



Championship points. But such a comparison is too simplistic, as is evident when you look at the torque output delivered by electric motors, one of several advantages found with electric power.

On the plus side

Evaluating the pluses and minuses of electric power technology (pun intended) in the specific discipline of speed hillclimbing, a number of very positive benefits become apparent. Startline acceleration can be very consistent – the first 64ft of events is timed for interest, 2.0 seconds equal to 1g acceleration – and significant gains or losses can be made in this first part of a run. With electronic, programmable controllers feeding power to the motors, perfect standing starts are possible every time (and just ponder the other vehicle dynamics possibilities that programmable control of individual motors could offer).

Then, no gear changes are required. Formula Lightning cars utilise multi-speed transaxles in order to accelerate their substantial mass up to quite high racing speeds. A lightweight car powered by electric motors that can run to 8000rpm and which develop maximum (prodigious) torque at zero rpm, does not need multiple gears on tracks where maximum speeds are not all that high.

That torque 'curve' itself is highly significant, especially compared to the low torque, high-revving motorbike engines that propel the aforementioned 1600cc racecars. In essence, depending on the type being used, electric motors produce maximum torque at zero rpm and this remains fairly constant, tailing off at high rpm. Internal combustion engines produce peak torque at medium to high rpm levels, and have a relatively narrow range over which substantial, useable torque is developed – another reason why gearing is required on conventional cars. As such, performance is delivered in a completely different way by electric motors, so comparing power-to-weight ratios doesn't enable sensible predictions of relative performance.

Above: twin controllers at the front look after the pair of fan-cooled front motors. Driveshaft to the driver's side front wheel is also visible

Right: some of the batteries revealed in situ M. Ogilvie

The transmission layout envisaged for the single-seater application, and which is currently being proven in Ogilvie's test car, is four-wheel drive. Previous manifestations of mechanical 4WD have appeared down the years in hillclimbing, and have demonstrated the expected traction gains in slippery conditions. However, inherent weight penalties have usually compromised dry weather performance and the sport has not yet seen a consistently and lastingly competitive 4WD proposition. In Ogilvie's electric application, the mass of the motors and 'transmission' is actually quite small, and the gains in tractive capability – and indeed weight distribution – ought to become very evident.

> "ELECTRIC MOTORS PRODUCE MAXIMUM TORQUE AT ZERO RPM"

Ogilvie also maintains that build costs and operating costs will be, relative to conventionally powered outfits, pretty modest, and also points out the local environmental benefits. There will be no smelly emissions and there will be no noise. Die-hard purists may baulk at these points, but surely it would be folly to not embrace these aspects and encourage the development of this 'neighbour friendly' motorsport technology? Of course the generation of the electric power used to charge the batteries might not be as

The speedometer and tachometer may be familiar, but the rest of the dash is filled with unique switchgear

Above: the front motor pack resides ahead of the batteries, and drives out to the front wheels

Left: the ingenious motor packs combine a pair of motors which each drive one of the two output couplings via reduction gears
(M. Ogilvie)

environmentally friendly as it could be, but getting that right is the responsibility of national governments. That said, the website of the Electric Auto Association (www.eaaev.org) maintains that electric vehicles can be up to 97 per cent cleaner than comparable petrol powered cars, including the pollution produced during power generation (although the figure depends on the mix of energy sources used for that power generation). These are sobering thoughts.

WISPER development

Ogilvie's composite Westfield (he designed the carbon version of that marque's well known road and track car) is known as the WISP (Westfield In Structural Plastics), and this very appropriately has become WISPER, the ER suffix standing for Electric Roadster. With this car he has been testing and developing motors, controllers and drivetrain for over two years now, self funding virtually the entire project to date. While researching electric motors Ogilvie came across the Stonehouse, Gloucestershire-based company Gravitron, and began discussions with technical director Morgan Nicholas. Gravitron's business portfolio covers a range of electric-powered vehicles including electric racing karts, and its expertise encompasses battery technology, motors, controllers, data acquisition and much else that was relevant to Ogilvie's project. The ideal technical partner had been found.

The WISPER is 4WD now but initially was two-wheel drive, while preliminary data on motors, controllers and batteries was gathered. It seems that available data from battery and motor manufacturers did not cater for the kind of

> **"'NEIGHBOUR FRIENDLY' MOTORSPORT TECHNOLOGY"**

'overdriving' scenario that was being developed on the WISPER, so it was a case of having to generate relevant knowledge. Various battery types were tried and tested, and the ingenious motor packs were developed.

The batteries are presently lead-acid items from Hawker, dimensionally similar to the well-known Varley Red Top 30, and weighing approximately 9kg apiece. Twenty of these amount to 200kg, including high current capacity cabling. The motor packs combine a pair of series wound DC motors back-to-back in machined aluminium end casings. These incorporate a pair of reduction gears on each end to step down the drive from the motors and transfer it at appropriate wheel rpm to the output couplings, which are on the same axle line, so to speak, on each end. One motor drives one coupling, so each pack drives two wheels, and there is a motor pack at each end of the car. As might be expected of one who worked at Team Lotus during the Colin Chapman era, Ogilvie has designed the motor casings to fulfil a further task – they can be stressed to carry suspension mountings.

Presently the WISPER weighs around 550kg and its four fan-cooled DC motors, nominally rated at 12kW each, are pushed to output around 37.5kW apiece, producing a total of 150kW peak power (201bhp), enough to endow sub-5 second 0 to 60mph acceleration and top speed approaching 100mph. Your writer was privileged to sample the car and can report that the acceleration was not only brisk, with no wheelspin (or noise...) whatsoever, but also *absolutely* seamless, given that no gear changing is required. The ➔

Specification

	'WISPER' 4WD	'WISPER+' 4WD	Single seater 4WD
Weight	550kg	450kg	300kg
Power	150kW	150kW	200+kW
Max speed	95mph	95mph	120mph
0-60mph	4.9secs	4.1secs	2.2secs
64 foot time	2.2secs	2.0secs	1.5secs
Batteries	20 x Pb-A	10 x Pb-A + 'supercapacitors'	Li ion + 'supercapacitors'
Battery voltage	60V	60V	60V or 80V
Battery current	0 – 900A	0 – 900A	0 – 900A/700A
Motors	4 x DC, 12kW nominal, overdriven to 37.5kW peak output	4 x DC, 12kW nominal, overdriven to 37.5kW peak output	4 x AC, 200+kW peak
Transmission	4WD, single reduction gear per motor	4WD, single reduction gear per motor	4WD, single reduction gear per motor, active motor control

THE BASICS OF BATTERY POWER

A glimpse at the basics of electric vehicles helps us understand the development routes in this project. The principle is simple – batteries supply the energy and electric motors drive the wheels, either directly or indirectly. In between the batteries and the motor(s), a controller (or controllers) matches supply to demand. In some applications a single motor may connect to a conventional gearbox and to a final drive unit for front or rear-wheel drive. Others may have two or four motors directly driving the wheels, perhaps through reduction gears.

Motors may either be DC or AC. DC motors offer simpler installations, but various types are available, which offer different characteristics.

Typically, a 'series wound' DC motor is used, which offers very high torque over a short duty cycle – a car's starter motor is a good example of this type. It is also possible to 'overdrive' such motors for a short time to attain several times their rated power output. AC motors offer somewhat different characteristics and some potential advantages, as discussed in the main text.

The job of the controller(s) is to take power from the batteries and supply it to the motor(s). The throttle pedal connects to one or more rotary potentiometers that provide a signal to the controller(s) to enable it (them) to determine how much power to deliver to the motor(s). Essentially, the controller is a switch that pulses at high frequency, so that at full throttle the controller supplies all of the of the voltage available to the motor(s). But, say, at 50 per cent throttle it 'chops' the voltage so that 50 per cent power is delivered. The controller's electronics enable fully variable switching so that anywhere from zero to 100 per cent of maximum voltage may be delivered, as required.

Batteries tend to be the well-known high capacity lead-acid (Pb-A) type which, at a nominal 12V apiece, can require a number of batteries to be carried to achieve the desired voltage and capacity. Naturally this represents considerable mass.

Other battery types in use include nickel-metal hydride (NiMh) and lithium (Li) ion. Choice is down to the capacity required, the discharge rate required, weight and cost. For example, suitable Pb-A batteries are internally more robust than regular automotive engine cranking batteries, are relatively cheap and offer rapid discharge rates (for high power generation) thanks to low internal resistance, but they are heavy. Li-ion batteries on the other hand were designed for low power output over long durations, but are lighter and more expensive, although the latest Li-ion battery technology enables fast discharge rates coupled to low weight, which might be an attractive proposition for motorsport use.

The internal resistance of motors and cables is a source of so-called 'I2R' efficiency losses, where **I = current and R = resistance**. From school physics we recall that **total efficiency = power input (watts = volts × amps) – losses (I2R)**.

This tells us that, even if the internal resistance of a motor is low, or the resistance of the cables is low, the very high currents (approaching 1000 amps) involved cause substantial power losses. The use of low resistance cabling is therefore crucial.

compact, lightweight and highly efficient controllers have been developed and programmed by Gravitron. They 'chop' the power at 15kHz in response to the signals from four separate potentiometers actuated by the 'throttle' pedal (better control was apparently found with separate throttle potentiometers).

Morgan Nicholas remarked that 'Martin's application is unique in that he wants the maximum acceleration available in what amounts to fourth gear! The lack of wheelspin is partly down to the [tall] gearing but also the programming of the controllers. There are also individual wheel speed sensors that will allow full traction control. And it will also be possible to get the four controllers to talk to each other and take in other sensor data, as well as wheel speeds, so we can actively distribute power around the car.' To which Martin Ogilvie added, 'the unique properties of electric motors and electronic control mean that almost limitless torque split variations to the four wheels can be achieved to suit any cornering and handling situation. Even lifting a wheel does not dissipate power since zero load draws zero current. Steering angle, spring deflection, g-loadings and speed inputs can all be programmed in to actively distribute power around the car, a task that requires complex hydraulic and electro-mechanical systems with traditional 'active torque split'.

> "INDIVIDUAL WHEEL SPEED SENSORS WILL ALLOW FULL TRACTION CONTROL"

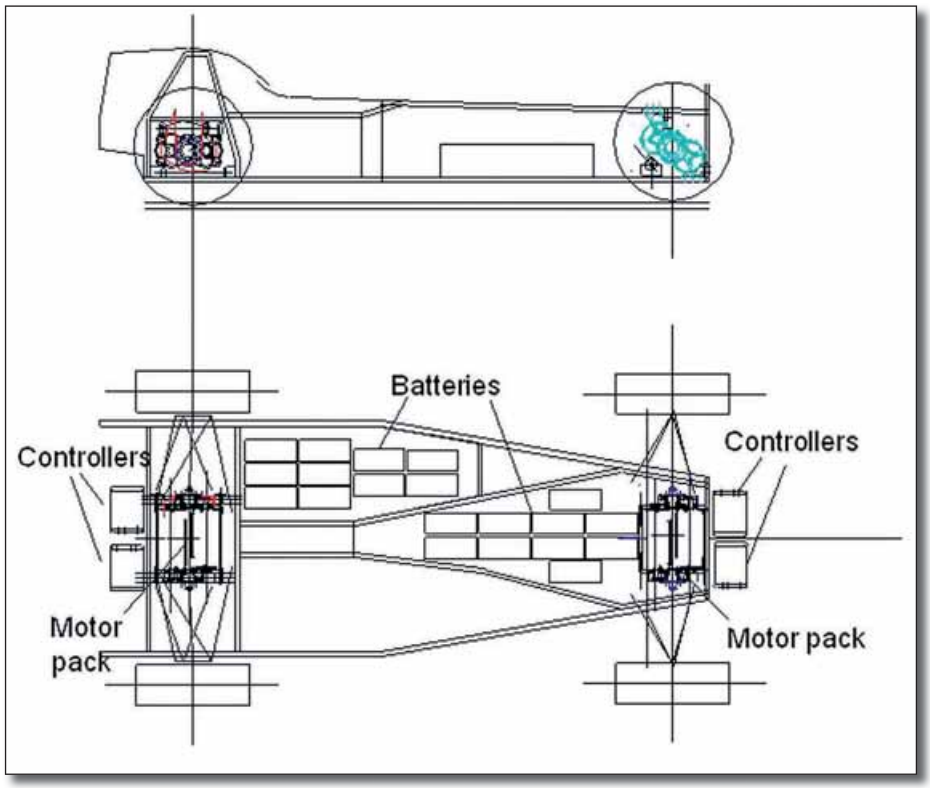
Martin Ogilvie and Morgan at the latter's Gravitron workshops in Stonehouse, Gloucestershire

Development of a racecar

But, for all its impressive performance, the WISPER is just a test mule. The leap to 200+kW and 300kg requires development on the motor and 'fuel source' fronts, as well as the building of a lightweight, composite racecar chassis. A lightweight road-going sportscar option also exists but it is clear where Ogilvie's preference lies. With his track record in making featherweight racecars, the most desirable and logical development route is the single seater option. So given the proven ability to make the requisite chassis and mechanical components, there are three key powertrain development steps to less weight, more power, and more controllability.

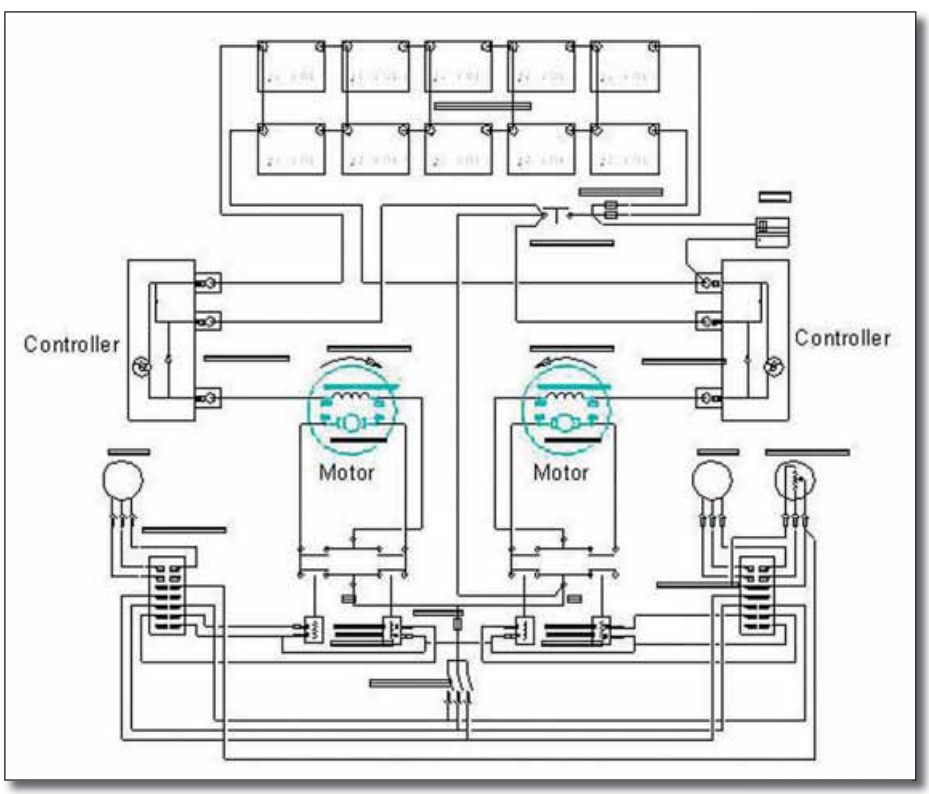
The first weight reduction step will probably be trialled on the WISPER, and involves replacing half the batteries with 'supercapacitors'. For →

those unfamiliar with these components, 'supercaps' store their electrical energy as a static charge, like conventional low power capacitors, but have capacitance values in the range 10 to 200 Farads at 100 volts, compared to 20 micro Farads to 2 Farads at 5.5 to 6.3 volts. Supercaps have pros and cons, but the beneficial features here include high power and high power density (ie low weight for the power stored), very fast charge and discharge rates thanks to low internal resistance, and no internal electrochemical reaction, which gives a very long cycle life. As such, supercaps will be able to provide the requisite short bursts of high power that this project requires, as well as saving considerable weight and not need replacing for years. Ogilvie has estimated a reduction of 100kg for the same power output in the 'WISPER+', which should see 0-60mph times down to near four seconds. And with their rapid charge rates, supercaps also offer regenerative braking potential. At writing time, Gravitron was negotiating for a set of supercaps to test.



Above: schematic layout of the WISPER (M. Ogilvie)

Below: electrical systems schematic of the WISPER (M. Ogilvie)

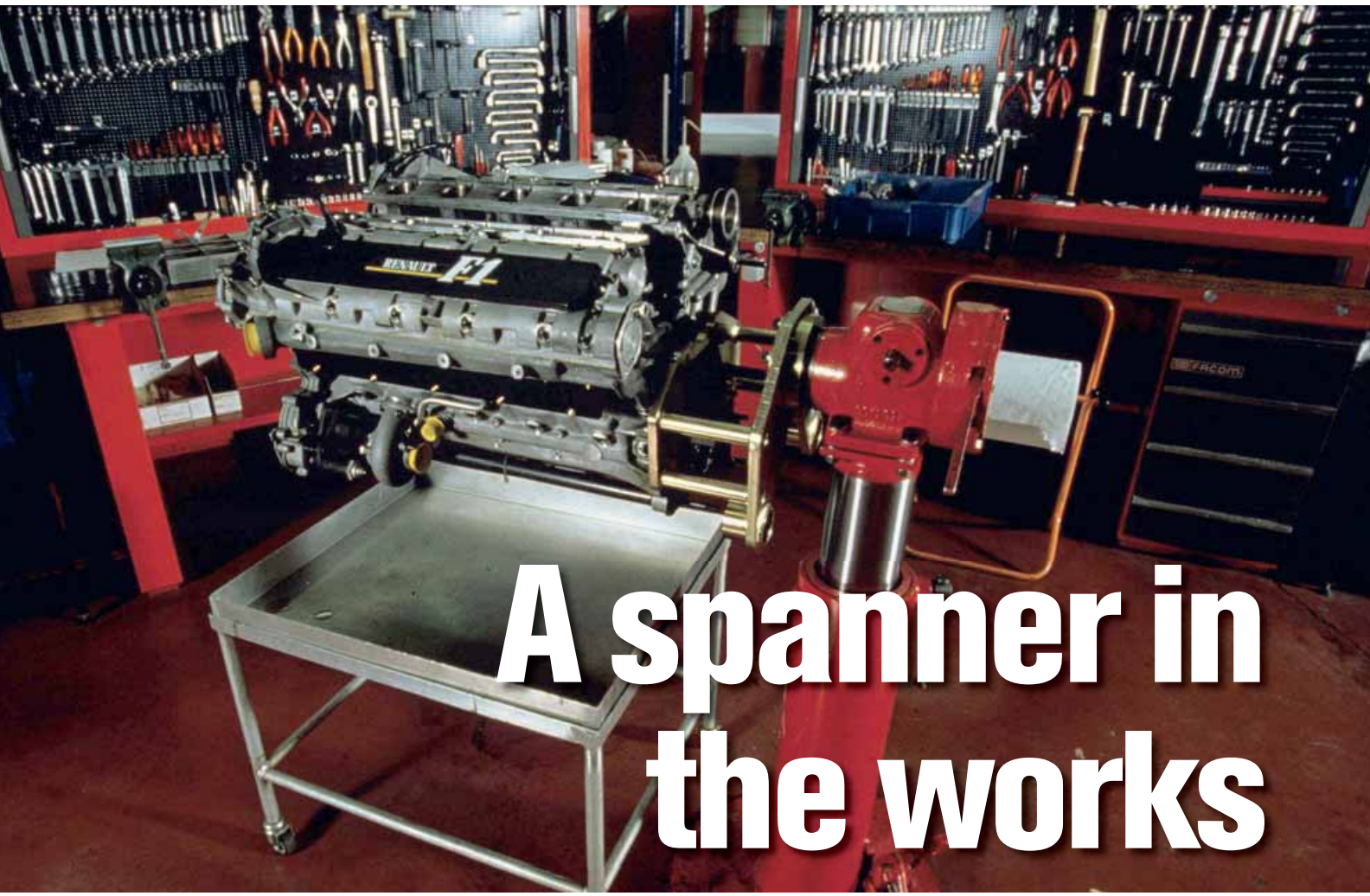


> **"THE FINAL PHASE OF THE PLAN IS TO CONVERT TO AC MOTORS"**

Shedding further weight will necessitate a new type of battery. As mentioned in the sidebar, Li-ion batteries offer weight savings, and the latest lithium polymer batteries are apparently capable of the high discharge rates required, while still offering significantly lower mass than Pb-A batteries. Indeed, it has been reported that Li-ion batteries have powered cars in the electric classes at the Pikes Peak hillclimb. Ogilvie has estimated that a further 50kg could be shed using these batteries, although initial cost is higher. Batteries need sourcing and testing to derive the requisite data for short 30 to 40 second bursts.

The final phase of the plan is to convert to AC motors. Control of AC motors is apparently better, offering high torque at start up and fully active torque control throughout a motor's range. And with a flatter torque spread available – there isn't the same drop off in torque at higher rpm that arises with DC motors, giving more 'power under the curve.' Because of better efficiency, especially if run at higher voltage, more absolute power should also be available. Further, should it prove necessary, it is possible to utilise liquid cooling. This motor technology is basically available off the shelf, although Morgan Nicholas anticipates that modifications to extract high power may be required, and Martin Ogilvie will certainly be keen to remove any surplus weight.

So the requisite technology either awaits or, with a relatively modest amount of project-specific development, could easily be applied. And the numbers and characteristics already available indicate the likelihood of success is very high. Ogilvie and Gravitron have taken the development of the test mule as far as they can without further funding. But, as Martin Ogilvie points out, 'this is an opportunity for some highly innovative media exposure for so-called 'green power' and it is intended to bring other backers on board to enable the final, cost-effective vehicle to be realised within the next 12 months.' *Racecar Engineering* hopes to be able to report soon on the 'ultimate electric racecar' in the carbon, so to speak...



A spanner in the works

Time is money, and time spent searching for mislaid tools is wasted money, but that looks set to change forever

Words | Ian Wagstaff

It is becoming increasingly common that the aerospace industry learns from the automotive industry or motorsport world, and vice versa. Coplan Ltd's new, patented ITC (Intelligent Tool Control) is a an example of this phenomenon. A particularly simple answer to an important question it also benefits from some of the skills used to develop the latest in automotive transmissions.

Control of where tools are, or should be, in the tool box is a significant matter – be it in the workshop or out at the racetrack or in a rally service area. It is even more crucial in the aerospace industry. Coplan's sales director, Terry Fryer, recalls being shown two F15 fighters at the Tindall air force base in Florida. 'Both were in pieces looking for lost tools. The cost attributed to finding those tools was astronomical.' The problem of FOD (foreign object damage) is obviously taken very seriously in the aviation sector and this was costing the US tax payer a lot of money. An electronic tracking system would, says Fryer, solve a huge proportion of the problems associated with mislaid tools and tool accountability.

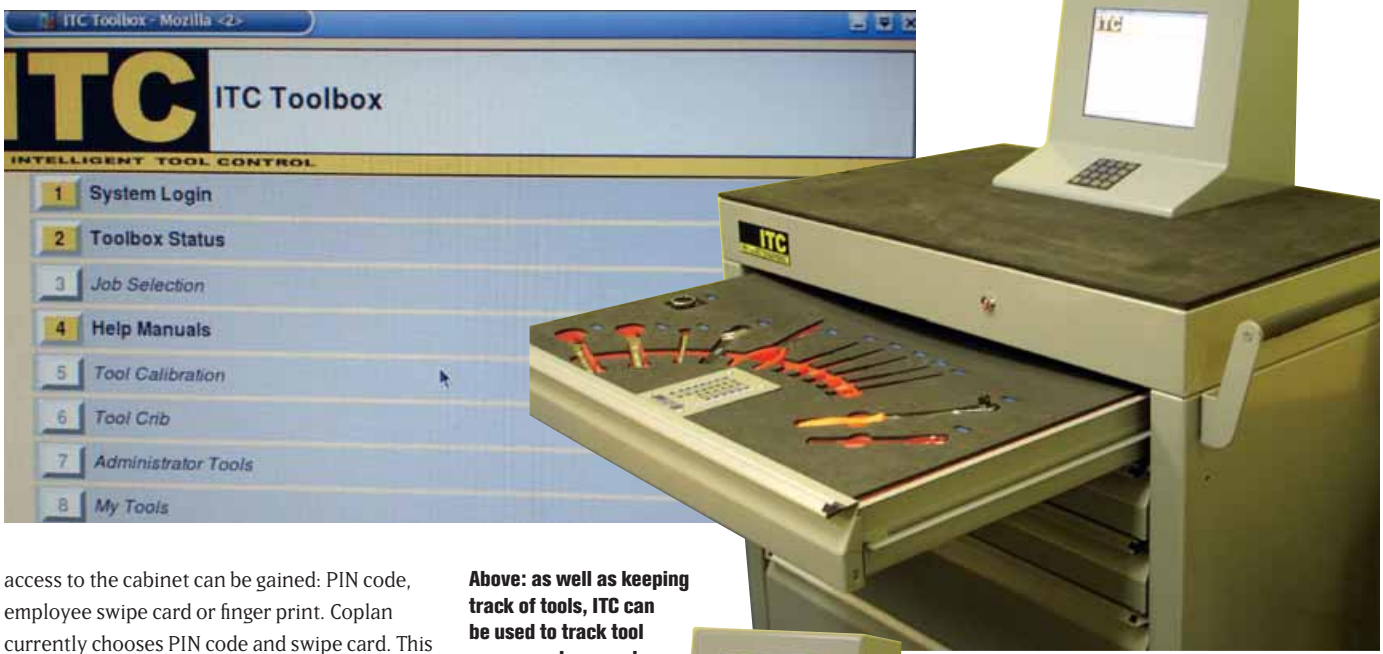
One solution to the problem could be to use an RF tagging system. However, this would not be ideal as a tag would have to be manufactured into every tool and, as Fryer asks, how do you tag a 1.5mm Allen key? Coplan's answer has been ITC, a non-obtrusive system whereby every tool from a PIN locked cabinet can be computer tracked and logged at all times, without the use of RF tags or bar codes.

> "SIGNIFICANT ADVANTAGES FROM AN INVENTORY CONTROL APPROACH"
>
> YYePG Pseudo Presets: The for Support

The motorsport connection

Currently, the USAF uses shadow foam in its tool boxes because nobody has previously been able to come up with a reliable electronic tracking system. 'This,' says Fryer, 'is where ITC steps into the arena.' Two neighbouring UK companies, Coplan and Zeroshift – the firm currently developing the seamless shift gearbox featured in Racecar Engineering V15N6 – have brought together the two disciplines of tool control foam and electronics to develop this system.

The concept starts with a standard tool cabinet (Coplan sources tailor-made cabinets from a UK supplier). There are a number of ways in which



Above: as well as keeping track of tools, ITC can be used to track tool usage, replacement or calibration needs and to assist in tool selection

access to the cabinet can be gained: PIN code, employee swipe card or finger print. Coplan currently chooses PIN code and swipe card. This can be further extended to controlling exactly which drawers can be opened. This is probably more important in the aerospace sector where, for example, a junior airman might only have limited access to the 'box as there may be diagnostic equipment in the 'box that he is not trained to use.

As the technician takes or replaces the required tools, the information is logged via wired LAN, wireless means to a custom supplied laptop or on board data storage. Originally the system featured magnetic sensors but Fryer points to the fact that plastic hand tools place an obvious limitation on such sensors. The sensors used in ITC are instead optical, looking for a light rather than a magnetic signature. Two optic devices, one of them an LED and the other a phototransistor, are used. The LED emits a light which, when reflected onto the phototransistor side of the circuit, will then emit a current within the circuitry which is detected as information.

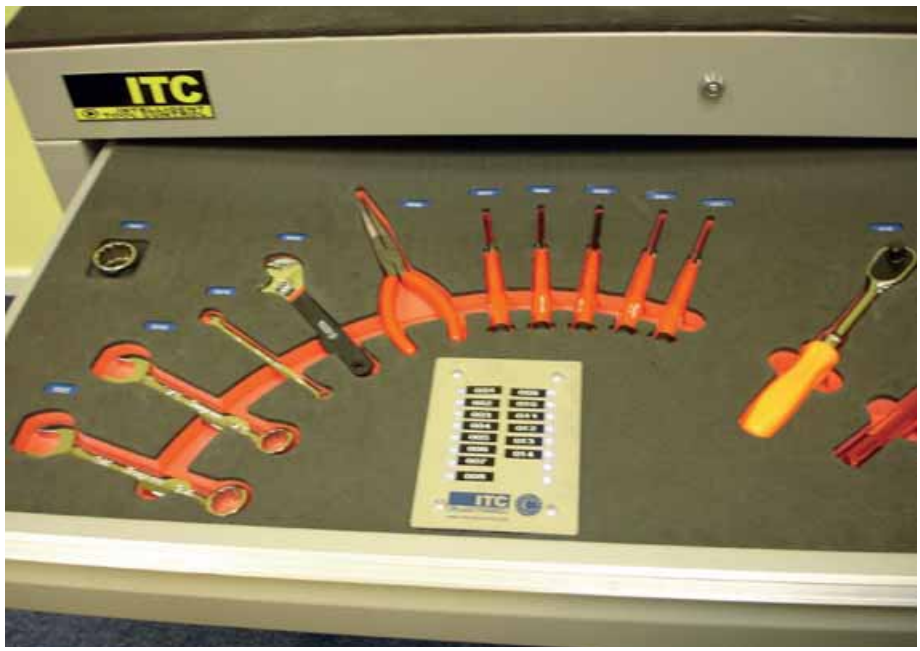
The electronics, 'the bright bit', as Fryer puts it, are supplied by Zeroshift. Coplan did try two suppliers before settling on its Milton Keynes neighbour, despite the fact that Roy King is a director of both companies. King, who started Coplan with his father about 18 years ago, gave Zeroshift the seed corn money to get inventor Bill Martin's innovative idea off the ground some three years back. The skill set used by →

"ITC CAN TRACK WHEN AND WHICH TOOLS NEED CALIBRATING"

Zeroshift to control its transmission system lends itself nicely to ITC. 'This is water off a duck's back to these guys,' says Fryer.

Victor ILunga, Zeroshift's controls manager, explains: 'There is a microprocessor in both the ITC and Zeroshift technology, but that is where the similarity ends. In the gearboxes we are controlling moving parts, whereas in ITC we are not. We are detecting the presence or the absence of a tool in ITC, which is completely different to what we are doing in the gearboxes.' However, the expertise gained in working in the Zeroshift technology 'puts us in a better position to do things like ITC.

'It is about having the skills to develop something that is fit for purpose and is specifically designed for volume production,' says Bill Martin. 'Both in Zeroshift technology, as well as ITC, we have sensors, which are sending information back to the microprocessors. Then we make decisions at the processor level, as to what the application of that information should be.'



Optican sensors were chosen for the tracking devices while PIN codes and swipe cards control access

The motorsport application

Applying ITC to the motorsport market might offer significant advantages when considered from an inventory control approach. For example, how useful would it be to know how long a particular component has been used in anger? If the part is controlled within an ITC system and this information is then linked to the vehicle's telemetry system, then you will know how long it has been in use.

Coplan is more than just the company that machines the foam. One of the company's strengths is that it is said to be good at supplying a finished solution. 'We need to turn up with a truck, wheel this off and plug it in. Customers do not want to have to buy the tool box, the tool control foam and the tools from separate suppliers,' says Fryer.

ITC's obvious benefit is in that it knows just where each tool is and how long it has been out for, information that can be useful to a supervisor carrying out a quick tool box status check. This can be used to ensure that a technician has not left the premises before returning all the tools they have been using. One requirement has been a user-friendly colour LED panel, signalling status and prompting necessary actions to and from the user. For instance, if an LED glows red there is obviously a problem, if it glows amber there is an action needed from the user. The 'tool missing' LED glowing red must trigger a search immediately, and management are made aware. Green obviously means that all the tools are in place. A lost tool is a serious issue. If a technician goes home having not replaced a tool they will be in serious trouble, so procedures need to be in place to prevent this happening. In the bedlam of a rally servicing area it will now be possible to see what is missing at a glance without losing time.

> "A MENU COULD BE SET FOR JOB SELECTION AND FOR HELP MANUALS"

However, there is more to ITC than the simple location of a tool. Another major concern is the tracking of tools that need to be taught, such as torque wrenches requiring calibration. ITC can track when and which tools need calibrating.

Other kinds of information can be accessed, including vendor, quality and usage information. For example, a kit of tools may contain 140 pieces. After a period of 12 months the kit can be interrogated to find out exactly how many have been used. It could also bring up the fact that a particular item is constantly failing. Examination of its usage could identify the reason why. 'You only really need to know the information when something has gone wrong,' says Fryer. However, a menu could also be set on the computer for job selection and for help manuals.

'The military are the people who drive this kind of technology,' says Fryer, and this is backed up by Coplan already having strong interest in the ITC product from North America's four largest defence companies — Boeing, Lockheed Martin, Northolt Grumman and the USAF. It is looking to make the first deliveries of the ITC system this spring. The company says the product will be rugged so that it can be used in all weather conditions and will be flexible in that it can be integrated into any database or tool management system. No tool need ever be lost again. RE

Boxes of tricks

When Coplan first invested in Zeroshift, the gearbox company was focused on a simple mechanical shift system. However, in developing the concept, it has acquired a range of skills in electronics and control systems. So, when Coplan wanted to develop it's Intelligent Tool Control it was pleased to find the necessary capability within its own group. This is not the only outlet Zeroshift is seeking for its broader abilities and expects outlets for its technologies.

Bill Martin of Zeroshift and Coplan's Roy King

C'est la Vee!

Formula Vees are often derided as being slow and ugly, but their continued popularity says otherwise. **Racecar** looks at the world's most prolific racing class

Words	Sam Collins; Mike Pye
Photos	Bill Bonow; Isadora Poggi

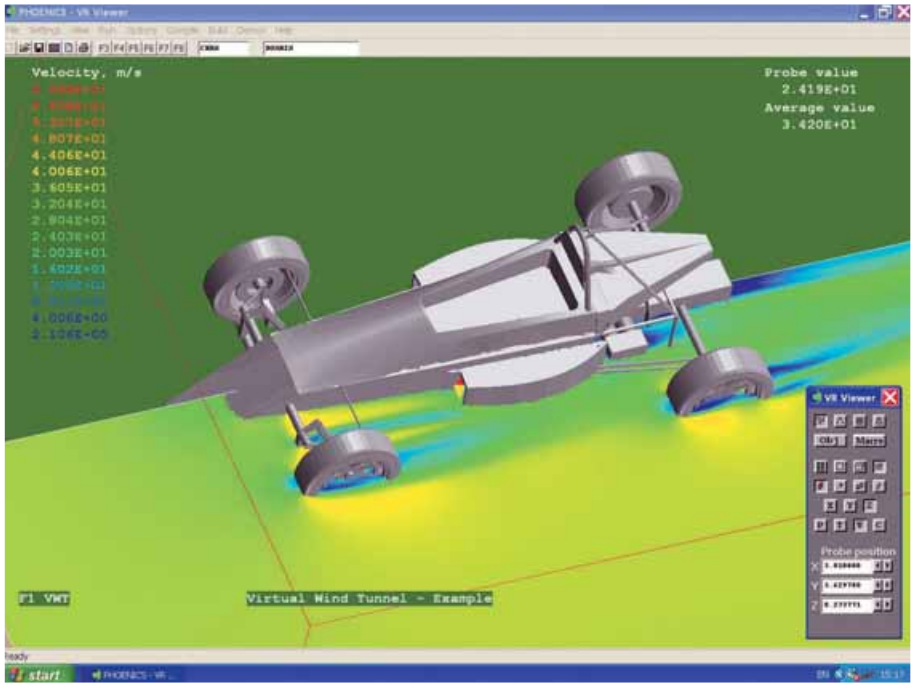
Many see Formula BMW as an innovative new racing series and the first rung on the proverbial ladder to grand prix racing. Introduced a few years ago, it consists of a number of national championships in various countries run to the same regulations. Once a year the top drivers from each championship meet somewhere and have a world final (last year it was held in Dubai). True, it's a great concept and has the potential to launch the careers of a few drivers, but it's certainly not a new idea.

Whilst the idea of single-seater racecars is hardly the first thing that jumps to mind when you mention the VW Beetle, the humble people's car's racing pedigree stretches back further than you might think. All the way back to 1959 in fact, and to a Florida-based businessman called Hubert Brundage. Brundage owned a hardware shop and was participating in sports car races with a car he'd built himself using mainly VW Beetle components. In 1952 he finished 11th at the Sebring 12 hours in his single seater 'special', which brought him to the attention of one Wil van de Kamp of Volkswagen AG. So impressed was the man from VW with Brundage's performance, he offered him a VW dealership, which went on to become Brundage Motors Inc – the distributor for Florida, Georgia and South Carolina, and later the well known Porsche dealership, Brumos, in the southern states of America. A visit in the early '60s to Italy brought him into contact with Enrico Nardi – the man behind the Nardi steering wheel brand. Nardi was also a racecar engineer and was familiar with the Volkswagen so Brundage commissioned him to build a VW based, single-seater racecar. This aluminium-bodied car was the first ever Formula Vee racer.

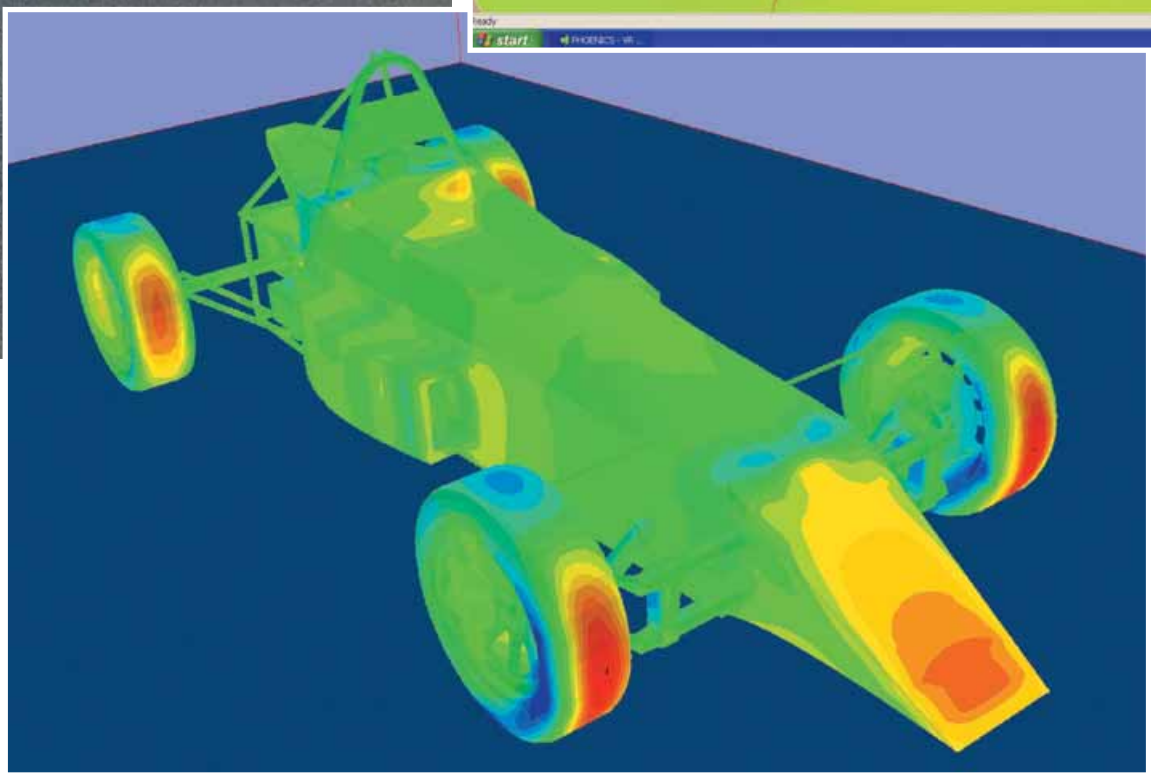
> **"POSSIBLY THE WORLD'S FIRST CONTROL FORMULA"**

The idea caught on and, by the early 1960s, other manufacturers saw the opportunity for a cheap, accessible racecar based on the proven

UK-spec Formula Vees are amongst the most developed in the world. Pictured here is the latest AHS and a re-worked GAC at Snetterton



CHAM



CHAM

Formula Vee is reliant on aerodynamics to gain an advantage but serious development work is rare. British firm CHAM did some work on a Sheane-shaped car which highlighted a few clear problem areas, such as the obvious flow separation just behind the nose

mechanics of the Beetle. The first to manufacture cars in numbers was Formcar (short for formula racing car) – a concern headed up by George Smith and Bill Duckworth and based in Orlando, Florida. The regulations at one point even stated that all cars must be Formcars built to an identical spec, making the series quite probably the world's first control formula, though that idea didn't last.

A second company, Beach, followed and, in 1963, the Formula Vee race series was officially recognised by the Sports Car Club of America.

While Beetles had been competing successfully in rallying, trials, autocross and circuit racing in the UK, Ireland and Europe since the early '50s, they were always handicapped on tarmac circuits by their high centre of gravity and swing axle rear suspension, but the tuning potential of both the engine and chassis was already well established. The answer to really unleashing the handling capability of the simple VW suspension design, however, lay in ridding the car of its ungainly bodyshell and moving all the weight much closer to ground level. And the only way to do this effectively was to scrap the VW floorpan as well, replacing it with a basic but rigid tube chassis, with coilover rear dampers and 'hairpin' trailing arms in place of the standard spring plates and a centralised driving and steering position. At around 375kg, even with a stock 1200cc Beetle engine, gearbox and drum brakes this made for a fun, fast and competitive racecar.

> "IT'S POPULAR BECAUSE IT'S CHEAP AND FUN"

Chassis design was effectively free and aerodynamics were restricted. The final paragraph in the 1963 regulations read, 'it is by no means intended that these specifications should provide a proving ground for engineering ingenuity and experimentation... Any interpretation of these specifications should be made within this spirit.' In short, this was to be a low cost, control formula for enthusiasts to compete upon equal terms. →

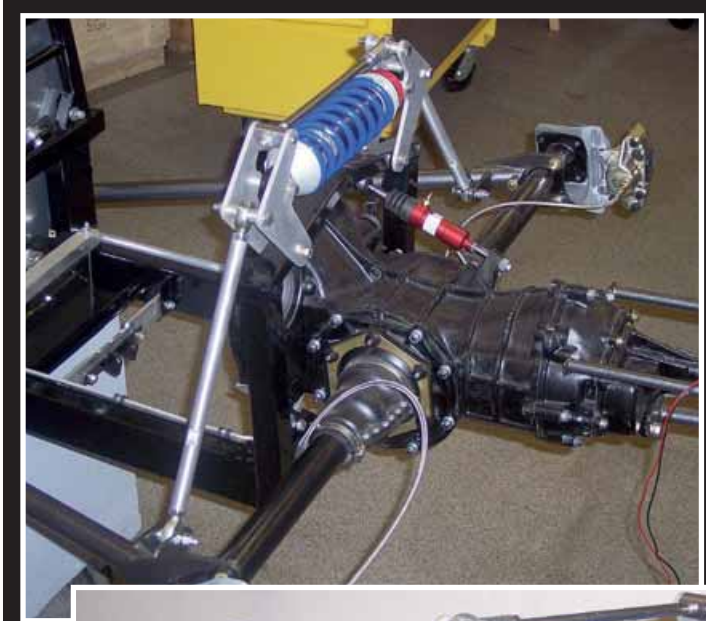
Formula Vee rear suspension

'Any suspension will work if you don't let it,' or so Colin Chapman is reputed to have said. In the case of Formula Vee it's a case of making the best of a bad job. At the front the parallel trailing arm geometry is reasonably benign, but the rear has vices that have caused decades of head scratching for Vee racers.

Its worst crime is a tendency to jack up. That is when the short swing axle starts to ride up over the contact patch lifting the rear of the car and pushing the outer wheel into extreme positive camber. All suspensions have a jacking element but the problems occur when it exceeds the vertical loading and the roll force. This usually happens under braking when weight is transferred to the front from the back allowing the rear end to rise, taking the roll centre up with it, increasing the jacking moment and reducing the roll moment. Volkswagen's rear suspension is particularly susceptible to this, particularly in a Formula Vee with its lower centre of gravity and it needs to be avoided at all costs if the handling is not to become demonic.

The simplest solution is a droop limiter (a device marketed since the '60s as a 'camber compensator') – a transverse spring that restrains the swing axles if they start to drop too far below horizontal. A more sophisticated alternative is a Z bar (introduced by VW on its 1500cc Beetle models in 1967), which works like an anti-roll bar in reverse, or as a roll promoter. When the outside wheel starts jacking, this device lifts the inside wheel transferring more weight to the outside suspension and resisting the jacking forces.

An even more ingenious solution is the system termed zero roll. This has become very popular among US Vee racers, being fitted to around 99 per cent of cars built in the last 25 years. As can be seen from the picture, connecting the tops of the two sides of the suspension is a droop limiter that can compress but not extend and, as such, prevents the driveshafts drooping, in turn preventing jacking. However, if fitted to conventional suspension, this zero droop configuration would experience rapid weight transfer on the track, resulting in savage and unpredictable handling. To prevent this, the system is designed without any roll stiffness at all, achieved by having a single spring damper unit connecting the two sides of the rear suspension as the only springing medium. It takes the squat and two-wheel bump loads but allows the chassis to roll freely, ensuring the rear wheels are always firmly planted on the road with equal loads. It is good for traction but the only thing that stops it falling over is the roll stiffness of the springs and anti-roll bars on the front end. Consequently, the car can be described as a tricycle as it corners on three wheels, the two rears and the outside front.



US-specification 'zero roll' cars use a clever rear suspension layout with a single, inboard, push-rod activated damper and a droop limiter

> **"ITS WORST CRIME IS A TENDENCY TO JACK UP"**

Curiously, chassis stiffness on these cars has become an irrelevance to the handling and, as can be seen, the rear part of the chassis is reduced to a pair of tubes with no attempt to create a triangulated structure. *CA-W*

Rise and fall

Soon the series was being replicated around the world – Finland, Canada, Australia, New Zealand, South Africa, South America, Britain and Ireland all ran Vee to roughly the same rules. And as a result of the series' early success, other manufacturers joined the fray, including Porsche with the Salzburg-built Austros, which went on to become class leaders in the field.

Eventually, Volkswagen's interest turned to water-cooled cars and it dropped its support of Formula Vee, which was increasingly seen as a slow, unreliable, oil-spilling anachronism of a racing series with ugly and outdated cars. Formula Ford was now the stepping stone to stardom and Vee grids were rapidly dwindling.

By the mid-1980s the global series had diversified, many switching to later engines from within the Beetle range, the most popular being the later 1192cc and 1584cc variants in various degrees of tune, though some had even turned to using water-cooled engines from VW's range. Grids in Britain at least were at a critical level, regularly attracting only around 12 entrants for each event. It was apparently the end of the road for these funny little racecars.

But last year the 750 Motor Club Formula Vee championship had more point scoring competitors in it than any other open-wheel series in Britain, and sometimes as many as 60 entries for one meeting. Ireland, South Africa and Australia are buoyant again, too, making Vee one of the world's biggest racing classes. So what happened? 'Scarab, a company founded by Stuart Rolt, started making cars again,' explains former British National Coal Board Museum curator and Vee stalwart Andy Storer. 'There had previously been no new cars on the market, so everyone had old nails. Myself and others bought these cars and started hiring them out.' The rental car scheme, which is still very much active with other teams, along with some subtle rule changes, slowly revitalised the series. A control tyre deal was struck with Dunlop in the UK, which has lasted 25 years, and gearboxes had to be standard VW units with fixed ratios.

> **"ONE OF THE LAST BASTIONS OF TECHNOLOGICAL FREE THINKING IN MOTORSPORT"**

Outside of the UK other series had also quietly kept going, changing their rules to the demands of the situation, whilst others fell by the wayside. The US and New Zealand series continued, too, but re-branded themselves as Formula First for marketing reasons.

Formula Vee world engine specifications

UK	1300cc air cooled VW, full race engines
Ireland	1600cc air cooled VW, mildly tuned
Australia	1200 and 1600cc air cooled VW
USA (Formula First)	1600cc air cooled VW
New Zealand (Formula First)	1200cc air cooled VW
South Africa	1400cc water cooled VW
Canada	1200cc air cooled VW

Formula Vee today

Today, Vee is growing rapidly again, with a large number of manufacturers producing cars and many of them renting out works cars to new competitors. 'It's popular because it's cheap and fun,' explains Alan Harding, owner of one of the biggest Vee teams in the world – AHS. 'All a driver needs to do is pay around £500 per meeting to a team for usage of a car. For that he gets everything: fuel, tyres, mechanics and engineers, the full works team. On top of the rental fee he has to pay the club his entry fee and that's it.'

Of course it's cheaper for a competitor to run his own car in true club racing style, and some do, but in this age of inflated land prices and long hours at work not everyone has the time, energy and know-how to do it. That doesn't stop people owning their own cars though and a number of teams offer owner/driver packages. 'For around £250 per event we transport the car from our factory to the track, run it for the driver, ➔

Under the skin of a Formula Vee, here a US-spec Evo chassis. Note the lack of triangulation. Unusually for Formula Vee, the US series uses slick tyres

maintain and look after it. We can even offer storage for it, at a cost,' reveals Harding.

Vee is also one of the last bastions of technological free thinking and engineering in motorsport. Beyond the control components pretty much anything goes within (and sometimes under) the weight limit. Most chassis are still steel spaceframes, but aluminium and even carbon monocoques have been experimented with – the latter being banned on safety grounds. Organisers could not determine whether the tubs were sound after accidents at a reasonable cost, and amateur maintenance was not easy.

This situation could be seen as a dark cloud over the long-term prosperity of the current glut of one-make racecars. What will happen to Formula BMW, for example, when the Munich marque decides to do something different? It certainly doesn't appear to have the potential to last as long as Vee has. And while Vee may seem like motorsport engineering's lost world, where prehistoric creations roam freely, remember that the VW Beetle – the world's best selling car – only officially went out of production a couple of years ago, so parts are still plentiful and cheap.

In Vee today there are countless manufacturers building cars, and each year more new cars come onto the market, many of them pushing the rules and discovering new avenues to research. What sets Vee aside is that much conventional racecar know-how does not apply – the Beetle-derived suspension and air-cooled engines see to that – and admittedly, a lot of the components used date back to 1930's Germany, but this has perhaps contributed to the series' longevity. All teams still strive to gain more power from the same old engine, an engine that has had as much tuning and development work done to it over its lifespan as probably any other engine in the world. The UK-spec 1300cc unit originally put out just 40bhp but now some of them are rumoured to be getting in excess of 100bhp, reliably. The flat four lends itself to modification, one only need look at the advertising in *Racecar's* sister title *VolksWorld* to realise that. One team is even reputed to have had its engine running at 11,500rpm on a dyno, though it was admitted 'it didn't do it much good.' Exact engine specifications and modifications are closely guarded secrets in the UK series, though the nature of the series means it's sometimes hard to hide developments.

Many Vee manufacturers employ high noses and a splitter to try and create an aerodynamic gain, though little wind tunnel research has been done to justify this. Pictured is a South African-built Lantis chassis

"MUCH CONVENTIONAL RACECAR KNOW-HOW DOES NOT APPLY"

One thing common in all the Vee series →

Formula Vee racing has always been close and action packed and British spectators regularly claim that Vees are the most entertaining formula of all to watch. Here, cars in the South African series battle for position. These cars do not use the Beetle's air-cooled engine, instead water-cooled, 1400cc VW units are fitted.

though is the battle against drag. Despite a ban on wings, everyone is trying to make their car pass through the air a little bit more efficiently than everyone else. Of course, with the sport's low-cost ethos, wind tunnel time is usually out of the question and those with good CFD knowledge are rare – nearly as rare as an accurate 3D model of a Vee. UK CFD firm CHAM did undertake some work on an Irish-bodied, UK-spec car in 2004 (see RE V14 N11) but the work was only to verify and promote its Phoenics virtual wind tunnel.

Pushing the boundaries

In the US series, competitors have been known to shroud their front beams to reduce the drag but there does not seem to be much real benefit to this. In the UK the Jenvey family racing team (of Jenvey Dynamics fame) tried to slip various floor shapes through that might act as diffusers, creating drag but also increasing grip. A rules clarification soon prevented that.

> "PARTS ARE STILL PLENTIFUL AND CHEAP"

Others have tried to use sheer power to overcome the drag, UK Vee engine builder, AHS, developing a 'side-draft' engine with modified cylinder heads. With the carburettors directly in the airflow around the rear of the car, it gave very good power but proved to be an aerodynamic disaster. This engine configuration was banned in 2004 on the grounds of cost. Though few of these 'developments' make it past the watchful eyes of the scrutineers, rules are still pushed, bent and sometimes even broken – the sign of a true racecar engineers' formula.

Formula Vee was reborn recently in the USA as Formula First, but is essentially the same series, employing 1 600cc air cooled VW engines. Interestingly, the cars are much shorter than their European counterparts

Most of the Vee series active around the world still use the venerable air cooled, flat four engine, with the notable exception of the South African cars, which instead use a 1400cc water cooled VW Polo engine. The air-cooled engines mean that thermal dissipation is important, as well as drag reduction. Jacer, an Australian constructor, recorded a peak oil temperature of 118degC in late 2005, which was significantly cooler than had been recorded in its previous models. Its new F2K6 model, whilst still reliant on ram air to cool the engine, has been designed with modern techniques to improve the flow around the car. A raised nose allows air to flow under the front beams and out either side of the cars' underside. It also has a 25 per cent reduction in frontal area over its predecessor the V2K.

Raised noses in Vee are becoming increasing popular, Jacer now being joined by a number of constructors from around the world, all using similar under-nose shapes. Most of them have slight dishing under the nosecone, or similar devices to separate the flow to each side of the car. However there is little clear evidence that this arrangement actually works, and the noses of many more conventional Vee manufacturers stay resolutely drooped. Whilst there is little definitive evidence either way, as with the beam fairings, anecdotal reports claim a faster straight-line speed for the high-nose cars.

> "QUITE POSSIBLY THE WORLD'S MOST PROLIFIC RACING CLASS"

And it's not just enthusiasts keeping the flag flying, Vee is good business, too. With more drivers than cars, companies struggle to meet demand, so it should be no surprise to hear that there are more active racecar constructors in Formula Vee than in any other class of motor racing, worldwide. In fact, the British Formula Vee championship is the nation's largest single-seater series; larger even the any of the Formula Ford series, and Vee is quite possibly the world's most prolific racing class.

With this sort of heritage, the other similar series have got some way to go to catch up. It will be interesting to see if Formula BMW will survive the test of time and continue on to become the new Formula Vee. RE

Storm is one of the newest manufacturers in Formula Vee, though currently only produces UK-spec cars. An Irish version is likely to follow soon. In the background, a Leastone and modified Sheane pursue the Storm

Be in control

Much more than just a way of soaking up the bumps, selecting the correct damper is crucial to optimising the performance of a racecar

Words	Dave Hancock
Photos	LAT

This month in Essentials we look at one of the more critical aspects of a racecar chassis and provide an overview of the science behind the complex art of damping. Understanding how you want dampers to perform is the first step toward making the right choice at buying time

Those of you with qualifications in vehicle dynamics will know there's a lot of complex mathematics involved in this area of racecar engineering, but equation crunching is not the focus of this series. Instead, we're concentrating on the 'need to know' information – for those of you disposed to be better race engineers.

Most physical systems are damped one way or other: a pendulum doesn't swing for ever, sound is damped in air and so on. Essentially, damping is a force generated in resistance to oscillation dependant on velocity. On a racecar, it is the motion of the suspension relative to the chassis that needs to be damped, and this is done by forcing fluid through an orifice or orifices – in other words, a damper. So far, so easy.

Now we need to think about the motions of a racecar. Racecars are frequently considered as a rigid chassis suspended with damped springs on four hubs (the so-called unsprung masses), all suspended on four tyres, each also having spring rates and damping. We have five 'bodies', each of which has three translational and three rotational degrees of freedom, giving a total of 30 degrees of freedom. With most of the mechanical components being non-linear, then even allowing for some of these degrees of freedom being fairly well constrained, we have some very complicated mathematics going on!

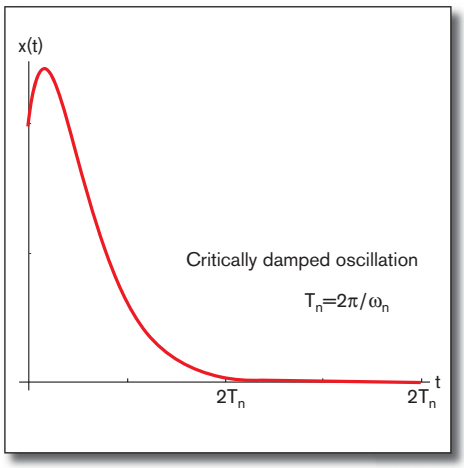
But we can begin to digest damping if we stick to manageable chunks and make some sweeping, if technically incorrect, simplifications.

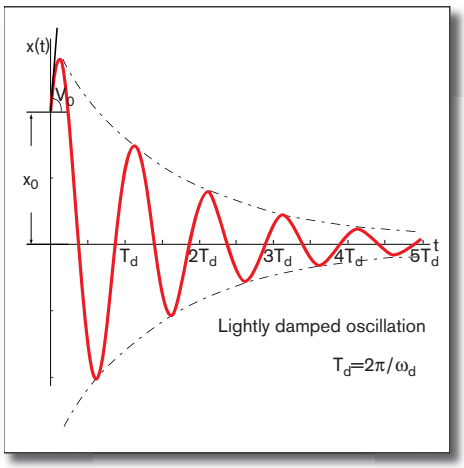
Now think about a single 'corner' model of a racecar and the vertical position of the chassis after the wheel has hit a bump. The corner will oscillate, at a frequency called the natural frequency (see sidebar). If there is friction or damping present, the amplitude will decrease gradually until it comes to rest. Reduce the damping and it will take longer to come to rest. Increase the damping sufficiently and a point will be reached where the chassis won't oscillate at all but instead settle straight back to its starting point. This condition is known as critical damping. Increase the damping further and the chassis will take, theoretically, forever to get back to its original position. Note that we are assuming solid tyres here!

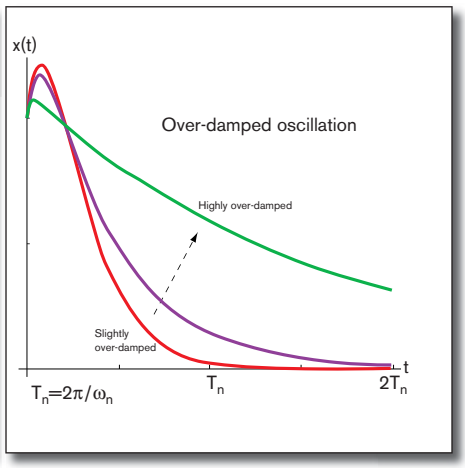
The equations for critical damping give us a mathematical way to calculate what is just enough damping to eliminate the oscillations and remove the energy from the system as fast as possible. Figures 1-3 show graphs that illustrate the oscillations that occur under different damping conditions. A good physics text book will give you the relevant equations.

The calculations for natural frequency and

"FORCES AT LOW VELOCITIES TEND TO BE DOMINATED BY FRICTION"







Figures 1, 2 and 3: representations of critically damped, lightly damped and over damped oscillation curves

Natural frequency

The natural frequency of a vehicle in heave, or ride frequency as it becomes in vehicle dynamics terms, is based mainly on the mass, spring rate and motion ratio. The ride frequency itself is an important number as it determines the speed of response to an input and can be used as a 'normalised' spring rate to allow comparison between different vehicles.

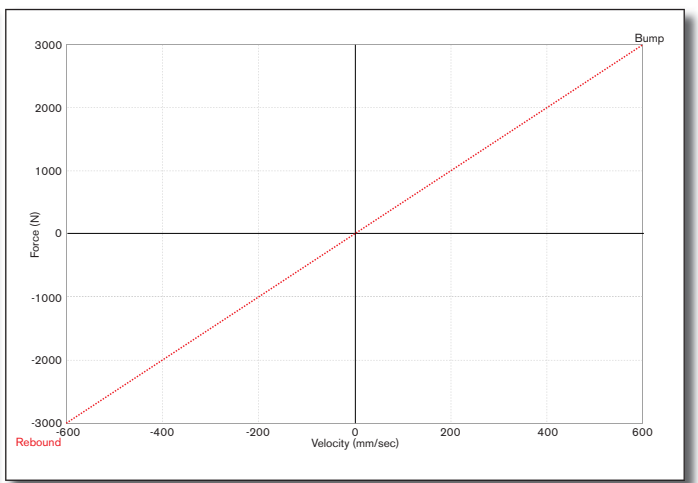


Fig 4: force/velocity graph with theoretical 'ideal' straight line plot

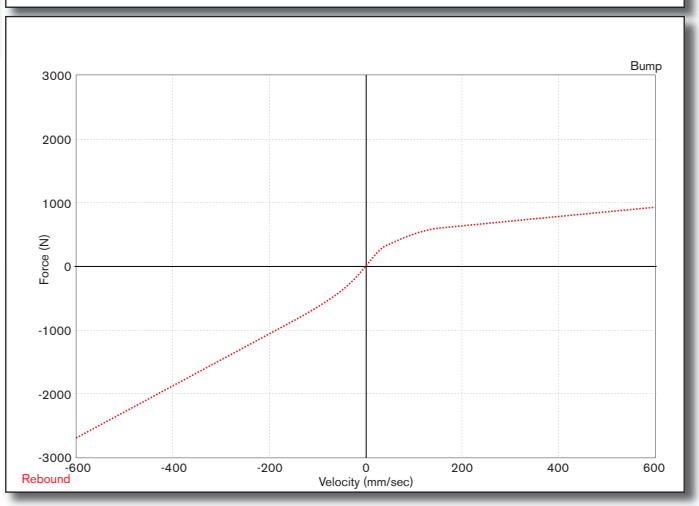


Fig 5: force/velocity graph with digressive damping plots

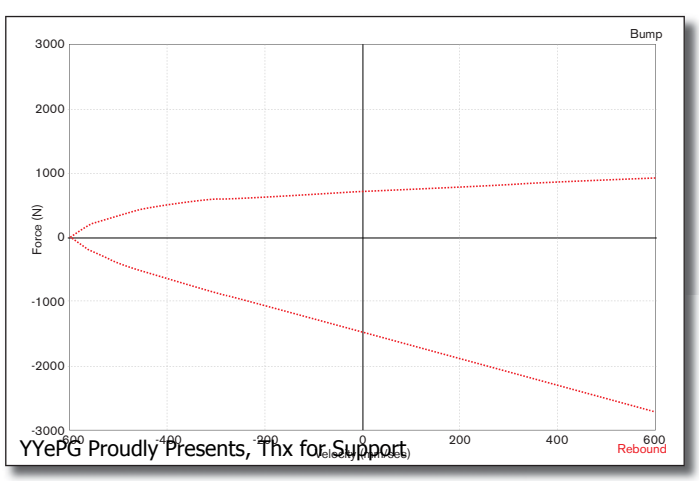


Fig 6: graph showing bump and rebound characteristics

critical damping are simple and widely available (see TD Gillespie, *Fundamentals of Vehicle Dynamics*, ISBN 1-56091-199-9 for example), you just have to be careful with the units. A simple utility program from Multimatic can be downloaded free from www.dynamicsuspensions.com/downloads.

Figure 4 is a simple force vs velocity diagram for a damper – in this case a theoretically 'ideal' linear example. On the x-axis, we have the velocity of a damper (usually expressed in mm/sec or inch/sec) and on the y-axis, the force generated by the damper (usually Newtons or pounds force). The top right quarter represents the damper being compressed (bump) and the bottom left the damper extending (rebound). Therefore, our straight line on this very simple graph would represent unsophisticated damping proportional to velocity (ironically, quite hard to achieve in a conventional damper because of fluid dynamics). In practice, most force/velocity diagrams look more like figure 5, right.

To save space, the rebound damping can be mirrored about the y-axis and placed in the bottom right-hand quarter of the graph (as represented in figure 6, right).

In both bump and rebound, a higher damping rate is usually required at low damper →

velocities and less at higher velocities.

The forces at very low velocities tend to be dominated by friction. Velocities to, say, 50mm/s (eg roll) have great influence on drivers' 'feel' of the car, while velocities up to around 400mm/s result from primary forces through the hubs (ie bumps) and velocities over, say, 400mm/s are only seen over kerbs or sharp edges on the track. Of course these velocities are dependant on vehicle stiffness and on the track in question. Figure 7 (right) shows this in diagrammatic format.

Traditionally, especially for road cars, less damping overall is used for bump (in an attempt to reduce the transmission of road inputs to the driver) than rebound. However, if there is too large a ratio between bump and rebound damping, jacking can occur and a succession of disturbances will have the racecar jacking down, rather than returning to its starting point. Modern racecar dampers are often set up with nearly as much damping in bump as in rebound.

We're beginning to build up a picture and we now have a graph that looks familiar – one that is typical of the shape produced by a damper dyno for a racecar damper. This is important because we are going to need to match the characteristics of the dampers available as closely as we can to the damping requirements of the vehicle, and the results obtained from a damper dyno are a good way to do it.

To learn more about the input of the damper supplier, *Racecar* spoke with Dr Rob Williamson, technical director of Multimatic Technical Centre Europe (MTCe), manufacturers of the Dynamic Suspensions brand of dampers and test equipment. Dynamic Suspensions dampers are exclusively manufactured for motorsport and high performance road cars and the company supplies its products to many of the world's leading motorsport teams.

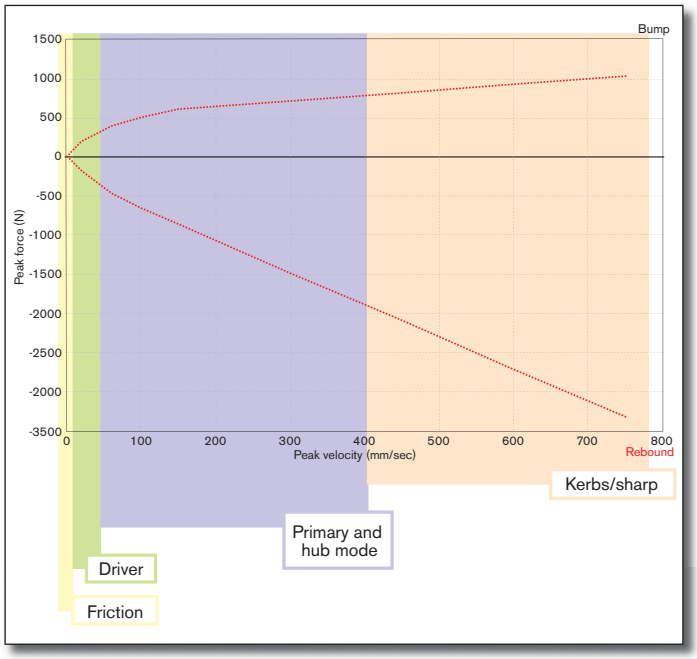


Fig 7: bump and rebound characteristics shown with changes in forces as felt by the driver as velocity increases

> **"RACECAR DAMPERS ARE OFTEN SET UP WITH NEARLY AS MUCH DAMPING IN BUMP AS IN REBOUND"**

Williamson discussed graphs (shown in figure 8, below) showing four different ways of looking at a single set of damper test data. Plot A shows force against displacement – a legacy from when these were the only measurements available – but still a common and useful way of looking at the data. Force/displacement only has meaning when we know that the test was performed with a sine wave at constant stroke. We then know the velocity for any displacement. Plot B shows the force/velocity plot discussed above. Plot C →

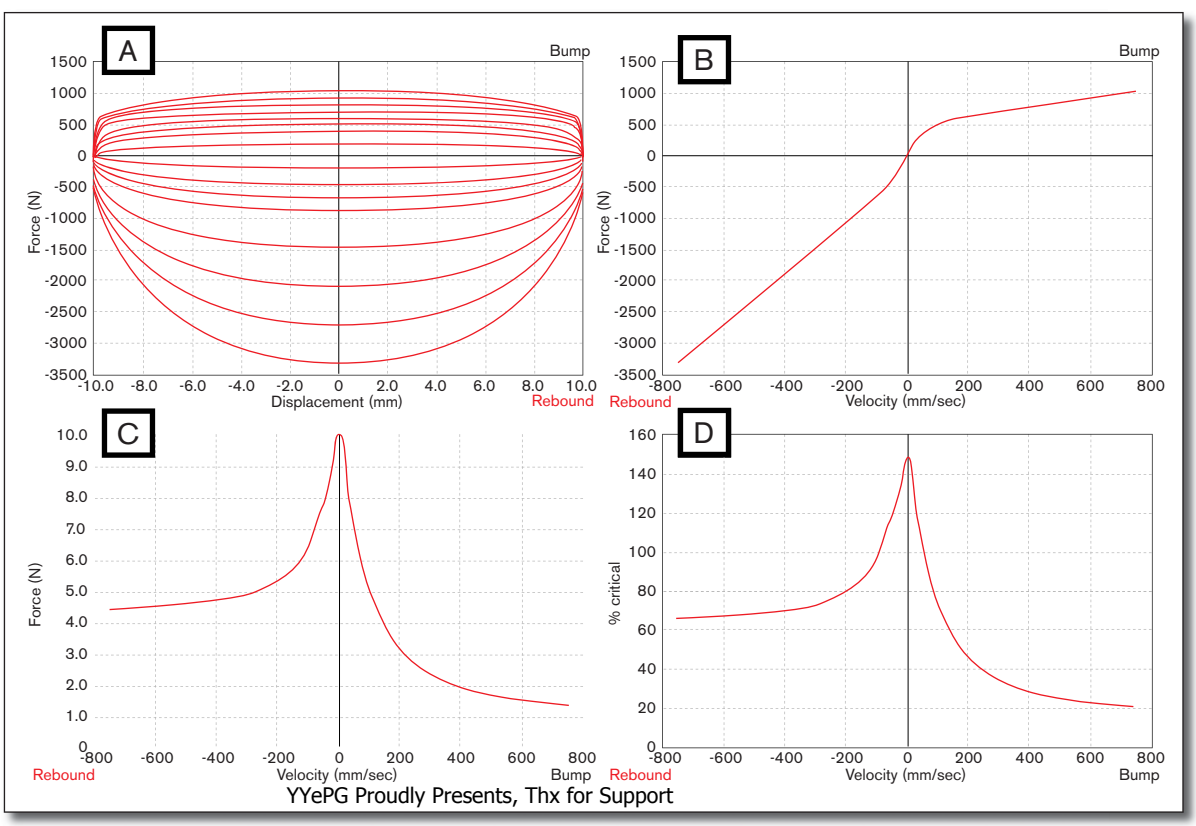


Figure 8: four different graphical representations of the same damper test data:
A – force vs displacement
B – force vs velocity
C – force / velocity
D – instantaneous damping coefficient / critical damping coefficient

shows the force data divided by the velocity to give an instantaneous damping coefficient. Plot D shows this coefficient divided by the critical damping coefficient and expressed as percentage critical damping.

Plot D, showing percentage critical damping against velocity gives us a way to compare different vehicles, allowing for differences in weight, spring rate and motion ratio. The critical figure calculated is only for one corner of a vehicle, and neglects the key effects of installation and tyre stiffness. Therefore it is a massive oversimplification. Nevertheless, it provides a way to try to transfer some of the 'feel' of one vehicle to another. The graph also lets us see how well damped the car is at different suspension velocities, compared to the critical damping figure. It is very common for the figure to exceed 100 per cent at low velocities.

This high damping at low velocities is due to a combination of factors: a fixed level of friction has a larger effect at low velocities; most damper valves have physical limitations which lead to a digressive curve and to a high low-speed damping coefficient; drivers often prefer the 'taut feel' of a vehicle with high low-speed damping.

From Williamson's experience, and making assumptions about tyre stiffness and so on, for most vehicles the maximum practical damping over a wide velocity range is less than 60 per cent of the critical damping figure. Indeed, Williamson plotted for us the percentage of critical damping against rebound and bump damper velocities for a high performance road car and a racecar – see figure 9, right. Note the similarities.

> "YOU WILL NEED TO KNOW SPRING RATES, MOTION RATIOS AND SPRUNG AND UNSPRUNG MASSES"

At this stage, you would usually involve your damper supplier. They should have the necessary experience and be able to make the correct assumptions to supply you with dampers that are in the right ballpark. Then it's a question of a session or sessions on a four-post rig and track testing to fine-tune the dampers.

Using this information, you can make a giant step towards the actual damping requirements, and hence the specifications of dampers. You will need to know spring rates, motion ratios and sprung and unsprung masses. MTCe has software that will produce the force/velocity damper graphs you require. Now you will be sourcing dampers that match the force/velocity profiles you have. This article is not a review of what is available but here are a few guidelines: for most racecar applications, four-way adjustable dampers are the norm these days and, for convenience, many race engineers prefer external adjusters. In other words, they will have a range of damping adjustment for low and high shaft velocities for both bump and rebound. You want a useable range of adjustment across the softest to stiffest settings. For larger changes in damping, most racecar dampers can be stripped and rebuilt with different internal components.

Dampers should be closely matched left to right and, obviously, lightweight. More expensive dampers are likely to have less internal friction, to be less temperature sensitive and to offer wider ranges of valving and adjustability.

Across their range of adjustment, four-way adjustable dampers will typically generate force/velocity graphs as shown in figure 10 when tested on a damper dyno.

MTCe often uses a corner-based critical damping approach as the first step towards specifying dampers. When time allows, a full vehicle model is used which allows for induced pitching due to unequal front and rear natural frequencies, and allows maximisation of damping for tyre rates and installation stiffnesses when known. The next step used is to test the racecar on a four-post rig. Not only are the test procedures repeatable but also installation stiffness, non-linear springs and/or motion ratio, friction and damper hysteresis and the damping of the whole car is taken into account. This should be followed by on-track testing – aided by the racecar's data acquisition system. RE

Motion ratio

We need to be very careful about the effects of the motion ratio between our wheels, springs and dampers. All vehicle dynamics calculations are done 'at the wheel' so the spring and damper forces and displacements and velocities have to be compensated appropriately.

The important thing is to remember that spring rates and damper coefficients scale with the motion ratio squared. And of course to be very clear whether the motion ratio is quoted wheel/damper or damper/wheel!

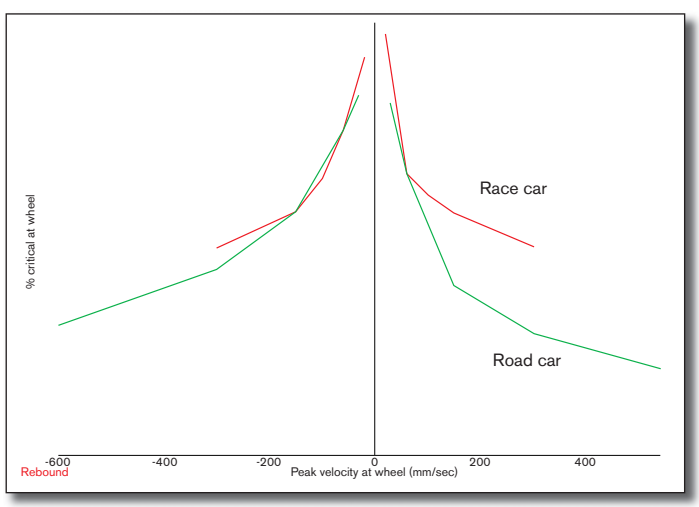


Figure 9: percentage critical damping/velocity graph with typical plots for high performance car and racecar

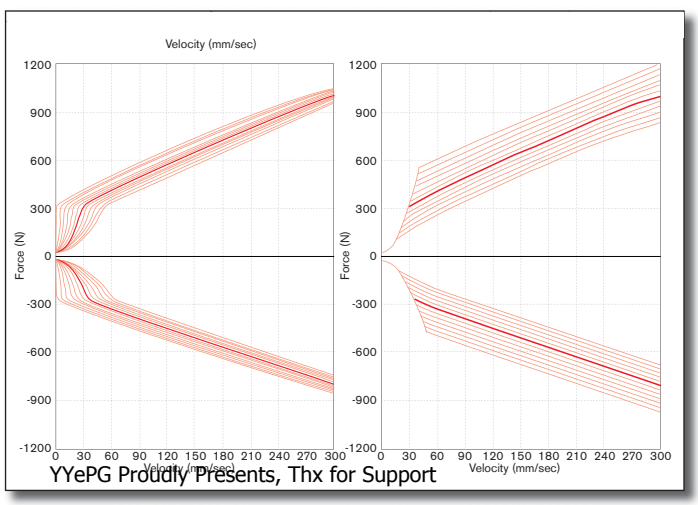


Figure 10: force/velocity graph with plots for range of high and low speed adjustments

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Racecar engineering

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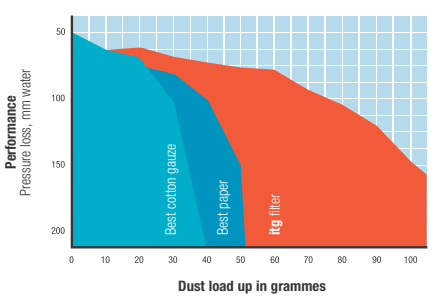

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Send your details to those listed below for each of Raceshop's sections. You can either send material direct to the Leon House address on Page 5, or to the email addresses below…

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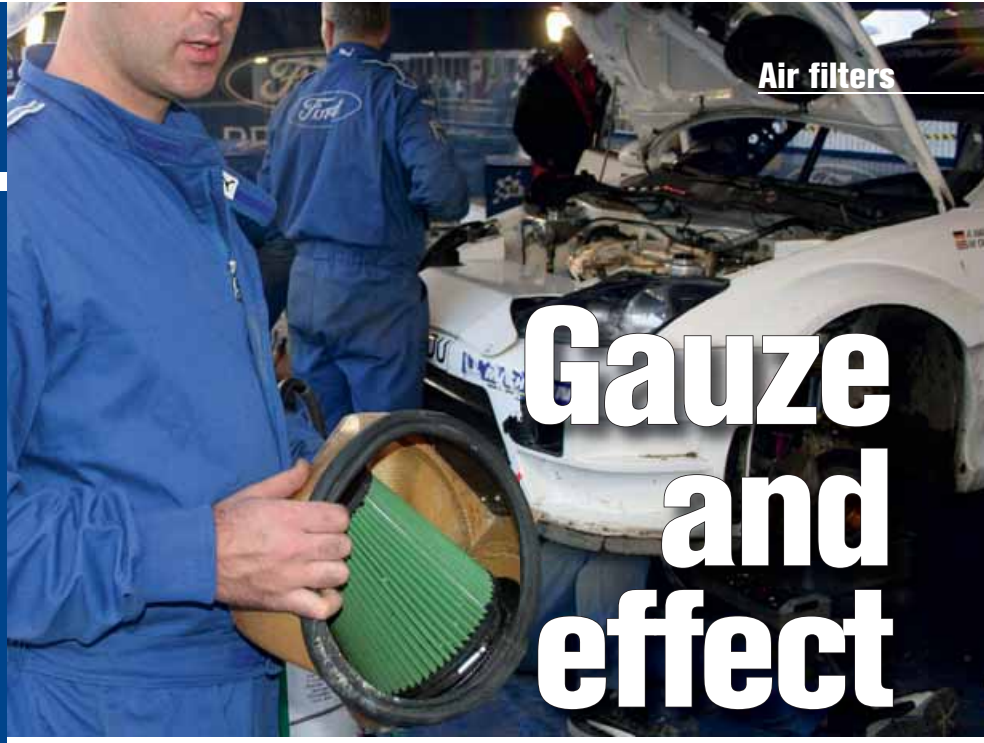


Gauze and effect

Air filter technology is far more complex than it might seem, as this round-up of the latest advances in the motorsport marketplace shows

Words | Ian Wagstaff

Above: Green filters by Chronosport use multi layer, cotton gauze technology

Despite the huge market for effective air filtration devices on road cars, the motorsport sector is, as Ramair supplier David Baker points out, 'a very niche market.' The paper used as a filtration material in conventional road use tends to be just too restrictive for the airflow required in racing.

Indeed, ITG points out that when it comes to the higher levels of motorsport it is generating a new product for each individual team order. Founded in 1987 it has become a long-term supplier to Formula 1, its customers encompassing three different engine manufacturers and four

"RETICULATED POLYESTER FOAM IS SAID TO ACHIEVE OPTIMUM PERFORMANCE"

teams. At the same time it provides for all forms of motorsport from endurance racing, where, for example, it suppliers air filters for AER and Judd-engined cars to sprint and midget racing in the USA and Formula 2 'stock cars' in the UK. Last season it was able to point specifically to success in such as the British Touring Car Championship with Team Dynamics (in the process taking the work from Ramair, which supplied →

ITG uses a 'Tri-foam' system in its filters, said to allow maximum airflow with no significant pressure loss

ITG prides itself on its ability to manufacture bespoke air filters for all motorsport applications, such as this Audi Cosworth RS6 unit

the 2002, 2003 and 2004 championship-winning Vauxhall team), as well as the Daytona 24 Hours-winning Riley-Pontiac.

In the field of historic racing ITG can provide product for most historic Formula 1 cars, particularly those using DFV/DFL engines, and has recently been able to supply a unique filter for the BRM V12 engine, as used in the P126. ITG's heritage is built on the supply of one-off product and this is an area it is continuing to expand.

The company believes that it was probably the first to manufacture what it describes as 'truly durable', high performance, foam-based production air filters. Compared to paper or other filter technologies, reticulated polyester foam is said to achieve optimum performance in three areas. Maximum airflow is maintained because of the foam's ability to allow air to pass through without causing a large drop in pressure. It is said to be more efficient in cleaning because of its capability to arrest a high proportion of airborne dust while feeding the engine clean air. It also has the capability to absorb a large amount of dust without reducing air flow capacity.

ITG uses what it describes as its 'tri-foam system', which features various thicknesses of finer or coarser foams depending upon the application. Tri-foam is said to give the company the flexibility to produce filters to exact specifications and, where high flow rates are possible, it claims to be able to tailor filters to arrest even the slightest dust traces. Other advantages claimed for ITG filters include a significant reduction in noise and, because of the use of the latest adhesives to bond the foam layers, a resistance to water, fumes, oils and fuels, including exotic racing fuels.

Pipercross has been manufacturing high performance air filters for over 27 years and, like ITG, is able to produce one-off, bespoke product. It also has customers in Formula 1, three teams using its product as well as a couple, including M-Sport, in the World Rally Championship. At the other end of the scale it provides product for Citroën 2CV competition cars. At Autosport International, Pipercross launched its new VForce intake system, which had been tested in extreme conditions at the Dubai Autodrome in the UAE by the Total Motorsport Solutions Honda Civic team. It was also announced that the China Dragon touring car squad currently racing in China will use the product in its Civic Type Rs. The company describes VForce as a 'totally different design' that has been 'designed from the ground up.' It believes it has re-written the rules and currently sees VForce as a showcase product, demonstrating what it can achieve. Its present costs put it firmly in the top end of the market.

VForce is said to feature a more free flowing foam than those used in traditional filters. The foam, a replaceable dual layer pre-impregnated reticulated polyurethane material, is the same grade as that used in Formula 1 applications. It is used in a high flow T304 stainless steel support system with the foam surrounded by carbon fibre directional vanes. These vector intake charges to the centre of the air filter base, apparently reducing turbulence and increasing air velocity. Through a combination of sourcing air from the coolest area of the engine bay and shielding the intake charge from under-bonnet heat, VForce achieves a typical temperature reduction of 5degC or more.

Pipercross also points out the lifespan advantages of foam as a filtration material. By combining multiple layers of foam, pre-impregnated with a dirt retention additive and with varying degrees of porosity to each layer, the life of the filter is vastly extended beyond cotton-gauze rivals, and even that of paper systems.

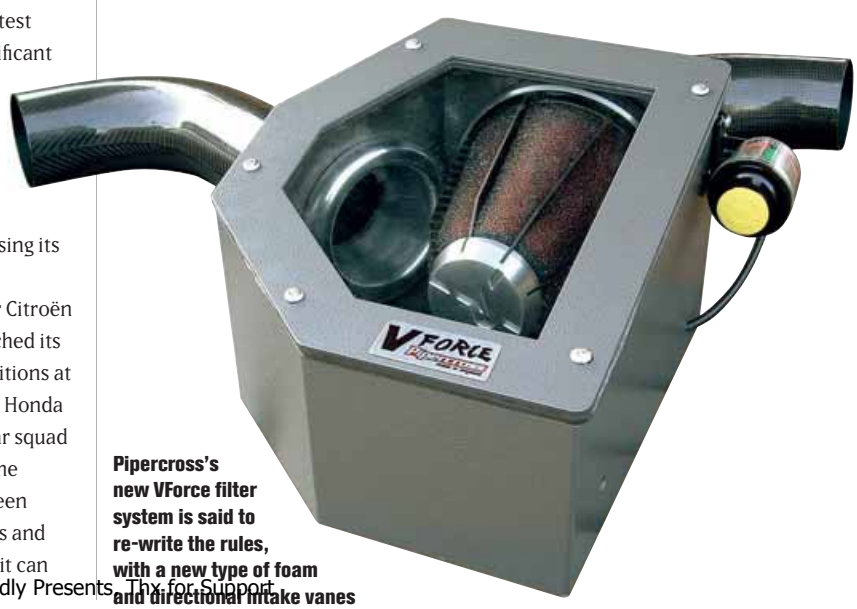
The VForce system became available on the market in February for the Civic Type R and also for the Renault Clio 182.

The Ramair brand is still available for motorsport applications through Raid UK Ltd. The road performance filtration market has been dramatically affected in Germany by the need to pass very stringent and expensive TüV legislation for car-specific kits. The German government wants to reduce automotive gas omissions and, together with Spain, are trying to convince other EEC members to follow suit. This has lead to a move towards universal filters. As a result, the market is now seeing the huge increase in filters manufactured in the Far East, which are aggressively priced and not tested for the application.

The manufacturing plant for Ramair is now owned by David Baker in Leicestershire, UK. Mindful of the need to honour long-standing agreements his company has had to diversify to maintain the life of the company. As far as motorsport specific applications are concerned though, the company still manufactures a range of bespoke filters for the racing world – mainly for use in Formula 3 and overseas Touring Cars.

> **"A SIGNIFICANT REDUCTION IN NOISE"**

Raid UK now manufactures both the Ramair and Raidhp air filters, often tailored to a specific purpose. It is able to create filters with anything up to five different stages of filtration. Different lamination of high, medium and low densities of foam are also offered to maximise power with open cell or closed cell foam to increase cleaner air into the engine body. The latter can be important for middle-of-the-pack runners who are usually in dirty air. →



Pipercross's new VForce filter system is said to re-write the rules, with a new type of foam and directional intake vanes

Ramair offers filters with up to five different stages of filtration and with either open or closed cell foam, the latter said to be particularly effective in dirty air

K&N's Apollo CIS (above) is a complete cold air system incorporating a cotton gauze filter

K&N NASCAR filters are traditional, deep pleat versions, not dissimilar to its road car units

The company also points out that race series often travels to different countries meaning that there is a need to change filter foam laminates to accommodate more hazardous conditions, such as sand or dust. Raid UK's advanced polymer treatment can also be applied to a filter as an additional layer of defence against fine dust. The company can provide a specially formulated cleaner to use when the filter appears dirty, after which the treatment can be re-applied.

K&N points out that its products are essentially not that different to that which it supplies for performance road use, though its offerings for Europe tend to be very different from that in the USA. It launched eight new round air filters for NASCAR use in February, for example.

The latest product that is exclusive to this side of the Atlantic is its Apollo Closed Intake System (CIS). This has been created to handle over 300bhp which, says the company, makes it suitable for a bespoke intake application or for the updating of existing induction kits that have already been fitted to the vehicle. Apollo CIS is a complete cold air system that incorporates one of K&N's cotton gauze filters. The housing is manufactured from co-polymer and black K resin, which resists heat build-up, keeping the intake charge cool. The system is supplied with a 70mm cold air feed hose and is intended for universal fitment. It has a 70mm intake neck as standard, with a range of stepped adaptors available to allow fitment to other intake sizes. It comes with the now familiar K&N million-mile warranty.

> **"DEEP PLEATS ARE SAID TO ENSURE A 10-20 PER CENT INCREASE IN SURFACE AREA"**

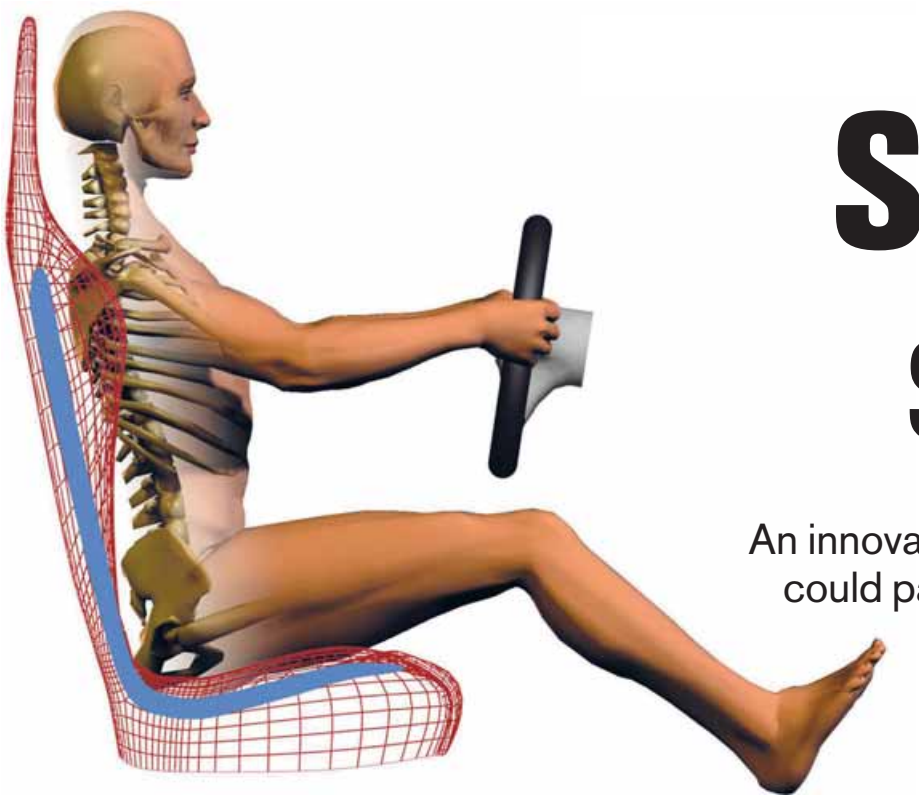
Green air filters are manufactured in France, by Chronosport, so it is not surprising that they have been found for some years in Henri Pescarolo's Le Mans contenders. The company also supplies to all of the current WRC factory teams (with the exception of Citroën), as well as a wide variety of other motorsport formulae down to such as the French Clio Cup. The company was formed in 1995 to design and manufacture premium cotton air filters for motorsport. It now claims to be Europe's largest cotton air filter manufacturer.

The deep pleats in a Green filter's cotton gauze are said to ensure that there is a 10-20 per cent increase in surface area to draw more into the engine. The cotton gauze is made up of a medium and fine layer to trap and hold dirt, dust and moisture particles as small as 0.50 microns. The filters can also be custom made with a different number of layers to suit a variety of conditions. The gauze is held in place by a fine alloy mesh.

It seems air filters are far from being an afterthought.

Green filters are currently used on all WRCs, except Citroën. Here a Mitsubishi

The French manufacturer also supplies product to Pescarolo for its prototypes



Sensible seating

An innovative new seat technology that could pay long term dividends for the health and safety of drivers

Words | Charles Clarke

The key to successful seating is in proper spinal support. As well as improved comfort, the ProBax seat allows increased bloodflow around the body

In an effort to improve driver comfort in its Elise and Exige models, Lotus will be fitting new ProBax™ seats as standard in all its MY 2006 cars. Donna Jackson, founder and director of product development, NuBax Ltd (the makers of the ProBax seat) has been in the prosthetics industry for 25 years and sees Lotus as an ideal partner through which to promote its exciting new product.

By changing the way the body is supported in the seat it is possible to get considerably more benefits than just straightforward comfort. Enhanced bloodflow leads to a corresponding increase in the transmission of oxygen to the body and brain, increasing alertness and muscle strength. This is critical in any car, but is particularly pertinent in racecars, especially those used in endurance events where racers fatigue more from poor seating and poor circulation than any kind of muscular discomfort. This increase in bloodflow has been confirmed by comparative laboratory measurements using regular and ProBax seats.

The underlying idea of the ProBax seat is to maintain the spine in its normal curvature so that it can support the body's weight more naturally. After all, the spine is meant to carry the body weight not the muscles. What NuBax has done is to create a standing attitude of the spine while you're sitting.

In the Lotus application, the ProBax seat uses the same seat frame as the standard Lotus seat, but a different covering material and the unique ProBax seat insert which does the orthopaedic 'tuning'. The old inflatable lumbar support devices are eliminated and the new seat actually weighs slightly less than the previous one – something that fits nicely with the Lotus design ethos.

The first sensation you experience when sitting in the ProBax seat is that it supports the spine from the base all the way up with no interruptions. This is initially a strange sensation as it is unlike most traditional car seats, but it negates the need for the complex series of motors, pulleys, levers and slides modern seat engineers employ to perform infinite adjustments to seating posture and position. This infinite adjustment in fact just over complicates the situation and it is easy for one adjustment to negate the therapeutic benefits of another unless you know exactly what you are doing. The beauty of the ProBax insert is that it is fixed and helps the body adjust its posture naturally.

So far NuBax's new seat has only been tested by private individuals but Lotus (right) has already seen its advantages and is currently fitting it to its 2006 Elise and Exige models

Currently there is no ProBax-equipped racing seat available on the market but, having tried the Lotus ourselves, we'd like to see someone get behind the idea and license this innovative product so others can benefit from its clear advantages. RE

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The Nitty-Gritty

Details of a new weld cleaning and marking system has been announced by Orbimatic (UK) Ltd, manufacturers of high technology Orbital TIG-welding equipment.

The Nitty-Gritty Clinox.ECO system removes oxides left behind after TIG welding stainless steel, but can also be used for localised electro-polishing and for marking metal surfaces.

The machine, being inverter-based, is lightweight, portable and energy efficient. It has three cleaning settings and a polishing setting. Two permanent marking modes, DC and AC, permit various marking styles to be produced and marking screens can be supplied according to customer needs. An optional label printer is available to produce unique marking screens.

All kits come in an ABS transport case and include a cleaning probe and consumable starter kit.

● **For more information call +44 (0) 1733 555285 or visit www.orbimatic.co.uk**

Managing pressure

Intercomp has developed an advanced system that allows drivers to monitor tyre pressures and temperatures direct from their seats.

The new on-board Wireless Tire Pressure Management System operates in real time announcing any high or low pressure or temperature conditions.

Four in-wheel sensors mounted in place of the valve stem of each tyre allow the system to monitor up to 70psi with an accuracy of +/-2psi. Pressures are displayed on a digital dash-mounted gauge, which reads in psi, kpa and kg/cm^2 units. Temperature readings are recorded in either degC or degF.

● **For more information call +1 763 4762531 or visit www.intercompracing.com**

High torque spanners

UK-based tool manufacturer, Britool, has released a new ratcheting combination spanner (wrench) set designed to withstand high torque levels.

Manufactured from chrome vanadium steel, then heat treated and nickel plated for protection, the set consists of 12 spanners sized between 8mm and 19mm, all of which feature a sturdy 72-tooth ratchet device with a five-degree arc. Each has a 15-degree offset head and a thin profile, making them ideal for working in tight, confined spaces.

The set is priced at £110 plus VAT ($191), and catalogued under part number RRJMSET1.

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RACEGEAR

New products and services for racecar engineers

Blast-off!

Guyson International, specialists in surface finishing machinery, has released a larger capacity bead blasting system for use in reconditioning, engineering and maintenance workshops.

The new Formula 2000 has a large chamber measuring 1165mm (46in) wide by 760mm (30in) deep. For ease of use the entire top of the cabinet can be flipped open so heavy or awkward components can be lowered directly onto the steel reinforced chamber floor.

The Formula 2000 comes equipped as standard with a Guyson 400 high performance suction fed blast gun and a continuous dust collection system. Fluorescent interior lighting and a large viewing window are designed for optimal working conditions.

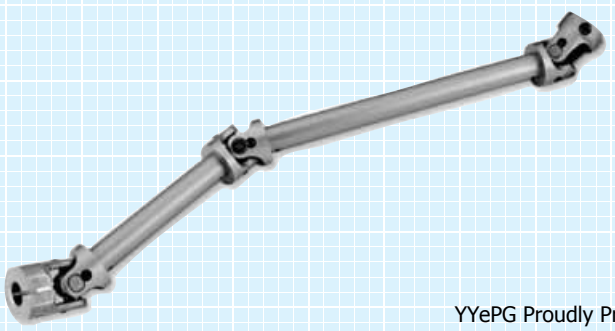
● **For more information call +44 (0) 1756 799911 or visit www.guyson.co.uk**

Racing joints

US-based universal joint manufacturer, Belden Inc, already provides a wide range of universal joints and driveshaft assemblies for various steering and gear change linkage applications but has now developed a series of linkages for the racing industry that focus on the cross and needle bearing design,

Preferred by many racecar engineers, this design has firm axial strength for push or pull loads and incorporates high strength alloy steel yokes with permanently sealed drawn cup needle bearings and a forged cross. Joints are available in a variety of materials including alloy, stainless steel or aluminium.

● **For more information in the UK call +44 (0) 1926 452747 or in the US +1 708 344 4600. Alternatively, visit www.beldenuniversal.com**



Short circuit oil

UK-based independent lubricant manufacturer, Millers Oils, has developed a new, synthetic, fortified oil specifically formulated for oval and short circuit racing.

The new oil, named COR 20W-50, has a 'sophisticated performance additive package and synthetic fortified formulation', said to offer competitive racers optimal engine performance and reduced power losses. The oil is recommended for use in competition engines such as the Rover V8, Ford Kent and Pinto, across all motorsport disciplines.

COR 20W-50 has been set with a RRP of £19.50 ($33.84) for five litres (1.32 gallons) making it competitive both on performance and on price.

● **For more information call 0845 6455377 from the UK or +44 (0) 1484 713201. Alternatively, visit www.millersoils.co.uk**

Ignition doctor

Agriemach has found a way to diagnose all ignition problems with its new spark plug firing indicator.

Within just a few seconds the indicator can determine if any individual plugs are not firing or if any are fouled or eroded. It can also detect plug wire damage and is said to be useful for diagnosing DIS coil problems.

Priced at £9.99 including VAT ($17.34) the spring-mounted spark plug indicator comes with detailed instructions. To order reference part no PM-3030.

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

RACEGEAR

New products and services for racecar engineers

SteelHead storage

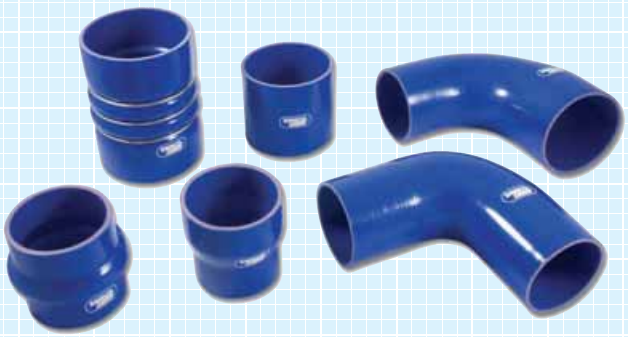
US-based SteelHead Design Inc has announced a new inventive shop storage and workspace solution.

The MTech system is available in various combinations and can be customised and continuously reconfigured for individual storage needs. Computers, electronic equipment and tools needing secure storage are provided for with a wide variety of drawers and slide-out shelves. Shelf units are designed to accommodate electronic equipment with rear cable access and louvers for ventilation. Adaptable stackable cabinets are also included in the system's special features and height adjustable work benches can be attached or used in a free-standing configuration.

All cabinets come fully built and are constructed from 16-gauge T304 stainless or powdercoated steel, which can be colour matched as required.

● **For more information call +1 800 261 0761 or visit www.steelheadesign.com**

Xtreme hoses



Samco Sport offers silicone hose kits to engineers who demand high levels of reliability in the intense conditions they compete in. But now Samco Sport has also released a brand new range of universal parts, under its Xtreme banner.

The new range of hoses are lightweight, flexible and designed to withstand temperatures of up to 250degC (482degF) and high pressure ratings. All Samco Sport hoses are manufactured in a high gloss finish and come in the colour blue as standard, though other colours are also available.

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

Composite courses

A new range of composite courses are being run by Dark Matter Composites Ltd to help enlighten the hobbyist or enthusiast.

Based at the company's workshop in Harpenden, England, the courses are being run throughout the week and at weekends by trade specialist Rodney Hansen. Covering topics such as wet lay-up laminating and composite repair, the courses are designed for all levels and use simple theory, demonstrations and practical application to aid understanding.

There are plans to add other courses in the near future, including pattern making, mould making, resin infusion laminating and pre-preg laminating.

● **Information about all the courses can be downloaded from the company's website: www.darkmattercomposites.co.uk. Alternatively, call +44 (0) 1582 469069.**

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
Name and number bold
£70 - 12 issues
Logo and full company details
£420 - 12 issues including web, address, email etc etc
£210 - 6 issues

www.racecarengineering.com

Andy King on Tel: +44 (0)20 8726 8329

andy_king@ipcmedia.com

Database 1

RACECAR MANUFACTURERS

1.1
Racecar Manufacturers

A-MAC USA (1) 408 727 9288
Fax (1) 408 988 8998
A-Mac Fabrication, 1745 Grant Street, Suite 2, Santa Clara, CA 95050, USA

ASCARI Tel 01295 254800
Fax 01295 255944
Overthorpe Road, Banbury, Oxfordshire OX16 4PN England

APOLLO RACING DESIGN LTD Tel 01280 813580
Fax 01280 823015
Email info@apolloracingdesign.com
Website www.apolloracingdesign.com
Millgate Barn, Radclive, Bucks MK18 4AB, England

BARRELLI Italy (39) 02 782427
Flli Barrelli, Via La Spezia 5, 20156 Milan, Italy

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

CARBIR USA (1) 262 377 2850
Fax (1) 262 375 1602
Carbir Race Cars Inc, 1220 Falls Road, Grafton, WI 53024, USA

CHEEK Norway (47) 90 78 70 32
Fax (47) 69 19 02 55
Cheek Racing Cars, Flatebyvn 3, 1792 Tistedal, Norway

CHEETAH USA (1) 408 492 1331
Fax USA (1) 408 492 1333
Omni Fab, 380 Martin Avenue, Santa Clara, CA 95050

CHEVRON Tel 01300 348499
The Chevron Centre, Piddle Trenthide, Nr Dorchester, Dorset DT2 7RF, England

US Importer Continental Crosslé Tel (1) 513 777 4545
9000 Debbie Drive, West Chester, OH 45069, USA

DALLARA Italy (390) 525 550711
Fax (390) 525 53478
Dallara Automobili, Via Provinciale 33, 43040 Varano Melegari, Parma, Italy

DEBORA France (33) 381 52 02 10 36
Fax (33) 381 51 18 51
bis Rue du Docteur Moras, 25000 Besancon, France

DAN GURNEY'S ALL AMERICAN RACERS,INC
Tel USA 714 540 1771
Fax USA 714 540 3749
2334 South Broadway PO BOX 2186, Santa Ana, CA 92707, USA

DJ RACECARS Tel 01663 734518
Fax 01663 732 130
Email del@djracecars.fsnet.co.uk
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 1DG 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 0JN 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 5RD, 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 (i) 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)932 225777 Fax : +44(0)932 222215
Unit 3 Shepperton Business Park
Shepperton, Middlesex TW17 8AA

ALL WAYS FORWARD	01242228111
ARP	USA (i) 805 525 5152
ARROW SUPPLY	01234 840404
CLARENDON	01455 841200
COAST FABRICATION	USA (i) 714 842 2603
DATUM ENGINEERING	02476 383032
DZUS FASTENERS EUROPE	01252 714422
FASTENER FACTORY	01327 311018
FLUID CONTROL PRODUCTS INC	USA (i) 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 (i) 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 (i) 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 (i) 312 865 5200
BRISE AUTO ELECTRICS	01322 277622
MM COMPETITION	08707 444666
McCLAREN ELECTRONICS	01483 264100

CABLES

CENTURY CABLES Tel 01733 211600 / Fax 01733 211082
Email kwhincup@yahoo.com / web www.centurycables.com

IS MOTORSPORT	USA (i) 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 (i) 513 459 8863

CONNECTORS

BERU F1 SYSTEMS	01379 646200
DEUTSCH	01424 852721
IS MOTORSPORT	USA (i) 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 (i) 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 (i) 312 865 5200
SBD MOTORSPORT	0208 391 0121
EFI TECH	USA (i) 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 (i) 714 897 6804
MSD IGNITION	USA (i) 915 857 5200
PI RESEARCH	01954 253600
PIAA (UK)	01934 814812
STACK	01869 240404
McCLAREN ELECTRONICS	01483 264100
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 (i) 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 (i) 716 631 2880
DC ELECTRONICS	01621 856451
SBD MOTORSPORT	0208 391 0121
EFI TECH	USA (i) 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 (i) 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 (i) 714 897 6804
PENNY & GILES	01202 409409
PI RESEARCH	01954 253600
QINETIQ	08700 100942
SPA DESIGN	01827 288328
STACK	01869 240404
McCLAREN ELECTRONICS	01483 264100
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 (i) 440 826 4488
MOBILIS	Canada (i) 450 647 1890
RALLY DESIGN	01795 531871
ZF	Germany (49) 7541 772543 UK 0115 9869211

WOODWARD MACHINE CORP TEL: USA (i) 307 472 0550
FAX: USA (i) 307 235 1551
Website: www.woodwardsteering.com
PO Box 4479, 3592 Burd Road, Casper, WY82604, USA

STEERING WHEELS

DEMON TWEEKS	01978 664466
MOUNTNEY	01525 381055

SWITCHES & KILL-SWITCHES

IS MOTORSPORT	USA (i) 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 (i) 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 (i) 916 638 7888
LOLA	Tel 01480 451301 Fax 01480 456722
PROFLEX UK	01200 442345
RICARDO MIDLANDS TECHNICAL CENTRE	01926 477208
ROD MILLEN MOTORSPORT	USA (i) 714 8472111

2.5 Suspension Components

ANTIROLL BARS

COIL SPRINGS	01142 758573
COMPTECH USA	USA (i) 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 (i) 916 638 7888
KIC INT MOTORSPORTS	USA (i) 604 589 3354
HARROP	Australia (61) 3 9499 7433
PRECISION	USA (i) 708 766 4402

BEARINGS & BUSHES

ABC AUTOSPORT BEARINGS • COMPONENTS
Tel : +44(0)932 225777
Fax : +44(0)932 222215
Unit 3 Shepperton Business Park
Shepperton, Middlesex TW17 8AA

AURORA BEARING	USA (i) 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 (i) 916 638 7888
RESB	0121 520 8271
ROSE BEARINGS	01522 500933

COILSPRINGS

COIL SPRINGS	01142 758 573
COMPTECH USA	USA (i) 916 933 1080
EIBACH	01455 285850
EIBACH	Germany (49) 2721 511220
GROUND CONTROL	USA (i) 916 638 7888
HYPERCOILS	USA (i) 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 (i) 916 638 7888
JRZ SUSPENSION	+31 026191155
MONROE AUTO EQUIPMENT	01904 631441
MORRIS DAMPERS INC	USA (i) 586 826 9141
MOTON	Netherlands (31) 413 259838
OHLINS RACING	UK 0208 974 1615
PENSKE RACING SHOCKS	USA (i) 215 375 8180 UK 01827 288328
ROEHRIG	USA (i) 336 431 1827

SPAX UK (Worldwide HQ) Tel: 01869 244771
Fax: 01869 240536 e-mail: sales@spaxperformance.com
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SPAX France	Tel: 0478 9042 43
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FASTENER FACTORY 01327 311018
GOLDLINE BEARINGS 01952 292401
GROUND CONTROL USA (t) 916 638 7888
KINSLER USA (t) 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

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EIBACH Germany (39) 2721 5110
UK 0455 285850
USA (t) 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

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Fax 01525 385898
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Email: info@circuitsupplies.com
Web: www.circuitsupplies.com
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (t) 239 772 4261
DELPHI BRAKE SYSTEMS 01926 472472
EBC BRAKES 01604 583344
ENDLESS BRAKES Japan (81) 267 68 0071

brembo

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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 (t) 310 533 1924 USA (t) 317 244 1000 USA (t) 704 662 9095
MOSA FREIN Belgium (32) 81 73 32 73

PERFORMANCE FRICTION BRAKES

PERFORMANCE FRICTION (t) 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 (t) 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 (t) 239 772 4261
GKN SQUEEZEFORM 01952 244321
PERFORMANCE FRICTION USA (t) 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 (t) 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 (t) 239 772 4261
CARBONE INDUSTRIE France (33) 0472 355700

HAWK PERFORMANCE

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
PERFORMANCE FRICTION USA (t) 803 222 2141
EUROPE +44 (0) 1280 843 390
MARDI GRAS M/SPORTS 01327 858 006
RAYBESTOS USA (t) 815 363 9000
TAR.OX Italy (39) 039 587814
TILTON USA (t) 805 688 2353
WILWOOD USA (t) 805 388 1188

FLUIDS

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

PADS

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

Carbon Metallic

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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 (t) 941 772 4261
PERFORMANCE FRICTION USA (t) 803 222 2141
01280 843390
RAYBESTOS USA (t) 815 363 9000
TAR.OX Italy (39) 039 587814
TILTON USA (t) 805 688 2353
WILWOOD USA (t) 805 388 1188

VALVES

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

2.8 Wheels

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

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CO-ORD SPORT 01384 216102
DUNLOP 0121 306 6000
Australia (61) 330 50333
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Fax Canada (t) 902 2282241
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255 Southwest Cove Road, Hubbards, Nova Scotia, Canada, B0J 1T0

GRIP TYRE SOFTENER

GRIP TYRE SOFTENER Tel 01933 312735 Fax 01933 317571
Web www.griptyresoftener.com
Email info@griptyresoftener.com
Unit 10, Midland Business Centre, Higham Ferrers, Northampton, NN10 8DN
GOODYEAR Germany (49) 2234 82031
USA (t) 216 796 2121
Canada (t) 416 684 7418
MICHELIN 01782 402284
France (33) 73 90 77 341
TOYO 01933 411144
YOKOHAMA 01582 633319
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 (t) 305 270 9433
CASTROL USA (t) 973 305 3912
CENTURY 01782 202521
DUCKHAMS OILS 0208 290 0600
ELF France (33) 1 4744 4546
UK 0208 902 8820
01372 222000
ESSO UK
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 (t) 713 932 9954
STP USA (t) 305 771 1010
UK 01488 682655
TECH-LINE USA (t) 919 480 0905
TEXACO UK 0207 719 3000
VALVOLINE USA (t) 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 (t) 901 795 2400
CONNAUGHT 01795 843802
CROWER USA (t) 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 (t) 313 791 4120
KENT CAMS Tel 01303 248666
KENT CAMS BY JT FRANCE (33) 3207 46480
LUNATI USA (t) 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 (t) 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

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ARROW PRECISION 01455 234200
ATECH MOTORSPORTS USA (t) 330 630 0888
CLARENDON ENG 01455 841200

ARROW

ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 1455 234200
Fax +44 (0) 1455 233545
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Email: enquiries@arrowprecision.co.uk
12 Barleyfield, Hinckley, Leicester LE10 1YE
CARILLO IND. USA (t) 949 498 1800
CONNAUGHT 01795 843802
CO-ORD SPORT 01384 216102
CROWER USA (t) 619 422 1191
SBD MOTORSPORT 0208 391 0121
ENGINES & DYNO SERVICES 01708 857108
FARNDON ENG 02476 366910
MANLEY PERFORMANCE USA (t) 732 905 3366
OLIVER USA (t) 616 451 8133
PANKL Austria (43) 3862 512500

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Fax: +33(0)320746489
Email: jmjacqueminn@nordnet.fr
Website: www.jacqueminntuning.com
SAENZ USA (t) 305 717 3422
SCHRICK Germany (49) 21 91 9500
SWINDON RACING ENGINES 01793 531321

CONROD BOLTS

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Website www.arp-bolts.com
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Fax +44 (0) 1455 233545
Website www.arrowprecision.co.uk
Email: enquiries@arrowprecision.co.uk
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BLANC AERO France (33) 296 68 33 39
CARRILLO INDUSTRIES USA (t) 949 498 1800
COAST FABRICATION USA (t) 714 842 2603
COSWORTH 01604 752444
USA (t) 310 534 1390
CROWER USA (t) 213 543 1390
SBD MOTORSPORT 0208 391 0121
LINREAD NORTHBRIDGE MOTORSPORT
Tel 01162 572924 Fax 01162 572901
Viking Road, Wigston, Leicester, LE18 2BL
PANKL Austria (43) 386 251 2500
ATECH MOTORSPORTS USA (t) 330 630 0888

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Fax: +44 (0)1384 216109
Email: sales@coordsport.com
Kings Street, Dudley, West Midlands DY2 8PX, UK
DKE 01455 273738
EAGLE USA (t) 901 345 5886
FARNDON ENG 02476 366910
GRAINGER & WORRALL 01902 324460
LAYSTALL ENGINEERING 01902 451789

NORTHBRIDGE MOTORSPORT

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

CRANKSHAFTS

CUSTOM CRANK Tel: 01902 422144
Fax: 01902 422133
Web: www.customcrank.co.uk
Email: markhenry.rigg@btinternet.com
THE CRANKSHAFT PEOPLE

CRANKSHAFT DAMPERS

VIBRATECH USA (t) 716 895 8000

FLYWHEELS

ALVIS ATL 02476 519311
ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 01455 234200
Fax +44 (0) 01455 233545
COMPTECH USA USA 000 916 933 1080
FARNDON ENG 02476 366910
HARROP Australia (61) 39 499 7433
KAITEN PRODUCTS USA (t) 714 220 2227
QUARTERMASTER USA (t) 847 540 8999
SWINDON RACING ENGINES 01793 531321

GASKETS

COMETIC BY JT FRANCE (33) 01207 46480
GOETZE Germany (49) 221 21 74690
GORE-TEX USA (t) 410 392 3200

HEADS

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

INJECTORS

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

INTAKE MANIFOLDS

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

JENVEY DYNAMICS 01746 768810
KINSLER USA (i) 810 362 1145
LINGENFELTER USA (i) 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 (i) 760 603 9895
GKN SQUEEZEFORM 01952 244321
LAYSTALL ENG 01902 451789
MAHLE Germany (49) 217 4690

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RACETEK NAK 02380 246986

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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 (i) 310 532 9737
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Email: sales@coordsport.com
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TOTAL SEAL USA (i) 602 678 4977
WISECO PISTON USA (i) 216 951 6600
Canada 800 265 1029

PISTON RINGS

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CORDS PISTON RING 0208 998 9923
FORD AUTO ENG USA (i) 805 2981785
GOETZE Germany (49) 221 217 4690
HI-TECH USA (i) 801 972 8766
TOTAL SEAL USA (i) 602 678 4977
TWR ENGINES 01993 871000

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Website: www.butserrubber.com
Email: butserrubber@btinternet.com
Mint Road, Liss, Hampshire GU33 7BQ

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Fax: (i) 661 295 8300
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FERREA USA (i) 954 733 2505
GGS VALVES LTD 01483 415444
QINETIQ 08700 100942
MANLEY PERFORMANCE USA (i) 732 905 3366
RACING ENGINE VALVES USA (i) 954 772 6060
SCHRICK Germany (49) 21 91 9500
SUPERTECH PERFORMANCE USA (i) 408 448 2001
SWINDON RACING ENGINES 01793 531321
VALVE TECHNICS 01604 706541
XCELDYNE TECHNOLOGIES USA (i) 336 472 8281

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Fax +44 (0) 1455 233545
CHE PRECISION INC Tel (i) 805 499 8885
Fax (i) 805 499 7810
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SERDI 01895 232215
SWINDON RACING ENGINES 01793 531321

VALVESPRINGS

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DIAMOND USA (i) 313 792 6620
EDELBROCK USA (i) 213 781 2222
HERBERT TERRY & SONS 01527 64261
KENT CAMS 01303 248666
KURT KAUFFMANN Germany (49) 711 518300
MANLEY PERFORMANCE USA (i) 732 905 3366
PERFORMANCE SPRINGS 01253 716900
SCHMITTHELM Germany (49) 62 217060

VALVE SPRING RETAINERS

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VALVE GUIDES

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3.2 Engine Ancillaries

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Fax 02476 307999
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KINSLER USA (i) 248 362 1145
PIPERCROSS 01604 671100

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SOLEX France (33) 14 729 7171
WEBER Italy (39) 51 417995
WEBCON 01932 787100

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BURNS STAINLESS USA (i) 949 631 5120

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Website: www.gds-exhausts.co.uk
Unit 8C Boundary Road, Brackley NN13 7ES

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FLOWMASTER USA (i) 616 463 4113

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
JETEX EXHAUSTS 01789 298989
MARK ORTIZ USA (i) 715 835 3292
PIPER CAMS 01233 500200
SPECIALISED EXHAUST 0208 648 4786

FUEL FILTERS

AN MOTORSPORT DESIGN 01628 776320
CONNAUGHT 01795 841802
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
FLUID CONTROL PRODUCTS INC USA (i) 217 324 3737
FRAM EUROPE 01443 223000
KINSLER USA (i) 248 362 1145
LEE PRODUCTS 01753 886664
SPV RACING Australia (61) 2 791 9899
THINK AUTOMOTIVE 0208 568 1172
TJ FILTERS 01752 667675
WEBCON 01932 787100

FUEL INJECTION

AC ROCHESTER USA (i) 716 359 6361
ASNU Tel 0208 420 4494
BGC MOTORSPORT 0208 880 4205
BOSCH 01895 834466
Germany (49) 711 811 USA (i) 312 865 5200
CONNAUGHT 01795 841802
SBD MOTORSPORT 0208 391 0121
FLUID CONTROL PRODUCTS Tel (i) 314 291 7223
GENESES ELECTRONIC SYSTEMS 01635 582255
INDUCTION TECHNOLOGY 02476 305386
JENVEY DYNAMICS 01746 768810
JOHN WILCOX COMPETITION 01455 230576

KINSLER FUEL INJECTION Tel: USA (i) 248 362 1145
Fax: USA (i) 248 362 1032
Email: kinsler@kinsler.com Website: www.kinsler.com
LINGENFELTER USA (i) 219 724 2552
MAGNETI MARELLI Italy (39) 2 668 33
MM COMPETITION SYSTEMS 08707 444666
MARREN USA (i) 203 712 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 (i) 714 897 6804
NIPPON DENSO Japan (81) 56 625 5511
UK 0208 591 7700
PECTEL CONTROL SYSTEMS +44 (0)1954 253610
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
TWM INDUCTION USA (i) 805 967 9478

FUEL LINES

AEROQUIP USA (i) 419 238 1190
AN MOTORSPORT DESIGN 01628 776320

ATL USA (i) 201 825 1400
Fax (i) 201 825 1962
Aero Tec Laboratories Inc, Spear Road Industrial Park, Ramsey, NJ 07446-1221, USA
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 841380
EXACT ENGINEERING 01803 866464
FAE MACHINE USA 317 243 3092
FLEXOLITE 01684 891898
FUEL SAFE UK 01799 541955
USA (i) 714 842 2211
GOODRIDGE CA USA (i) 310 533 1924
GOODRIDGE INDY USA (i) 317 244 1000
GOODRIDGE EAST USA (i) 704 662 9095

GOODRIDGE UK Tel 01392 369090 / Fax 01392 441780
Exeter Airport Business Park, Exeter, EX5 2UP
HENRY'S ENG USA (i) 410 535 3142
JLS MOTORSPORT Tel 0121 525 7733

KRONTEC MASCHINENBAU Gmbh
Fitting & Hose Systems
Pommernstraße 33 93073 Neutraubling
Tel: 09401 5253-0
Fax: 09401 5253-10
KS MOTORSPORTS Germany (49) 2271 44905
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 (i) 216 232 2282

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

FUEL VALVES

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

HOSES & HOSE-ENDS

AEROQUIP USA (i) 419 238 1190
AN MOTORSPORT DESIGN 01628 776320

BROWN AND MILLER UK Tel: 01753 553610
Fax: 01753 577477
Unit 7-7A, Langley House, Middle Green Trading Estate, Langley, SL3 6DF USA Tel: 704 793 4319
Fax: 704 793 4321
4005 Dearborn Place NW, Concord, NC 28027
DELPHI BRAKES SYSTEMS 01926 472472
EARL'S USA (i) 310 609 1602
EXACT ENG 01803 866464
FASTENER FACTORY 01327 311018
FHS MOTOR RACING 01753 570863
FLUID CONTROL PRODUCTS INC USA (i) 217 324 3737
Fax (i) 217 324 3717
GOODRIDGE UK 01392 369090
GOODRIDGE CA USA (i) 310 533 1924
GOODRIDGE INDY USA (i) 317 244 1000
GOODRIDGE EAST USA (i) 704 662 9095
HCL FASTENERS 01282 411992
HENRY'S ENG USA (i) 410 435 3142
JLS MOTORSPORT 0121 525 7733
KINSLER USA (i) 248 362 1145
SAMCO SPORT 01443 238464

SFS PERFORMANCE Tel: 01582 488040
Fax: 01582 412277
Website: www.sfsperformance.co.uk
Unit E Kingsway Industrial Estate, Kingsway
Luton LU1 1LP
SPECIALTY FASTNERS 01803 866371
SPEED FLOW 0208 530 6664
THINK AUTOMOTIVE 0208 568 1172
UNICLIP AUTOMOTIVE 01932 355477
XRP INC USA (i) 562 861 4765

INTERCOOLERS

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

OIL COOLERS

AEROQUIP USA (i) 419 238 1190
CV PRODUCTS USA (i) 910 883 4096
DOCKING & CO 01372 857164
EARL'S USA (i) 310 609 1602
EXACT ENGINEERING 01803 866464
FAE MACHINE USA 317 243 3092
FLUID CONTROL PRODUCTS INC USA (i) 217 324 3737
Fax (i) 217 324 3717
GOODRIDGE UK 01392 369090
GOODRIDGE CA USA (i) 310 533 1924
GOODRIDGE INDY USA (i) 317 244 1000
GOODRIDGE EAST USA (i) 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 158660
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 (i) 310 534 1390
EARL'S USA (i) 310 609 1602
ED PINK ENGINES USA 818 785 6740
EXACT ENGINEERING 01803 866464
FLEXIBLE HOSE 01753 570863
FRAM FILTERS 01443 223000
KINSLER USA (i) 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: (i) 916 987 7629
www.drysump.com
CONNAUGHT 01795 843802
JENVEY DYNAMICS 01746 768810
MILODON USA (i) 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 682261
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 (i) 310 609 1602
RTRAC Germany (49) 9725 5075
STARTLINE UK LTD 01933 665752

THROTTLE BODIES

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

THROTTLE VALVES

JENVEY DYNAMICS 01746 768810
KINSLER USA (i) 248 362 1145
LUMENITION 0207 403 4334
TREVOR MORRIS ENG 01547 530289
TWM INDUCTION USA (i) 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 7413
ED PINK RACING ENGINES USA 818 785 6740
EDELBROCK USA (i) 213 781 2222
TREVOR MORRIS ENG 01547 530289

3.3 Engine Electronics

COMPUTER SUPPLIERS

ACES 01206 395124
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) 711 811
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 266655
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 264100
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 1300
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) 711 811
USA (1) 312 865 5200
CONNAUGHT 01795 843802
DATASPARES 0208 463 9229
SBD MOTORSPORT 0208 391 0121
McCLAREN ELECTRONICS 01483 264100
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 3BU England
AVL DEUTSCHLAND (49) 6134 7179-0
Gmbh Germany
DATASPARES 0208 463 9229
ENTRAN 01923 893 999
KISTLER INSTRUMENTS 01420 544477

kulite

KULITE SENSORS Tel 01256 460646
Kulite House, Stroudley Road, Basingstoke, RG24 8UG, England
MAGCANICA INC USA 858 454 8950
McCLAREN ELECTRONICS 01483 264100
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 9721-984399
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 227739
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

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

DINO PAOLI S.R.L. Tel: +390 522 300828
Fax: +390 522 304864
email: info@dinopaoli.com
Website: www.dinopaoli.com
Via Guido Dorso, 42100, 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
MGB TOOLS 0151 4236455
MACHINERY SALES USA (1) 520 490 4000
MAKINO USA (1) 800 552 3288
MEDDINGS MACHINES 01752 893277
MILLS ENGINEERING 01603 745531
MILLSITE ENGINEERING USA (1) 304 273 5353
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
T&S 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 470098

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) 901 581 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 (t) 800 413 6688
LINCOLN ELECTRIC USA (t) 216 481 8100

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

LATHES
RMT MECHATRONICS 01565 650411
LOCK-N-STITCH USA (t) 800 736 8261
MAGNAFLUX USA (t) 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

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 (t) 614 755 7000

WELDING EQUIPMENT
AMILLER ELECTRIC MFG USA (t) 800 426 4553

4.2 Factory Software

CAD & CAM SOFTWARE
BRIDGEPORT MACHINE USA (t) 248 299 1750
DASSAULT SYSTEMES USA (t) 818 673 2134
DELCAM 0121 766 5544
EXA USA (t) 781 676 8552
MITUTOYO UK 01264 353123
PARAMETRIC TECHNOLOGY 01252 817000
QinetiQ 08700 100942

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

PERF. SIMULATION
D.A.T.A.S 01603 506626
PI RESEARCH 01954 253600
PERFORMANCE TRENDS USA (t) 248 473 9230
RICARDO USA (t) 734 397 6666
SERVOTEST 0208 707 1400
VEHICLE DYNAMICS PERFORMANCE USA (t) 512 450 1035

Database 5
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 (t) 310 533 1924
GOODRIDGE INDY USA (t) 317 244 1000
GOODRIDGE EAST USA (t) 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 (t) 602 254 0024
LONGACRE RACING USA (t) 425 885 3823
OMS RACING 0113 2575956
PACE PRODUCTS 01284 850960

Redline MOTORSPORT

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 (t) 708 949 9100

COMPUTER HARDWARE
ADVANCED AUTOMOTIVE 01753 642019
CALEX INSTRUMENTATION 01525 371128
CRANFIELD 01234 751361
DYNOLAB USA (t) 206 243 8877
FASTER SYSTEMS USA (t) 415 332 6064
FUELTRONICS Australia (61) 0883632199
FUJITSU 0208 573 4444
GENESIS 01635 582255
KISTLER Switzerland (41) 52 224 111
NOVA USA (t) 615 832 6355
OLIVETTI 0208 785 6666
PERFORMANCE TRENDS USA (t) 248 473 9230
RACING CAR COMPUTERS 01279 812496
STACK 01869 240404

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

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

EAR DEFENDERS
DEMON TWEEKS 01978 664466
FASTENER FACTORY 01327 311018
RACING RADIOS USA (t) 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 (t) 403 277 6020
TITAN MOTORSPORT 01480 474402

FIRE EXTINGUISHERS
CHUBB 01932 785588

FEV

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 (t)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 696690

HAND PUMPS
EXACT ENGINEERING 01803 866464
FACOM 01932 566099
SILVERSTONE RACE SERVICES 01327 858441
SNAP-ON USA (t) 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 (t) 404 889 4096
HELLA 01295 272233

JACKS
ARGO MANUFACTURING USA (t) 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 (t) 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 (t) 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

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

RADIO SCANNERS
QINETIQ 08700 100942
RACING RADIOS USA (t) 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 0733 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 01931 402440
THE STRAIN GAUGING CO 01256 320666
SPA AEROFOILS LTD 01827 260026
UNIVERSITY OF HERTFORDSHIRE 01707 284270

SETUP GAUGES
A.R.T. USA (t) 914 889 4499
CYBER DYNAMICS 01869 347812
DEMON TWEEKS 01978 664466
ILONGACRE RACING USA (t) 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 (t) 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 (t) 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 (t) 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 (t) 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 (t) 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 (t) 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 01132 575956

TYRE WARMERS
BANDIT Australia (61) 3 9318 0644
DEMON TWEEKS 01978 664466
GRAND PRIX RACEWEAR 020 8987 5500
JAYBRAND 0733 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 749777

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 (t) 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

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 (t) 562 597 0001
AERODINE COMPOSITES	**USA (t) 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 (t) 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 (t) 970 472 1288**
AERODINE COMPOSITES	**USA (t) 317 271 1207**
APPLIED FIBREGLASS	01842 765339
ASTEC	01332 875451
B&K 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 (t) 727 539 0605**
COMPOSITE WINGS	**01953 885478**

Cranfield UNIVERSITY

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 (t) 706 658 2853
DU PONT	UK 01438 734000 Switzerland (41) 22 717 5111 USA (t) 302 774 1000
FIBREGLASS FABRICATIONS	0208 568 0293
G FORCE COMPOSITES	01243 544192
HEYES ENGINEERING	01453 750491
HITCO	USA (t) 213 516 5707
JANUS TECHNOLOGY	01753 869996

KOMPREX

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 (t) 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 (t) 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 (t) 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

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 (t) 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 608080
BRADY FABRICATIONS	01869 252750
BRISE ALLOY FABRICATIONS	01322 222343
BSS PARTS	01772 601602
CHEVRON RACING	01565 777195
CHIP GANASSI RACING	01243 544192
CML GROUP	0151 647 5531
COLMET PRECISION	01296 681658
COMPOSITE DESIGN	USA (t) 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 (t) 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 (t) 888 249 0013
MASON ENGINEERING	USA (t) 805 527 6624
MICRO CRAFT	**USA (t) 909 947 1843**
MIKE TAYLOR DEVELOPMENTS	01609 780123
MIRKO RACING	USA (t) 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 545366
RICARDO MIDLANDS TECHNICAL CENTRE	Tel: 01926 477152 Fax: 01926 319352 Email: iain.wright@ricardo.com
RILEY & SCOTT	USA (t) 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 (t) 413 2560861
SPA AEROFOILS LTD	01827 260026
SOUTH CERNEY ENGINEERING	01285 860295
UNICLIP AUTOMOTIVE	01932 355277
VAN DYNE ENGINEERING	USA (t) 714 847 4417
VIN MALKIE RACING	01565 777395

MOULDING

ADVANCED COMPOSITES	01773 763441
AERODINE COMPOSITES	**USA (t) 317 271 1207**
ASTEC	01332 875451
BENTLEY CHEMICAL TRADING	01562 515121
BUTSER RUBBER	01730 894034
CML GROUP	0151 647 5531
COMPOSITE DESIGN	USA (t) 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 (t) 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 (t) 970 472 1288**
ENABLING TECHNOLOGIES LTD	01983 550483
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 (t) 214 503 8044
CONCEPT MOTORSPORT	0208 568 0293
CONTINENTAL M/SPORT	USA (t) 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 (t) 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 721802
HARPERS PERFORMANCE	01642 818188
HARTWELL	01202 556566
HAUS OF PERFORMANCE	USA (t) 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 (t) 904 439 5283
LINGENFELTER	**USA (t) 219 724 2552**
MARDI GRAS MOTORSPORTS	01327 858 006
MATHWALL ENGINEERING	01252 703191
MATRIX ENGINEERING	USA (t) 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 (t) 408 776 0073
MIS M/SPORTTECHNIK GERMANY	(49)2636680394
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 (t) 812 546 4220
PRIMA RACING	0115 9491903
PRODRIVE	01295 273355
QUICKSILVER RACE	USA (t) 3016989009
QUORN ENGINE DEVELOPMENTS	01509 412317
RACE ENGINE DEVELOPMENT	USA (t) 760 630 0450
RACESPEC	01925 636959
RACE TECHNIQUES	01242 245640
RACING BENT	USA (t) 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 (t) 416 759 9309
SEARLE	0208 305 2250
STEVE CARBONE RACING	USA (t) 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 (t) 714 847 4417
WARRIOR	01825 764833
ZYTEK ENGINEERING	01332 48974
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 (t) 714 545 2755

HEWLAND

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 (t) 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 812454
ZF	Germany (49) 7541 77 2543 UK 0115 9860211

8.3 Suspension Services

SETUP SPECIALISTS

ACTIVE ENGINEERING	USA (t) 714 637 1155
ANDREASON RACING	01300 348499
ATHON MOTORSPORT	0114 2490 272
AZTEK	01509 261299
BEAUFORT RESTORATION	**01795 830288**

DAVID POTTER CONSULTING 0031(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**
c/o Isport International Website: www.shockbox.co.uk
Email: shbj@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 868177
AEROMET 01795 415000
GM DESIGN 017 985 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 531130
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 017 985 9964
FINECAST 01903 765821
H GRIFFITHS ENGINEERING 01582 600629
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 662288
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 262499
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) 3862552122500**
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 01491 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 017 985 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 887371
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 2693
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@atild.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
MATREX 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

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 832288
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

DEFORMATION TESTING
PHYSICAL DIGITAL 07880 703010

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 582044
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 6615
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 455611
TREVOR MORRIS ENGINES 0154 74289

DYNAMOMETER SUPPLIERS

AVL DEUTSCHLAND

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)2634680394
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 78608
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 435189
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 891277
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
SWINDON RACING ENGINES 01793 531321
TREVOR MORRIS ENGINES 0154 74289
VAN DYNE ENGINEERING USA (1) 714 847 4417
WARRIOR 01825 764833
WESLAKE DEVELOPMENTS 01797 224000

ENGINE BALANCING

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FLOWBENCH ANALYSIS

ADVANTEC NEW TECHNOLOGY (49) 2261 61901
AM TEST SYSTEMS 01253 780780
BOB WIRTH RACING USA (1) 510 487 3279
CRANFIELD UNIVERSITY 01234 754152
HAUS OF PERFORMANCE USA (1) 714 545 2755
INTEGRAL POWERTRAIN 01908 278600
LINGENFELTER USA (1) 219 724 2552
LOTUS ENG 01953 608000
MAXSYM ENGINE TECH 01608 685155
MOBILIS LAB CANADA (1) 450 647 1890
NEIL BOLD ENGINEERING 01204 71636
RACE ENGINE DEV USA (1) 760 630 0450
RACE TECHNIQUES 01242 245640
RICARDO INC USA (1) 734 397 6666
RICARDO 01273 794144
TREVOR MORRIS ENGINES 0154 74289
U.M.P.S 01784 439771

FUEL ANALYSIS

AM TEST SYSTEMS 01253 780780
BOB WIRTH RACING USA (1) 510 487 3279
CRANFIELD INSTITUTE 01908 694134
LOTUS ENGINEERING 01953 608000
QINETIQ 0 8700 100942

INJECTION ANALYSIS

ASNU 0208 420 4494

OIL ANALYSIS

AM TEST SYSTEMS 01253 780780
BOB WIRTH RACING USA (1) 510 487 3279
CRANFIELD INSTITUTE 01908 694134
LOTUS ENGINEERING 01953 608000
QINETIQ 0 8700 100942
RICARDO 01273 794144

RACE ENGINE DESIGN

RICARDO

RICARDO CONSULTING ENGINEERS
Tel 01273 794144 Fax 01273 794572
Email: dave.morrison@ricardo.com
Website: www.ricardo.com
Shoreham by Sea, West Sussex. BN43 5FG

TEMPERATURE MONITORING

AM TEST SYSTEMS 01253 780780
BOB WIRTH RACING USA (1) 510 487 3279
CALEX ELECTRONICS 01525 373178
CCA DATASYSTEMS 01525 378938
CONNAUGHT ENGINES 01795 843802
INTEGRAL POWERTRAIN 01908 278600
LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788
MIRA LTD 0247 635 5000
MOTOR SPORT ELE AUS (61) 73290 1309
MOTORSPORTS INTERFACE 01788 890412
QINETIQ 0 8700 100942
RACEPARTS 01491 37142
RICARDO 01273 794144
THE STRAIN GAUGING CO 01256 320666
TREVOR MORRIS ENGINES 0154 74289

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AVL DEUTSCHLAND

AVL DEUTSCHLAND Gmbh GERMANY (49) 6134 7179-0

TEST CELL DESIGN

MARTYR TEST TECHNOLOGY 01386 792125

9.3 Transmission Testing

TESTING SERVICES

ANEX SYSTEMS 01869 345038
ANTHONY BEST DYNAMICS 01225 867575

AVL DEUTSCHLAND

AVL DEUTSCHLAND Gmbh GERMANY (49) 6134 7179-0
AVONBAR 01932 840058
BEAUFORT RESTORATION 01795 83288
CRANFIELD INSTITUTE 01908 694134
DAVID BROWN VEHICLE TRANS 01484 422180
EUROTECH MOTORSPORT 02476 672959
HALIBRAND USA (1) 800 824 7947
UK 01978 361176
HAUS OF PERFORMANCE USA (1) 714 545 2755
HEWLAND ENGINEERING 01628 827600
LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788
MARK BAILEY RACING 01264 860114
MIRA LTD 0247 635 5000
PDS RACING 01977 611928

QUAIFE

QUAIFE ENGINEERING Tel 01732 741144
Fax 01732 741555
Email info@quaife.co.uk www.quaife.co.uk
Vestry Road, Sevenoaks, Kent, TN14 5EL
RICARDO 01273 794144
RICARDO 01926 319399
ROADSPEED PERFORMANCE 01453 750864
SCHENCK PEGASUS CORP (1) 248 689 9000
SERVOTEST LTD 020 8707 1400
SIEMENS AG Germany (49) 941 790 5313
THE STRAIN GAUGING CO 01256 320666
ZF Germany (49) 7541 77 2543
UK 0115 9869211

DEFORMATION TESTING

PHYSICAL DIGITAL 07880 703010

9.4 Suspension Testing

TESTING SERVICES

ANDY ROUSE ENGINEERING 02476 635182
CRANFIELD INSTITUTE 01908 694134
EUROTECH MOTORSPORT 02476 672959
HAUS OF PERFORMANCE USA (1) 714 545 2755
INSTRON SCHENK 01494 456789
JENVEY DYNAMICS 01746 768810
LOLA Tel 01480 451301
Fax 01480 456722
MARDI GRAS MOTORSPORT 01327 858006
MIRA LTD 0247 635 5000
PILBEAM RACING DESIGNS 01778 424838
RACE TEC DESIGN & ENG 01386 871292
RACRAFT MOTORSPORT 01707 45946
RATRACE MOTORSPORT 0208 203 8700
RICARDO 01273 794144
RICHARD HINTON RACING 01279 771667
RMCS (CRANFIELD) 01793 785359
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
ROEHRIG ENGINEERING USA (1) 336 431 1827
SERVOTEST LTD 020 8707 1400
SCHENCK PEGASUS USA (1) 248 689 9000
SPA DESIGN LTD 01827 288328
STARTLINE UK LTD 01933 665752

9.5 Brake Testing

DYNAMOMETER SUPPLIERS

BOSCH 01895 834466
MTS POWERTRAIN TECHNOLOGY 01932 351516
DYNOMITE USA (1) 603 329 5645
KISTLER INSTRUMENTS AG Tel Switz (41) 52 224 111
Fax Switz (41) 52 224 1414
Email info@kistler.com
PO Box, CH-8408 Winterhur, Switzerland
MIRA LTD 0247 635 5000
WILWOOD ENG USA USA (1) 805 3881188
UNICO (UK) LTD 01908 260000

TESTING SERVICES

HAUS OF PERFORMANCE USA (1) 714 545 2755
EUROPEAN FRICTION 017 9714837
MIRA LTD 0247 635 5000
RICARDO 01273 45561
SIEMENS AG Germany (49) 941 790 5313
THE STRAIN GAUGING CO 01256 320666

9.6 Metal Testing

CRACK TESTING

BEAUFORT RESTORATION 01795 83288
CMI GROUP 0151 647 5531
CRANFIELD UNIVERSITY 01234 754152
GM DESIGN 017 985 9964
MIRA LTD 0247 635 5000
ORANGE COUNTY USA (1) 800 359 8378
QINETIQ 0 8700 100942
RICARDO 01273 45561
RMCS (CRANFIELD) 01793 785359
SCHENCK PEGASUS USA (1) 248 689 9000
SPA AEROFOILS LTD 01827 260026
STRAIN GAUGING CO 01256 320666
SWINDON RACING ENGINES 01793 531321
UNIVERSITY OF HERTFORDSHIRE 01707 284270
VIN MALKIE RACING 01565 777195
WESTLAND HELICOPTERS 01935 702190

STRENGTH TESTING

AR CORNELL 01245 268098
ARMOR-ALL PRODUCTS 01799 513130
AVONBAR 01932 840058
BA HARRISON 016 2769351
CMI GROUP 0151 647 5531
CRANFIELD UNIVERSITY 01234 754152
GRIFFITHS ENGINEERING 01582 600629
HIGH TECH PERFORMANCE USA (1) 818 908 0943
DONCASTERS 01332 864900
MRE 0208 889 1633
MIRA LTD 0247 635 5000
NITRIDING SERVICES 01952 677372
ORANGE COUNTY USA (1) 800 359 8378
RICARDO 01273 45561
QINETIQ 0 8700 100942
RMCS (CRANFIELD) 01793 785359
ROUSH RACING USA (1) 315 591 4184
SCHENCK PEGASUS USA (1) 248 689 9000
THE STRAIN GAUGING CO 01256 320666
UNIVERSITY OF HERTFORDSHIRE 01707 284270
ZEUS MOTORSPORT 01604 878101

Database 10

SERVICES - GENERAL

10.2 Paddock Services

AIR FREIGHT FORWARDERS

ALL WAYS FORWARD 01242 228111
EMO AIR CARGO 0208 577 5100
FIRSTAIR 01784 421451
JIM RUSSELL FREIGHT 01332 811931
MSAS 0208 890 1355
MW FREIGHT SERVICES 01753 680800
RAPID INTERNATIONAL 01895 446442
UNION AIR TRANSPORT 0161 436 7074
WINWEST Australia (61) 2 522 4618

MOTORHOME

ATLANTIC COAST 01297 552222

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Fax +44(0) 161 426 0010
Website www.americanmotorhomes.co.uk
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Lomberhaey Farm, Andrewlane,
Highlane Village, Stockport SK6 8HY
DAVID WILSON'S TRAILERS 01825 740696
DUDLEYS 01993 703774
MIDLAND INTERNATIONAL 02476 336411
SPIRES OF OXFORD 01865 875539
ULTRA INTERNATIONAL 01766 770011
WESTCROFT AMERICAN 01902 731324

TRAILER HIRE

11/56 MOTORSPORT 01543 480309
BRIAN JAMES TRAILERS 01327 260733
DAVID WILSON'S TRAILERS 01825 740696
DC TRAILERS 01406 380224
ELLIS ENGINEERING 01277 631274
HOPKINS MOTORSPORT 0117 9509294
MOBILE PROMOTIONS 01832 733460
NEIL BAINBRIDGE RACING 01296 714547
TON HIRE 01892 836155
WARWICK TRAILERS 01962 732681
WARWICKSHIRE TRAILERS 01564 792337

Rear wing details

Pressures and flows around the rear wing

Continuing with the aerodynamics of an entire single seater, this month we look at pressure patterns around the dual-element rear wing of a 2001 Reynard Champ Car. Although the regulations on wing dimensions and configuration are unique to the category, once more some of the generalities apply to other applications.

Figure 1 shows the static pressures around the rear of the car, and clearly the rear wing develops high static pressure on its top surfaces and low static pressure on its lower surfaces. The pressure differential integrated over the wing's plan area results in about a third of the car's total downforce in this configuration. A rear wing develops significant drag too, and this type of wing might be expected to have a lift-to-drag ratio of around 3:1. Some of that drag arises from the static pressure differential between the forward and rearward facing surfaces ('pressure drag'). With a powerful wing like this though a significant proportion of its drag arises from the formation of vortices from the tips – once called 'induced drag' but now usually referred to as 'vortex drag'. The creation of these tip vortices induces additional static pressure reduction behind the wing, leading to further drag.

Figures 2 to 6 show vertical slices through the length of the car and the air around it. At the top of each plot is static pressure, showing where aerodynamic forces are being generated. The lower half of each plot shows total pressure, a measure of the energy in the airflow. As air passes over the body it loses energy due to skin friction, viscous shear forces and flow separations. Total pressure remains high where these effects have not 'stolen' energy, but where energy losses occur, total pressure decreases.

Figure 2 shows a slice along the car's centreline. Concentrating on the vicinity of the rear wing, the static pressures can again be seen to be high above and low below the wing, and this view illustrates how far off the wing surface the pressure changes are felt. Clearly the reduced static pressure region extends well below the wing to interact with the rear underbody. The total pressure plot also shows the influence of the wing on the airflow coming towards it as well as leaving it. Although the wake of the pop-off valve on top of the engine (and the roll hoop) extends well downstream towards the centre of the wing, the downwash induced by the wing ahead of itself brings higher energy air onto its leading edge. Aft of the wing, the upwash deflects the airflow up at quite an angle, and clearly also drags the core of the car's wake upwards, too.

Moving 350mm outboard (figure 3), the environment around the rear wing is rather different. The total pressure plot shows cleaner 'onset flow', with more high-energy airflow approaching the wing and passing under it as well as over it. This portion of the wing works most effectively, generating the lowest pressure coefficients of the whole span under the suction surface.

Another 100mm further outboard (figure 4) and the onset flow is different again, as shown by the total pressure plot. Well upstream of the rear wing the driver's mirror can be seen to generate a wake, and just ahead of the wing the influence of the details on the rear of the sidepod and the rear wheel can also be seen. These effects combine to reduce the total pressure of the airflow passing beneath the wing, although again the wing's downwash brings more energetic airflow down towards its leading edge.

Y = 525mm (figure 5) is in line with the inside face of the rear wing end ➔

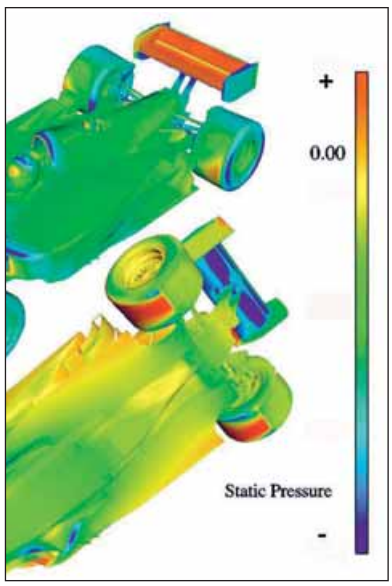
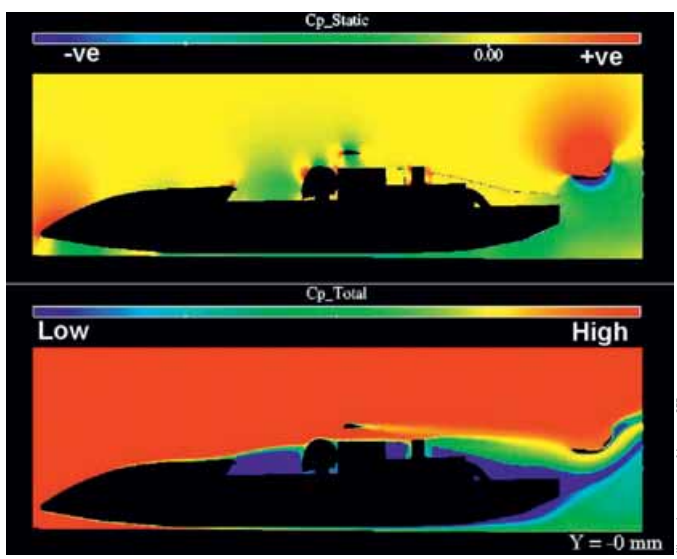


Figure 1 (left): the static pressure differential between the top and bottom surfaces of the rear wing enable it to generate almost a third of the car's downforce in this configuration

Figure 2 (below): a slice at the car's centreline shows the static pressure differential, and the total pressure plot shows how the wing influences the airflow



Illustrations courtesy: Advantage CFD

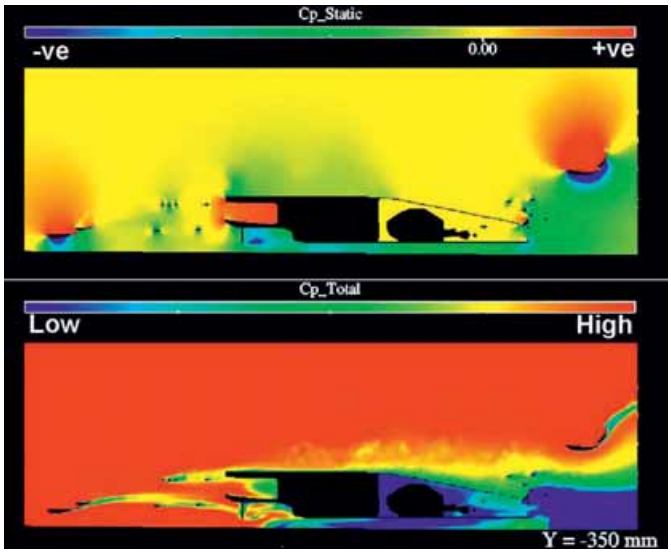


Figure 3: 350mm outboard of the centreline the onset airflow is at its best, and the rear wing is working at its best

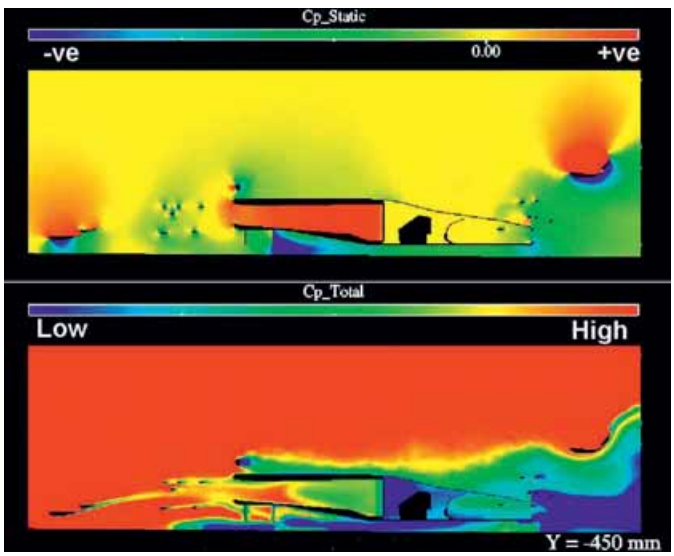


Figure 4: 450mm from the centreline and upstream components are taking their toll on the quality of the onset airflow

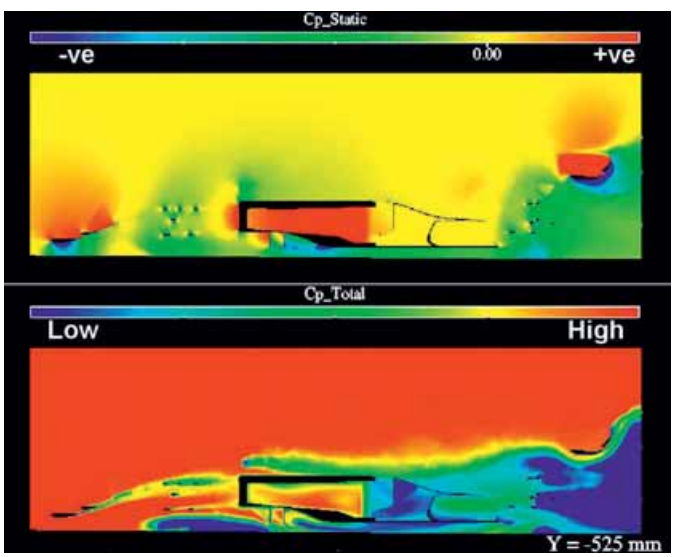


Figure 5: in line with the inside of the rear end plate and the disturbance from the wheel is trying to make its presence felt

plate. The total pressure plot shows less energetic flow reaching the wing, and the disturbance caused by the rear wheel is more apparent. The static pressure plot looks rather different here, the end plate delineating the high

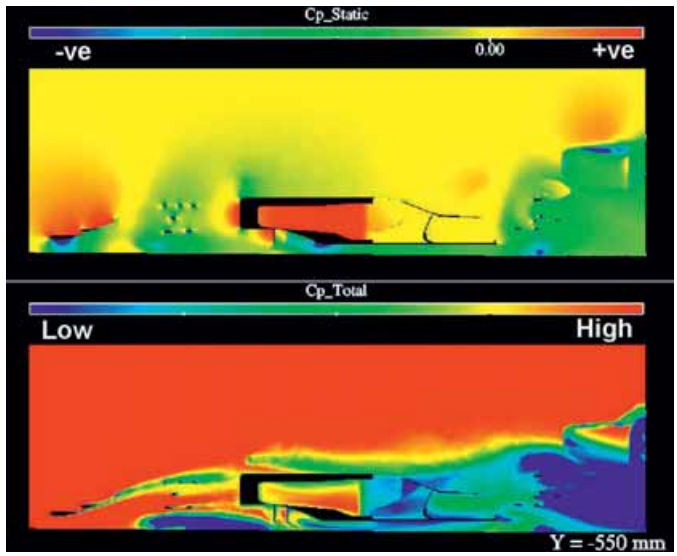


Figure 6: 550mm from the centreline and the rear end plate outline can be seen via its influence on both plots

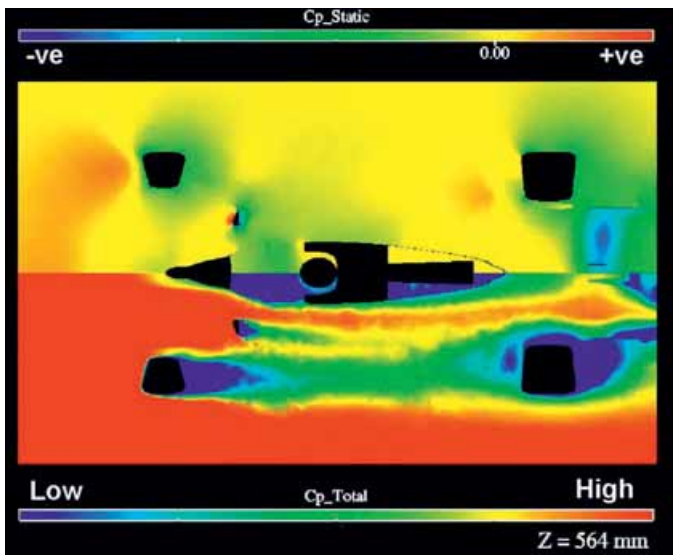


Figure 7: this horizontal slice just below the rear mainplane shows how the wing works at its best where the total pressure in the onset flow is at its highest. Notice how the wheel wake is pushed outboard of the end plate

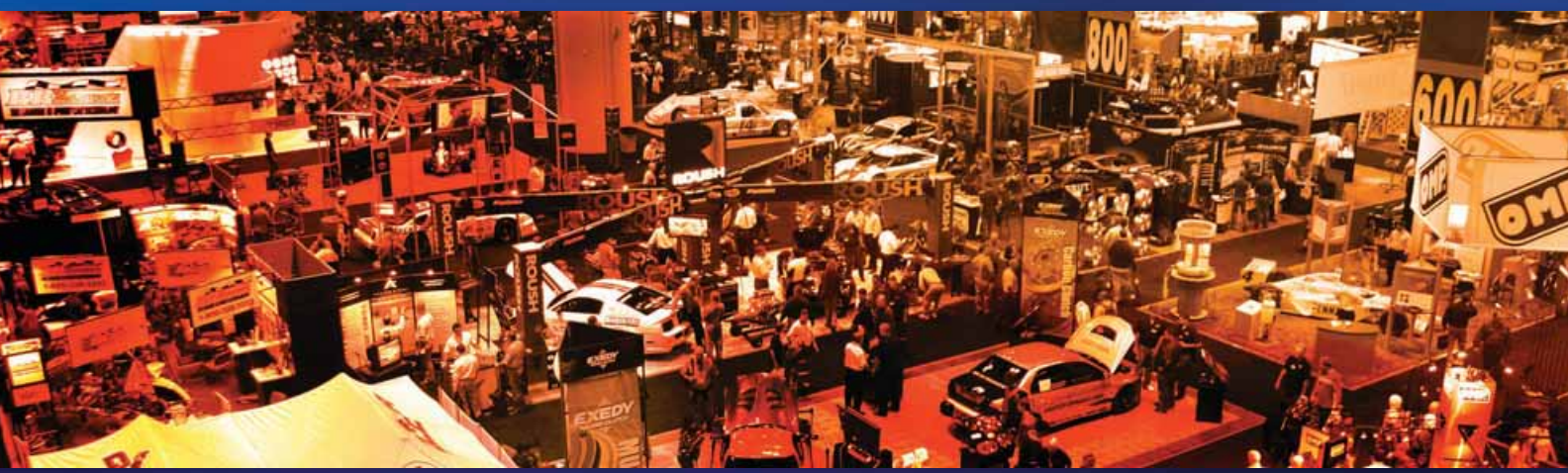
static pressure region above the wing. The lower tip vortex core (shown in dark blue) can just be made out in line with the bottom of the end plate.

The slice at Y = 550mm (figure 6) is taken just outboard of the end plate, the shape of which is visible in both plots here. In the static pressure plot the end plate outline is made apparent by the upper tip vortex core (dark blue) forming on the top edge, and the small strip of raised static pressure (yellow) forming ahead of the Gurney on the outboard rear edge. In the total pressure plot there are losses from the end plate's leading edge that trail back and down with the prevailing airflow direction. And the low total pressure (dark blue) immediately behind the vertical Gurney is also visible.

Figure 7 is looking from above at a horizontal slice just below the rear wing mainplane. The lower half of the plot shows total pressure, and the narrow band of high-energy airflow (red) approaching the wing part way across its span is evident. The static pressure plot in the upper half of the plot shows the low static pressure region below the mainplane is at its broadest (front to rear) in line with where the total pressure in the onset flow is at its highest (a third way across the span). Note also how the end plate seems to segregate the wheel wake from the flow under the wing.

So although the rear wing exerts considerable influence on the approaching airflow and the regions around it, clearly its performance is in large part governed by the 'quality' of the onset airflow. RE

Everything happens here first!



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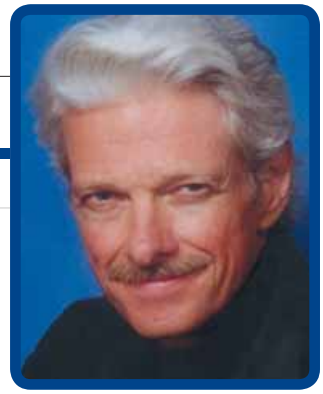
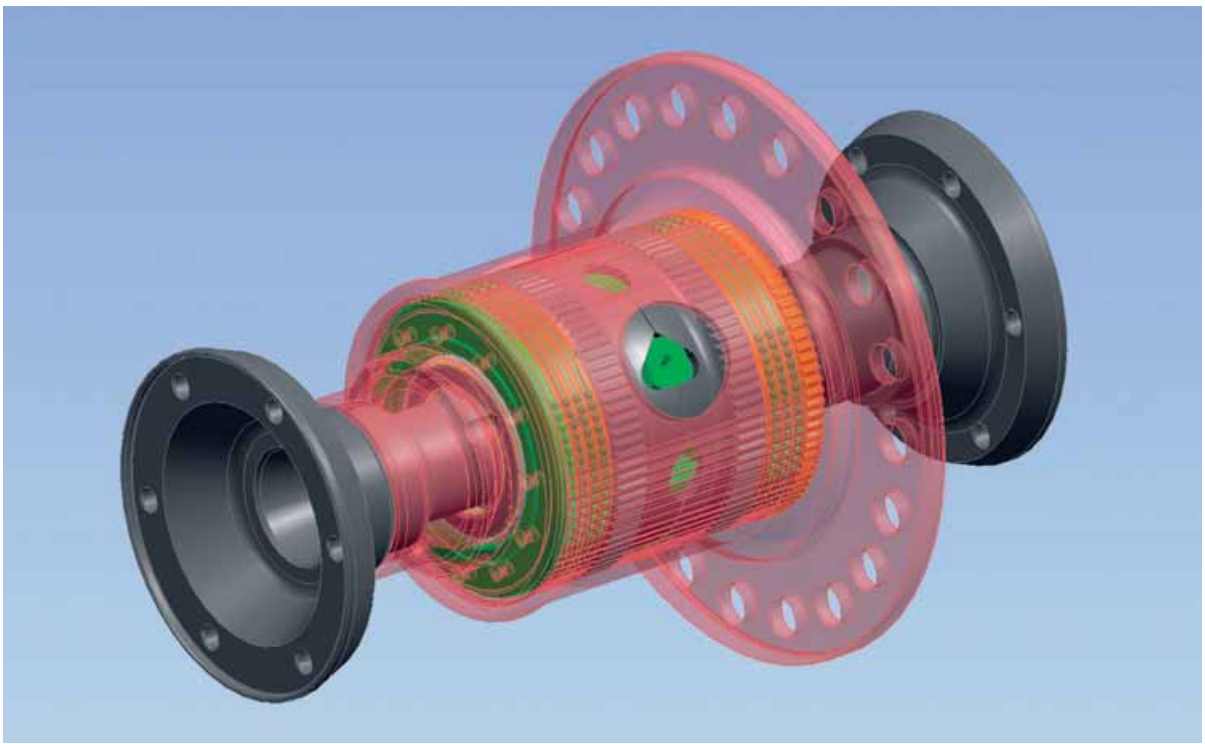


Diff differences



The plate-type differential is generally favoured in motorsport arenas where active diffs aren't allowed, due to its greater tuneability and resistance to wear

CAD illustrations courtesy of Xtrac

Q **Which differential would be best for road racing in my 300bhp Porsche? The question arises because a supplier suggests that a plate-type limited slip is better suited to road racing than a worm gear-style torque bias diff. I have used both and found I liked the torque bias diff and, from what I read, I thought it was a better design. The supplier states that the LSD will be better in corner entry and exit. What is your opinion?**

A Clearly, both worm gear and clutch pack differentials have their adherents, and both are used successfully in various types of motorsport. You say you have personal experience with both types of final drives, and have already formed a preference, so the most obvious answer would be that you've answered your own question and don't need my advice.

However, the situation is actually a bit murkier, because the behaviour of both types of differential can vary according to design and tuning details. Both types are similar in that they generate a locking torque in response to the total torque being transmitted. In both types, the locking torque depends on pressure angles. In a ZF-style clutch pack design, the angles are those of the ramps on the spider shaft and the housing halves. In a worm gear design, it's primarily the helix angle on the gear teeth themselves, and secondarily the pressure angle of the tooth profile. Lubricant choice also influences behaviour.

Consequently, all clutch pack diffs don't act alike and neither do all worm gear diffs. A lot depends on how a specific example is tuned.

That said, the clutch pack design probably offers a greater range of tuning options, and probably greater wear resistance. With the worm gear designs, we are trying to make gear teeth act as a friction device. Clutch discs are designed to be a friction device, whereas gear teeth can be made to act as a friction device, but they are less comfortable in that role. This affects the →

> **"BOTH CLUTCH PACK AND WORM GEAR DIFFS RELY ON COULOMB FRICTION"**

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**

ability of the differential to maintain consistent properties through time, and the unit's longevity, too.

The pressure angles determine how rapidly locking torque builds as transmitted torque increases. The pre-load in the diff determines how much locking torque there is when no torque is being transmitted. A clutch pack is easily pre-loaded, and it maintains its pre-load relatively well, especially if the pre-load is applied by springs or some other compliant system such as dished clutch plates. Worm gears can similarly be pre-loaded, but because they are not very compliant, the pre-load rapidly goes away as the teeth wear.

Courtesy of Quaife

A worm gear diff is well illustrated by this ATB (automatic torque biasing) unit from Quaife

One limitation in worm gears is that the pressure angle is generally the same for forward torque and rearward torque (as when engine braking, or when transmitting brake torque from a single rear brake, as seen in FSAE cars). In a clutch pack diff, it is possible to use different ramp angles for power and deceleration.

Another peculiarity of worm gear designs is that because power and deceleration apply force to opposite sides of the gear teeth, pre-load doesn't have identical effects in both directions. If we pre-load the gears in the direction they're loaded under power, what happens under deceleration is that we have diminishing friction with increasing reverse torque, until the pre-load is overcome, at which point locking torque is zero. As reverse torque increases beyond that point, locking torque builds again. With a clutch pack, pre-load has similar effect in both drive and deceleration modes.

This means that we can make a worm gear diff act differently in drive and deceleration, but not in a manner that's independent of pre-load.

One interesting, though uncommon, trick we can use in a worm gear diff is to use plain thrust washers to absorb the thrust of the worm gears in one direction, and needle thrust bearings to absorb the forces in the other direction. This can afford us a limited measure of difference in friction depending on torque direction.

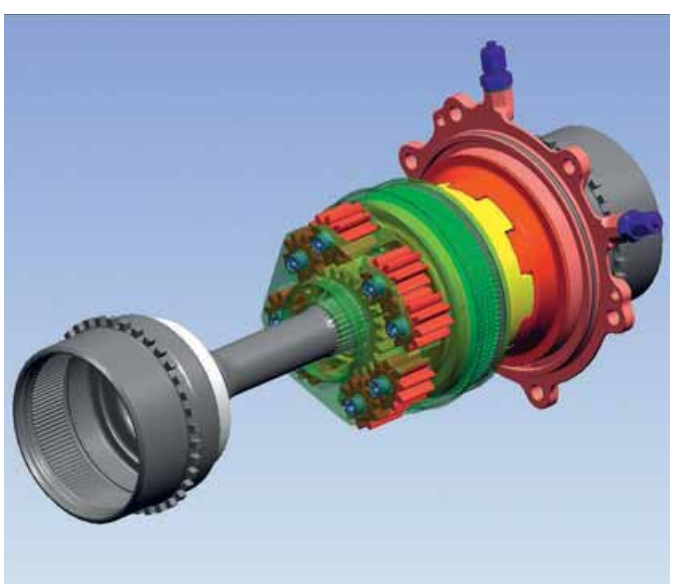
Last year's North Carolina State University FSAE car had a diff like this. It will be clear, however, that using these tricks is not as straight-forward as varying the ramp angles in a clutch pack diff.

Finally, neither option is ideal, because neither is speed sensitive. Both clutch pack and worm gear diffs rely on Coulomb friction, which is largely dependent on normal force and not speed. We would rather have the locking torque vary with the speed difference between the wheels, either entirely or at least in part. This argues for either a pure viscous limited slip, or a design that uses a pump, driven by relative output shaft rotation, to load a clutch pack, or one that combines viscous effects with a clutch pack.

> **"NEITHER OPTION IS IDEAL BECAUSE NEITHER IS SPEED SENSITIVE"**

Cliff Hawkins of Xtrac adds:

My preference would be VCP (viscous combined plate), then a plate diff, then a worm diff. The worm differentials don't have the tuneability for motorsport though, as pointed out above, which probably explains why Xtrac has never fitted one in a racing gearbox. Without pre-load neither of the two differentials mentioned here will cope well with mixed surfaces, a fact which lends more weight to your speed sensitive argument. RE



Viscous effect adds control to a plate-type diff in a viscous combined plate unit

Xtrac 247 heavy duty unit is an adjustable plate diff, also available with viscous

DON'T SACRIFICE THE WIN

The difference between WINNING and LOSING is STAYING CONNECTED...

Get Connected!

ADEL WIGGINS GROUP *Flexible Tube Connectors*

SECURE YOUR WIN

Stay connected with Adel Wiggins Flexible Tube Connectors! The difference between winning and losing is in the connection. Do not sacrifice a win to a simple hose blowout or burst. This occurs when conventional hose clamps or barbs fail to secure the hose located between the connections or components. Adel Wiggins Flexible Tube Connectors eliminates these failures. This is why they have caught the attention of so many professional racers today. One of the main reasons for its popularity is its ability to be removed or installed with only one hand quickly and easily, whether they are being used with tubing or hose. Adel Wiggins Flexible Tube Connectors are offered standard in lightweight aluminum and are available in stainless steel or titanium upon special order. They have an operating temperature range from –120° F to 800° F and are able to withstand boost and pressure levels in excess of 125 PSI.

SAFETY-LOCKING, ONE HAND INSTALLATION

The locking latch design eliminates troublesome and time-consuming installation of safety-wire or the necessity of tools to make the connection. The electrical bonding feature eliminates the external clamps, fasteners and jumper wire required in some applications. Elimination of lock wire holes, bolt-on bars, grounding clamps, snake clamps and jumper wires removes what can be a cumbersome and unattractive connection. The W900 series minimizes weight and unit cost, while retaining the proven performance and reliability of other WIG-O-FLEX connectors.

APPLICATIONS

FEATURES: Lightest of all flexible tube connectors

- Saves installation and tear down costs • Full range of stocked sizes: 1/2" to 4"
- Saves time, space, and weight • Easy, one-hand installation • Design flexibility

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