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INSIDE: PRI ORLANDO SHOW PREVIEW

The International Journal

Racecar engineering™

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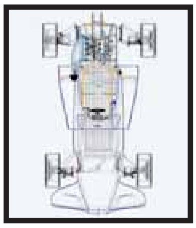

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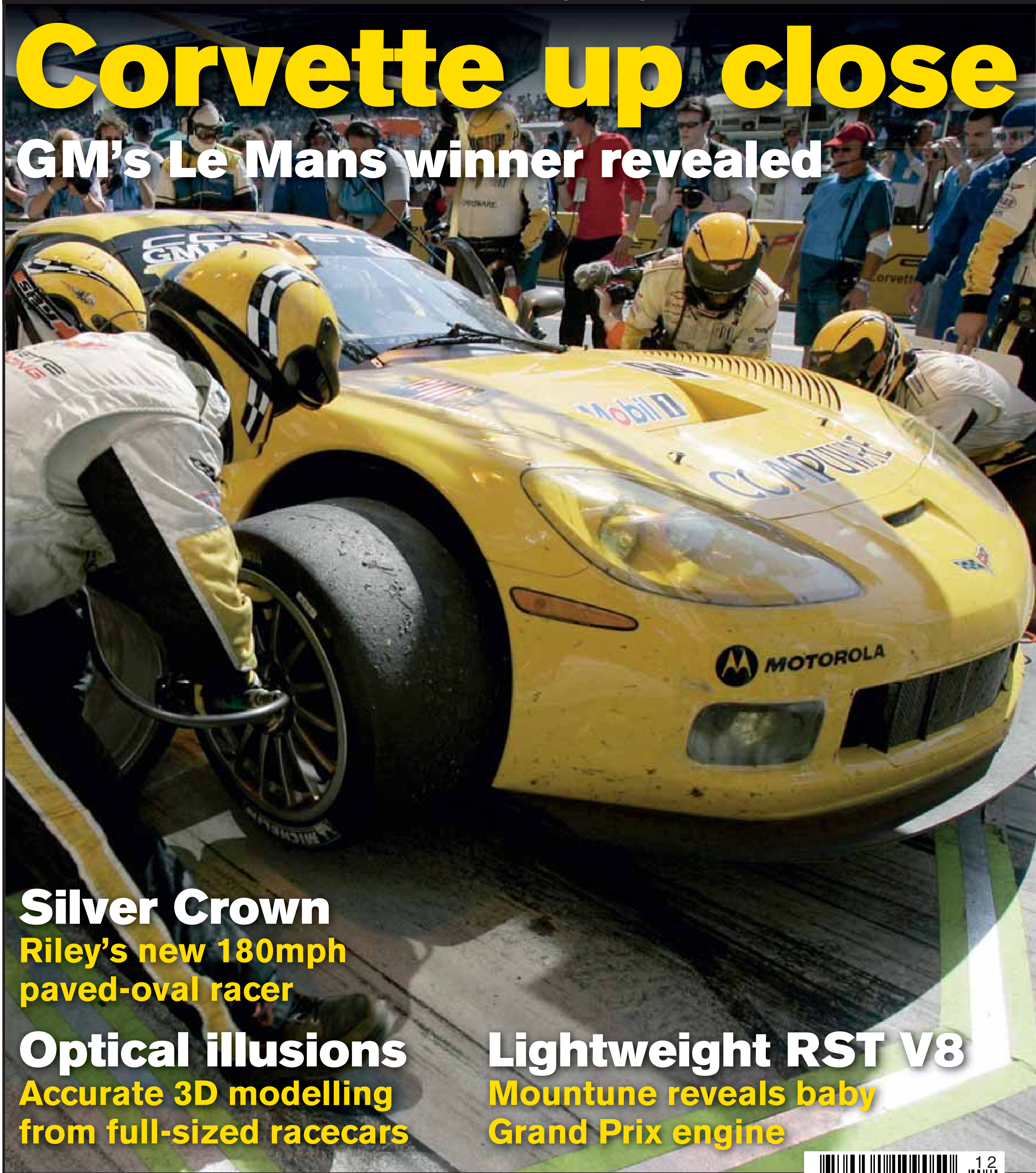

Corvette up close
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Looking for a Christmas gift for someone who has everything?

The International Journal Racecar engineering

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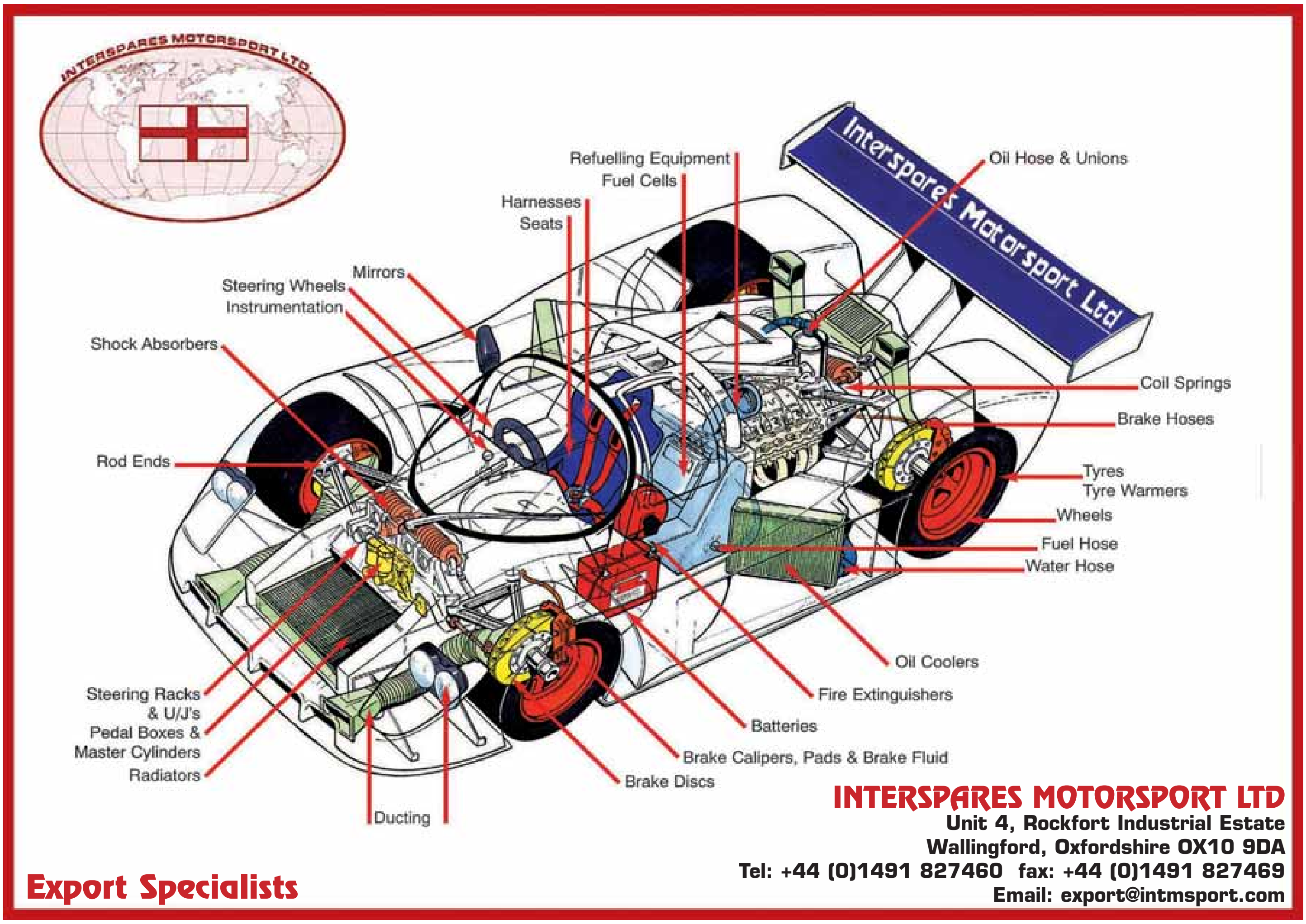
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Write Line

Are you running a racecar and, if so, are you running it on an alternative fuel? Stupid question; you run it on the stuff that comes from the pump like everybody else. Why? Because there are no points awarded for making life difficult for yourself. And who can blame you. In the typically hand-to-mouth world that is motorsport, there is no room for the bigger picture or the higher ideal. Not unless you have money pouring out of every pocket, in which case going racing will soon put a stop to that.

But energy efficiency is something motorsport needs to embrace and, more importantly, needs to be seen to embrace. Consider this – global warming and melting polar ice caps is clear to everyone except the most delusional. Carbon dioxide is a major contributor and humans produce 75 per cent of the planet's CO_2. Does that make you and your racecar guilty of all the world's climactic ills? No, your contribution is negligible, but not everyone will see it that way.

Attitudes toward energy consumption are changing. Already, SUV drivers are having abuse hurled at them by the more fundamentalist greens and very soon motorsport is going to be as socially acceptable as smoking has become today. In short, the sport we love, and the industry many of us depend on, is heading for a major image problem.

> “VERY SOON MOTORSPORT IS GOING TO BE AS SOCIALLY ACCEPTABLE AS SMOKING”

That is, unless we can head it off before the anti-motorsport lobby gathers momentum. What can we do? Well, standing back and pointing out, perfectly reasonably, that 'it is not all our fault,' will not win us support from anyone. Motorsport has to be seen to be actively contributing something and seen to be a force for good. In fact, anyone involved in motorsport knows that, for the power they generate, racing cars are actually pretty fuel efficient. That has come at the price of millions of man years of research and development.

Also, some teams have already toyed with more efficient fuels like bioethanol, LPG and diesel. But asking for an average racer competing in an average series to switch to an alternative fuel is not realistic. You are only likely to consider a switch if you can see some advantage. Equivalency formulae for different fuels are an option but success is usually rewarded with a tweak of the ratios, instantly robbing you of any advantage.

It would be more attractive if alternative fuels brought a financial advantage. If there was racing budget available through an alternative fuels strategy, then a disorderly queue would form in no time. If car, engine and fuel manufacturers were obliged to spend a proportion of turnover on alternative fuels research, that could include motorsport. Suddenly the sport would see money coming from research and development spend, not just from marketing budgets. All that engine development budget would have a payback as alternative fuels were made to deliver the kinds of power and fuel efficiency motorsport demands. It would also mean our sport would once again be perceived as the laboratory for better road cars rather than a stage for the wealthy to squander the world's precious resources. It could happen. Start lobbying your political leaders now.

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Charles Armstrong-Wilson

The International Journal
Racecar engineering

Pit Crew

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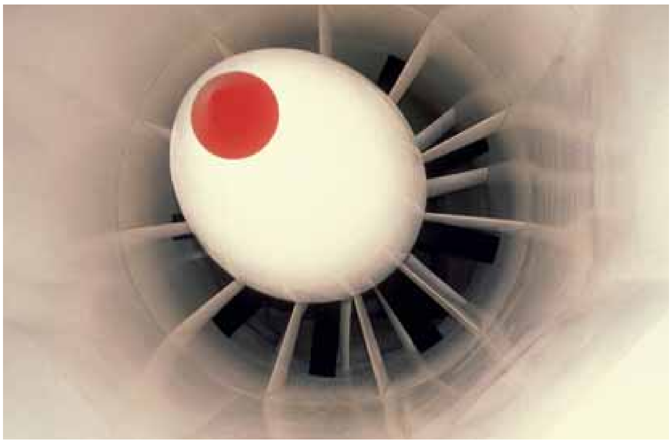
NEWS IN BRIEF

- Formula 1's new 2.4-litre V8 engines are proving unpopular with drivers who claim they are 'boring'.
- BAR Honda's attempt to hit 400kph on the Bonneville salt flats was interrupted by a deluge of rain. The campaign has not however been abandoned.
- Silverstone is looking to receive a £600m overhaul and redevelopment. The BRDC is currently seeking private sector investors.
- SCSA stock cars are set to run on road courses in 2006. The English version of the ASA series had previously just raced on the Ovals at Rockingham and Eurospeedway. Four road courses are on the provisional calendar.
- Champion Audi won the 2005 ALMS once again using its dominant Audi R8s. The replacement for the R8 is strongly tipped to make its ALMS debut next year.
- Radical has broken the production car lap record at the Nürburgring using a road-registered SR8 LMP3. The record now stands at 6m55s – a full 20 seconds faster than the previous record.
- Renault edged out McLaren in China to win the F1 World Constructors' Championship. The Enstone, England team was delighted.
- Porsche's RS Spyder dominated the LMP2 class on its ALMS debut. Lapping Laguna Seca within seven tenths of a second of the pace-setting Zytek LMP1.
- Ferrari obsessed GT2 team Scuderia Ecosse has been linked to a rumoured new LMP project from the Maranello constructor, despite team boss Stuart Roden commenting to RE at Le Mans that he did not think LMPs had any place in sportscar racing.
- British Formula Vee chassis manufacturers AHS, GAC and Storm lined their cars up at Snetterton recently for a forthcoming Racecar Engineering feature.
- Formula Ford is set for a new engine. The 1600cc powerplant was to be revealed at the Formula Ford Festival as RE closed for press.

The importance of wind

Whilst the FIA is using CFD to find out how F1 cars operate together, and to try and promote better racing, the competitors in its premier series continue to invest in aerodynamic tools. Toyota F1 is commissioning a second tunnel at its Cologne HQ. The new tunnel will be a 50 per cent scale unit similar to the one the Japanese funded, German-based team already uses. Construction work started in October and the team aims to have the tunnel up and running by the end of 2006.



LAT

Top Formula 1 teams continue to invest heavily in wind tunnel test facilities

Meanwhile, in Switzerland BMW is planning to increase the number of staff at its Hinwil facility, mainly to allow the outfit to operate the 100 per cent wind tunnel it has acquired there 24 hours a day.

A source in a front-running team claimed that 'wind tunnels and people can do in about 30 seconds what computers take weeks to do. Using a bit of both is the best thing to do.' A comment which appears to reflect the current feeling within the industry that suggests a combination of both CFD and wind tunnel work is the ideal solution. This has not been lost on BMW's F1 team (or, in its predecessor form, Sauber) who commissioned the Dalco super computer 'Albert' earlier this year, primarily for CFD work. The new staff increases, allied to the use of 'Albert', should greatly increase BMW F1's aerodynamic development capability.

Whilst it appears that F1 teams are still willing to spend millions on finding that extra 10th with aerodynamic solutions, it is worth noting that the draft 2008 Formula 1 regulations (see debrief V15N9) demand far more basic and perhaps less critical aerodynamics.

Restricted V10s look strong

Ian Harris

Even with the new restrictions in place, old spec V10s are rumoured to be outperforming current spec V8s, which could make for an interesting 2006 season…

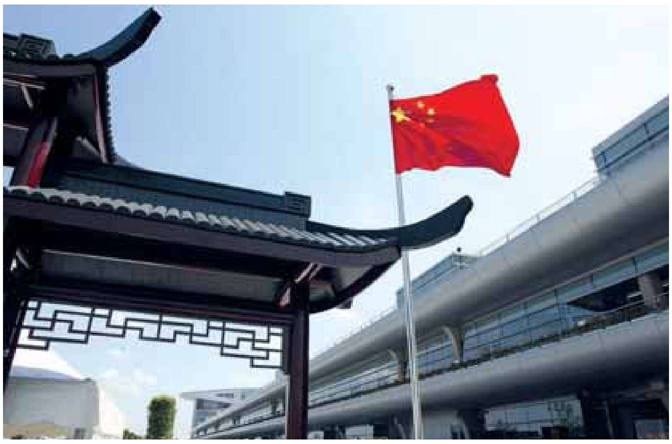
Proposals on how to restrict V10 engines used in Formula 1 from next season have been revealed. Old spec 3.0-litre V10 engines will be fitted with a 77mm air restrictor and be limited to 16,700rpm. This aims to provide equivalency with the 2.4-litre V8s that most teams will be using in 2006. However, recent comments from senior figures within the teams suggest there is a feeling that a good quality restricted V10 would still have an advantage over the V8s. Allied to this, rumours suggest that some teams who officially intend to run a 2.4 are in fact developing restricted 3.0-litre units.

Currently there is a gentleman's agreement between Ferrari, Honda, Mercedes, Renault, Toyota and BMW not to use the 3.0-litre engines, but speculation suggests at least one team has broken the agreement already.

Push for Chinese motorsport

Four leading European figures in the international motorsport industry have formed Asia Racing Technologies (ART), an organisation that aims to nurture the embryonic Chinese motorsport industry. If ART achieves all its aims a Chinese Formula 3 chassis could hit the track in the not too distant future.

GianPaolo Dallara, Jean-Claude Migeot, Bruno Engelric and Luca Birindelli are going to be working with Chinese counterparts to achieve their objective. 'The four of us have seen a lot of success over the past 25 years and we believe the time has come for us to give something back to motorsport,' explained Birindelli. 'China now has the top of its motorsport pyramid but it will only develop outside the Chinese Grand Prix if we really invest time and expertise to assist China in developing home grown motorsport from the base right to the top of the sport. Our mission is to provide our Chinese partners with the right training, technology and logistics to fast track the development of the Chinese motorsport industry.'



LAT

European industry figures aim to fast track the Chinese motorsport market

China already features highly on the world map of the automotive industry and, since the building of the impressive F1 circuit in Shanghai, has started to appear on the Motorsport map, too. Chinese road car manufacturer Brilliance has been linked to a WTCC campaign in 2006 and there has been strong support for the Chinese A1 Grand Prix entry.

ART has already started a recruitment programme for Chinese engineers and is looking to invest in the nation's motorsport development. A scheme run directly by ART will see the training of 15 to 20 engineers each year. Young Engineer Training aims to create a minimum population of Chinese motorsport engineers of between 50 and 100 – all of whom will have relevant practical experience at F3 level by 2010.

'The tutoring cycle will consist of a three-month training period and a nine month practice period in Europe, inside ART companies and associated companies,' explained an ART source. 'This will be followed by a minimum 12-month practice period in China, and we believe that every year 15 to 20 engineers will be trained in mechanical design, aerodynamics, engine development, manufacturing, electronics and racecar preparation. We hope the future Chinese motorsport entrepreneurs will emerge from this population.'

By the time this population has developed, ART will have set up and prepared research and development facilities near the Shanghai circuit. This Chinese version of 'Motorsport Valley' will promote individual enterprises by graduates of the young engineer programme, and is likely to support new championships in China and the Asia-Pacific region.

In addition, ART will support a Chinese racing drivers' school, a Chinese F3 championship and a project to design, contruct and run a Chinese F3 car, complete with Chinese engine.

Honda finally takes the plunge with BAR

Honda has revealed it is the latest manufacturer to have a full works Formula 1 team after purchasing BAR. The Japanese manufacturer has acquired a 100 per cent shareholding in the Brackley, England-based team. 'After discussing Honda's future F1 participation, we have decided that Honda should own 100 per cent of the team,' explained Honda's Hiroshi Oshima. 'From next season, we will be even more energetic in our F1 activities, working hard as a team in order to improve our technology, develop our young engineers and achieve our goal of winning the world championship.'

Earlier this year Honda purchased a 45-per cent share of the team and has now acquired the 55-per cent stake owned by British American Tobacco. Honda will now join BMW, Toyota, Renault and Ferrari as full manufacturer teams.

It won't be the first time Honda has had a factory F1 team – in the 1960s Honda had a moderately successful campaign before withdrawing. Engine supply deals have also netted a number of world championships in recent years.

[In 2000 Honda returned to F1 with BAR when a Harvey Posthlewaite-led works chassis project was abandoned after the designer died. The BAR deal saw Honda assist with chassis technology development as well as engine supply.]

Rumours circulating at the Japanese Grand Prix suggested Honda is also looking at supplying V8 engines to a so-called 'B' team to run next year. Dome was linked to the new team which could be run out of the former McLaren factory in Woking, England. Dome is known to have strong links with Honda and also harbours long-held aspirations for F1, even going so far as to build the F105 a Mugen-Honda powered prototype F1 car in 1996. A second Honda-influenced team would give the manufacturer a second vote in the increasingly controversial GPMA/FIA dispute, and a greater say over any rule changes.

The FIA has revealed that it fully expects at least two new teams to enter Formula 1 by 2008 and that there should be 24 cars on the grid. Also that costs will be slashed, but so far no word on how.

LAT

Honda is the latest manufacturer to join the F1 race, now fully controlling BAR

INTERCOM

MIKE BRESLIN

Former British grand prix commentator Murray Walker always used to say that Formula 1 spelt backwards is 'if'. But actually Murray, it's Eno Alumrof, which sounds like the name of a seedy, basement-dwelling fence in a crime novel, but we'll let that pass. Point is, there are more variables in this sport of ours than in most others: what if he'd been in that car? What if his engine had lasted? What if his lap had come before the rain…? And so on.

But to me, the biggest 'what if' of them all is this: what if there had never been any interference in the design of Formula 1 cars? What if the purity of racing the 'fastest cars on earth' had always been the driving principle – what if nothing had ever been banned? Or, to put it another way, what if Formula 1 was formula libre?

Where would we be? Would we have computer controlled moveable aerodynamics or would ground effects and rear fans make the cars low, wingless, wide and flat?

Then again, what of the mechanical grip: big fat slicks, or maybe eight wheelers, part Tyrell P34 at the front and part Williams FW08B at the rear? I guess the cockpit would be enclosed, maybe the wheels too? Perhaps the fascinating thing would be the balance between engine size and aeros – and let's not forget turbocharging and supercharging.

But whatever the winning 'formula' would be it seems fair to say we would still be in the same position, with all the cars looking pretty much alike, firstly because after years of development on the track and in the windtunnel the optimum package would have been reached, secondly because most teams would be unable to afford the development and we'd have a grid of copy-cat cars – just like all those Lotus 79 clones in 1979.

I guess we'd also have exotic (maybe dangerous) fuels and materials, and enough driver aids to make the pilots redundant – believe it, in 1993 they were even looking at a system that would automatically apply opposite lock, I seem to remember.

And what about safety? Would the drivers have to wear G suits? Why not take it a step further, ejector seats maybe – just look out for the tunnel at Monaco…!

Just a dream, or nightmare. But wouldn't it be great if someone did build a no-holds-barred racecar, to show what could be done, provided you could find a place to run it. The best racecar ever, coming to a salt flat near you soon…

Grand Prix Masters hits the track

Delta Motorsport's Grand Prix Masters car took to the track for the first time in October. After completing 300 miles of running at the Pembrey circuit in South Wales the test was declared a success.

The new series, set to start in South Africa on 13 November, pitches retired F1 drivers against each other and has attracted a number of household names.

The Reynard 98I Champ Car based chassis was thoroughly reworked by Delta, making it more modern in appearance and more driver friendly though without employing so called driver aids. Weighing in a 650kg less driver, the cars should provide some spectator friendly high speed racing.

The Grand Prix Masters car has undergone successful tests in Wales

Power is supplied by a Nicholson-McLaren 3.4-litre V8, an engine that is essentially a developed and naturally aspirated Cosworth XB engine. The 600bhp 80-degree unit is not rev limited and produces maximum power at 10,400rpm and torque at 7800rpm

A six-speed sequential transmission supplied by Ricardo is actuated by an Equipmake paddle shift system. However, drivers will still have to pull away using a foot clutch though gearshifts are clutchless.

AP Racing supplies the braking system, which features cast iron discs and carbon metallic pads. 'We have not opted for full carbon brake discs as part of the attraction of the Grand Prix Masters series will be proper overtaking – something that is incredibly hard when you have short braking distances that carbon discs allow' explains Delta Motorsport's Simon Dowson.

Control tyres will be supplied by Cooper Avon, and currently compounds are being selected for the GPM series.

'This series is all about close, exciting racing that provides entertainment to everyone watching.' claims Dowson. 'For that reason we have designed a car that is seriously quick but also balanced and stable – something that allows the drivers to use their skill to drive on the limit. We will also keep a close eye on how much drivers can adjust their cars. The plan is only to allow limited adjustment in areas such as aerodynamics, ride height, suspension settings and so on. We will even choose gearbox ratios before we get to the track to ensure that all the cars are as closely matched as possible. I think you can compare them to a modern GP2 car and say that, while in performance terms they will be very equal, our cars will be more driver-friendly and certainly will slide around a bit more.'

New student competition

European Formula Student/SAE teams had a new event to contest in England in October. The Institute of Mechanical Engineers (ImechE) organised an event at Silverstone entitled 'Learn To Win'. The event expected between 20 and 30 teams to take part in the event as Racecar closed for press, including some from continental Europe.

At the two-day event students had a full day of engineering seminars and feedback session covering every element of the Formula Student competition, with talks being given by a number of established engineers. David Gould of Gould Engineering, spoke on design, John Hilton and Nick Chester of Renault F1 spoke on engine work and car development respectively whilst Ford employees Terry Griggs and Richard Brown spoke on the cost and presentation events seen in Formula Student. Finally, MSA Scrutineer Chris Baker spoke on car safety.

The following day students were scheduled to take part in an all day dynamic only event that would train drivers and allow teams to practice running the car.

Talk of a four-event UK based dynamic championship in 2006 was said to be wide of the mark.

Italy's version of Formula SAE was deemed a success, with Graz University of Technology's TUG racing team taking the spoils.

Meanwhile Kanazawa University won the Student Formula SAE Competition of Japan.

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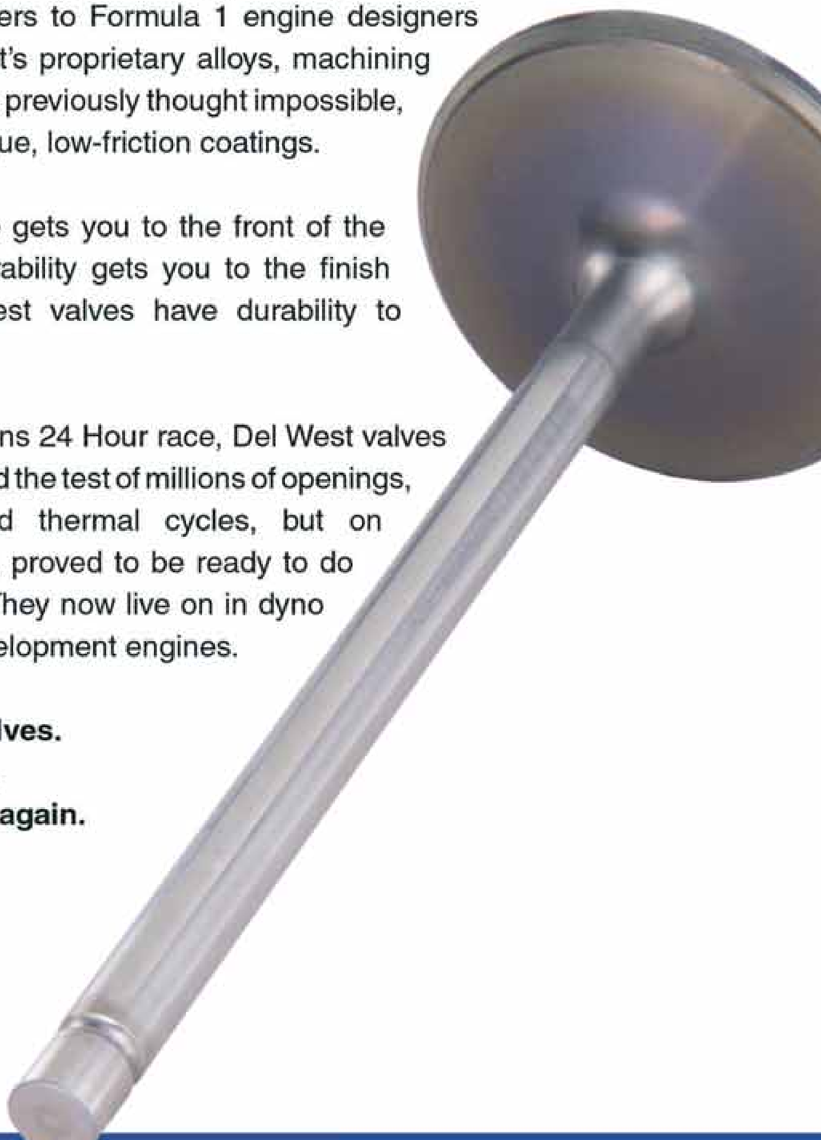

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Unveiled Porsche's progress

Porsche's newly DHL liveried LMP2 contender took part in its first race at Laguna Seca as part of an intensive testing program. Information regarding the RS Spyder (type 9R6) has been relatively hard to come by, as the car was built and developed in absolute secrecy. The carbon monocoque chassis has been developed at Porsche's Weissach facility. However Porsche claims to have steered clear of exotic materials to keep costs down for the future customer teams who will run the car. The chassis has been tuned to suit the 'angular and uneven race tracks of the ALMS' and is said to respond well to bumpy surfaces.

The chassis is propelled by the all-new Porsche MR6 3.4 litre V8 engine, developed especially for endurance racing. Porsche claims that the 32-valve engine develops 480bhp at 10,300rpm, and 274lb/ft of torque at 7500 rpm. A ZF

LAT

Porsche's RS Spyder (type 9R6) has been undergoing extensive track testing

Sachs triple-plate clutch transmits the power to Porsche's in-house GR6 gearbox installed longitudinally. In conventional fashion the aluminium gear casing is a fully stressed structural member.

Suspension is double wishbone front and rear with adjustable toe, camber and ride height, the four way spring damper units are supplied by ZF Sachs.

AP Racing carbon discs supply stopping power, with 380mm rotors on the front and 355mm on the rear.

At least two cars have been built to date, two cars in a white works livery were seen testing at Barcelona, Spain in late summer. At this second major test the cars aerodynamics, set up and transmission control systems were worked on with some success however it was felt that the car was not reliable enough to take part in its debut race, originally scheduled to be Petit Le Mans. 'In order to ensure performance and reliability at a high level in a completely new car, no stone is left unturned in an intensive testing programme' explained Hartmut Kristen of Porsche 'At the moment the RS Spyder is delivering the required performance but not the reliability required for a 1,000 mile race like Petit Le Mans'

The testing increased in its intensity with further tests in Europe and the US prior to the cars first race at Laguna. After completing two and half days testing at Road Atlanta, which included a full tech inspection by IMSA and the ACO, the car was deemed ready to race.

NEWS IN BRIEF

- Russian manufacturer Lada has revealed that it plans to enter the World Touring Car Championship in 2006, with eyes on a serious campaign in 2007 and 2008. Lada has been flirting with international motorsport for some time after producing a prototype Super 1600 rally car.

- German Firm MTEC Sport is considered the most likely candidate to run the works Ladas.

- Team Halfords Dynamics won the BTCC in late September in front of crowds of sponsors and friends. Castrol also used the event to launch its new oil range entitled Edge.

- The BTCC plans to keep it on the streets with at least four urban racecar demonstration events planned for 2006. The last one in Milton Keynes, UK, drew a crowd of 15,000.

- Prodrive is moving closer to a WTCC deal for 2006 claim RE sources in Banbury, UK.

NPL composite expansion

NPL Technologies, the UK-based supplier of patterns to the motorsport industry, including F1 teams, has added a new composites facility. The 1000m^2 composites department comprises a release agent room, a clean room, two autoclaves, a post-curing oven and a freezer for storing carbon materials.

The release agent room has full air extraction and will, in due course, be temperature controlled and have infrared dryers. At the time of writing, release agents are air-dried in ovens. The clean room, where lay-up takes place, is temperature controlled to 19degs C and has a CNC pre-preg cutting machine. There are two new Scholz autoclaves – one 5m long by 2.1m diameter (maximum working temperature and pressure 200degs C and 14bar), the other somewhat smaller at 2.2m by 1.3m diameter (175degs C and 20bar). Importantly,

Just one of NPL technologies' water cooled autoclaves

each autoclave is water-cooled – not yet a common feature with the autoclaves used in motorsport. The controlled cooling of carbon composites following the heating cycles is critical to reducing stresses in the component and is a mandatory process with aerospace work. The larger autoclave will accept all F1 parts plus complete sportscar bodywork, whereas the smaller one is most cost-effective for components such as wings, nosecones and so on. At the time of writing, some carbon composite materials suitable for motorsport are difficult to obtain in small quantities because of high demand from the aerospace industry. However, NPL receives regular supplies because it orders in large quantities – arising from its work for aerospace and automotive companies. This means that, for small jobs, it can often provide the carbon composite materials to produce a mould and/or the required number of components. NPL can also manufacture inserts to be moulded into components.

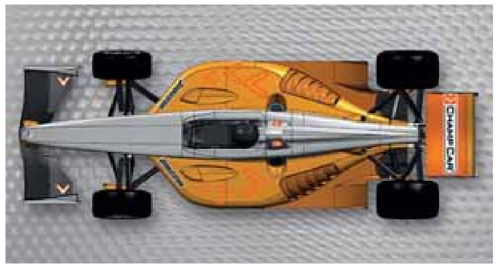
Panoz to build '07 Champ Car

Élan Motorsports Technologies (aka Panoz) has been announced as the sole supplier for the Champ Car World Series chassis from 2007 onwards. The company – which already supplies a proportion of the IRL field – will create the Panoz DP01, which is to take much of its look from the current Lola Champ Car chassis but will be smaller and 165lbs lighter. It will also feature smaller wings and larger tunnels, as well as an on-board starter, which could mean less yellow flag time. Safety is also to be improved, with upgraded head protection and leg padding, as well as a collapsible steering column. Side intrusion panels, a two-stage nose crush structure and a rear crash box will be included for oval races.

The engine will be the next generation of the 2.65-litre, turbocharged Ford Cosworth V8, beefed up to 775bhp. With Cosworth now in US hands this will mean the series will rely totally on North American-owned suppliers for its engines and chassis – something that has not happened in a premier US single seater series since Indianapolis in the 1960s.

The 2007 package has been designed to reduce operating costs. The new rolling chassis will cost around 35 per cent less than the current car while the cost of spare parts, it is claimed, will yield a saving of nearly 50 per cent. The design also allows Champ Car to explore technologies such as carbon brakes.

Winning the Champ Car business must be seen as significant for Don Panoz's company. Its CEO, David Bowes, told *Racecar Engineering* that it 'will allow us to invest in even more technology, software and hardware. Thus it will take us up a couple of notches of the ladder of service and support.' In 2003 Élan supported the Reynard teams in Champ Car in an attempt to improve their competitiveness against the Lolas. At the time it employed a number of Lola's Champ Car design team, including its senior designer Simon Marshall. Bowes said then 'I would love to be involved in CART, although it looks as if 2005 will be our earliest opportunity.' Changes in the direction Champ Car has headed means that he gets his wish two years later.



The 2007 Champ Car will be smaller and lighter, powered by a 775bhp version of Cosworth's 2.65-litre V8

In recent years Champ Car has been open to a variety of suppliers and has been the preserve of the British manufacturers Lola, Reynard and, before that, March. Latterly though it has been dominated by Lola, which achieved its position in a competitive environment. The Huntingdon-based company did not learn that it had lost the business until 10 October, the day before the official announcement. Lola Group executive chairman Martin Birrane has expressed his surprise that the company did not win the contract but points out that the A1 Grand Prix series, Formula Nippon and LMP1 sportscars are just three projects that 'have been or are about to be launched.'

Lola offered its support to the future of Champ Car and also stated that it 'offered a very competitive tender' but that 'forces beyond its control meant that the long partnership with Champ Car came to a conclusion.' Seven tenders were received by Champ Car but those from Lola and Panoz are thought to have been the only realistic propositions.

All chassis and component design work will be conducted in Georgia, along with construction and shipping. Simon Marshall is to head up the chassis design team, along with Élan aerodynamicist Nick Alcock, who will be using a 50 per cent wind tunnel and CFD to develop the car. Testing is scheduled to start in July with up to 1000km of testing to prove the design before going into production.

Lola's proposal

Lola's proposed design for the B07/00 Champ Car was revealed a few days after the CCWS decided to adopt the Panoz DP01. The car was going to be smaller, lighter, faster and stronger than the existing car.

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Future car tests

NASCAR tested its 'Car of Tomorrow' at Talladega and Atlanta during October with apparent favourable results.

The new car is two inches taller and aimed at making racing more competitive, with less emphasis on aero and more placed on driver safety. It will also be four inches wider, with the roof (or greenhouse area as NASCAR refers to it) looking much larger and the drivers' seat four and a half inches closer to the centre of the car than it currently is.

Another major change is a flatter front end and the use of a splitter-style spoiler at the bottom of the front valance and a similar 'bolt-on' rear spoiler. Both are designed with simpler aero matching in mind, enabling the governing body to make changes quickly to even the playing field. The chassis is totally different, too, with much taller frame rails and, instead of the different types of chassis currently used for various types of tracks a common layout is to be used.

Shocking business!

NASCAR officials look on as height sticks are used to measure running heights after the Dover race

LAT

RCR crew chief Todd Berrier was asked by NASCAR to leave the Talladega track and placed on suspension until 19 October. He was also fined $10,000 (£5750) when a fuel vent tube exiting the rear panel of Harvick's RCR Chevy was found to have 'fallen' inside the trunk during qualifying. Also the rear shock absorber access panels in the trunk were open, thus allowing air to flow inside the trunk helping to keep the rear of the car low – a great benefit at restrictor plate tracks. The Chevrolet run by Berrier had its outside pole run deemed void and started the race at the rear of the field. Berrier had been previously suspended for four races in March and fined $25,000 (£14,350) when he was found to have blocked off the fuel vent hose during qualifying at Las Vegas.

Meanwhile, six cars had rear shock absorbers confiscated after the Dover race, including the Hendrick cars that finished one-two. It took a while for the cars to pass post race inspection as the shocks had to settle before passing through the height stick. While using all legal parts the teams had found a way to make the shock work in arrears, using more pressure in the reservoir and effectively holding the rear of the racecar higher in the air, therefore creating more downforce on the rear spoiler. The team was not penalised, but NASCAR issued a technical bulletin a week later – the bulletin mandates gas pressure not be more than 75psi, and a smaller reservoir on top of the shock.

Downsizing the families

NASCAR is working on plans to limit the number of teams a car owner in Nextel Cup can field. Currently Jack Roush owns five Cup teams and Hendrick four, plus a part time effort. Although the rulebook says two is a maximum, teams get around this by listing family members as owners of their third or fourth teams, for example.

The current ruling has come under fire with Roush owning 50 per cent of the cars in the Nextel Cup Chase. The new idea is likely to be phased in some time during 2007 and should aid the single or two car teams if it can be implemented effectively. Three is a number NASCAR in still chewing on, but two could become the norm in the distant future.

End of the line for Pikes Peak

The Pikes Peak International Speedway has been sold to International Speedway Corp. – a division of NASCAR – and will be razed once grandstands and other equipment has been moved from the track to other ISC owned facilities. The 1200 acre site will then be sold. The one-mile flat oval built in 1996 was used for Busch, IRL, IMSA and USAC races. ISC will apparently lobby NASCAR to move the sole Busch Series date to Martinsville – a track ISC purchased in 2004.

But looking to the future, the date (along with a Cup race) will more likely be used once NASCAR has located a site for a new Pacific North West venue in either Washington or Oregon.

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Less than 10 years old, Pikes Peak Speedway is soon to be razed to the ground

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Controlling the show

A1GP has gone to great lengths in its efforts to make engineering contribute to the entertainment for spectators rather than detract from it

BY CHARLES ARMSTRONG-WILSON

The emphasis in A1GP was put firmly on entertainment, Sheik Maktoum wanting a series that looked exciting and would appeal to spectators around the world

Creating a single-chassis formula is often seen as a short route to building a second-rate car. With nobody to compete against, where is the incentive to make it good because they are all going to be equal? However, the team behind A1GP was very aware that the series would stand or fall on its entertainment value. So, cars that were not spectacular on track, were unable to race closely or even just looked dull were not going to fill the grandstands. With that thought in mind, the A1GP cars had to deliver much more than the bare minimum often asked of controlled formulae racecars.

While Lola is keen to point out that its A1GP racecars are not dressed-up versions of its last F3000 chassis, much of the chassis and suspension design is clearly descended from the last F3000 cars and teams that had been involved in the previous second-tier formula were quickly at home with the car.

The 3.4-litre V8 is made by Zytek, code named ZA1348, and is a close relative of the company's sportscar engine but can trace its roots back to a John Judd design. The all-aluminium engine was developed specifically for the A1 car by Zytek Engineering and weighs 120kg. Published figures quote maximum power of 520bhp and 442Nm of torque. Engine revs are capped at 9000rpm but teams have found a useful spread of power from 5500rpm to 8700rpm. However, to spice up the action, Zytek was briefed to enable a power boost button to increase power by 30bhp. This can be used up to four times in a sprint race and eight times in a feature race. It enables a function in the management map and is reset after each race by Zytek engineers.

All cars run with the same Pi Research Delta dash unit which gives 8Mb of flash memory and 500Hz logging speed, but teams are strictly controlled on what parameters they can log and how many channels.

Power is transmitted via a carbon clutch to the specially-commissioned six-speed, transverse transmission. In early testing these units showed a heat problem and, just three weeks before the first test at Silverstone, the internals were switched from the original supplier to Xtrac, though kept within the original magnesium casing. Since the change the units have run reliably. Zytek also supplied its EGS paddle-shift system, allowing the sequential gear selection to be operated from the steering wheel. This is the same system developed for the company's LMP1 sportscar and can effect changes in 40 milliseconds.

All cars are equipped with spec Öhlins TT44 dampers with three-way adjustment and the prototype was tested on Lola's rig to give teams baseline damper settings. Carbon carbon brakes were rejected in favour of steel and were supplied by AP Racing, along with four-piston calipers.

In the interests of the show, much of the car's design was dictated by aesthetics, and if there was a question mark over how well the A1GPs would work, then this is where it stems from. Early drafts of the car featured narrower tyres and Sheikh Maktoum himself is said to have insisted on more rubber to make it look more exciting. Consequently, the Cooper Avon control tyres are 11.75in wide on the front and 13in wide on the rear. The teams have not found tyre degradation an issue, nor have they found an increase in grip. The biggest problem has been getting them up to temperature. In fact some teams found rear end grip a limiting issue.

Likewise, the aero has been influenced by a large aesthetic input into the design. The original brief called for a shape reminiscent of a shark or a stingray, but it also directed that the cars should be able to race closely which meant the disturbance from the wake, and the front wings' susceptibility to dirty air, needed to be kept to the minimum. Working within these limitations, Lola conducted an aero programme to produce a workable aero package. The result comes with a full aero map and is described by the teams as generally benign, although not very responsive to changes. Eric Boullier of the DAMS team felt it was 'less pitch sensitive than the Dallara GP2 or World Series cars.' Some teams also found certain curious effects of the aerodynamics. Reducing the ride height initially increased the downforce as expected but, beyond a certain point, it started to reduce again before the car reached minimum height. Also, the front wing tabs, when adjusted beyond a certain point, would increase downforce but reduce drag.

All teams have to work out of the same premises in the UK, preparing and repairing the cars in allocated working areas. Cars are then moved between events by the organisers, limiting the time teams have with their cars. This completely rules out extra testing and any unofficial rig or wind tunnel work. But from a logistical point of view, how does it work for teams based all over the world? 'Ask my logistics manager,' says Boullier, 'it's a big problem for him.'

"THE A1 GP CARS HAD TO DELIVER MUCH MORE THAN THE BARE MINIMUM"

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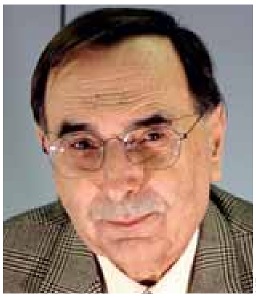
● **Richard Irons** has been appointed composites manager of NPL Technologies. Irons has previously worked with composites for McLaren, Tyrell and Minardi.

● **Peter Todd**, an executive at the UK's ASN Motor Sports Association (MSA) died last month. He had worked at the MSA for 19 years and prior to that at Brands Hatch Circuits.

● Indy Racing League vice president of business affairs, **Ken Ungar**, has resigned from his post. Ungar had been in the position since 2001 after having been chief of staff at the Indianapolis Motor Speedway.

● AP Racing has appointed **Charles Bolton** as managing director designate, as part of a separation of the roles of chairman and managing director, currently both filled by Mark Wingrove.

● **GianPaolo Dallara**, **Jean-Claude Migeot**, **Bruno Engelric** and **Luca Birindelli** have joined forces to form ART (see debrief p7 for the full story). They will be working with **Hannah Sun**, the managing director of Chinaboard investment, and **Shi Tianshu**, president of FSAC, China's ASN.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GianPaolo Dallara


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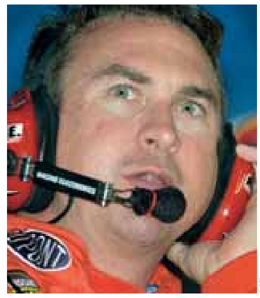
Ken Ungar


LAT

Robbie Loomis

● **Ken Norris**, one of the world's leading speed record engineers, has died aged 83. Norris had worked on projects ranging from Donald Campbell's Bluebird K7 water speed record challenger to Richard Noble's Thrust 2 and Thrust SSC land speed record breakers. More recently Norris had been consulting on the Quicksilver water speed record attempt.

● **Bob Kettleboro** has been appointed as the Grand Prix Masters race control director. Kettleboro is race control director for the BTCC and a member of the organising committee for the British Grand Prix.

● **Robbie Loomis** stepped down from his crew chief position at Hendrick Motorsport during September – a role he had been in since 2000.

● 26-year-old **Steve Letarte** will fill the void left by Loomis. Letarte joined the Hendrick team in 1996 as a tyre specialist and was being groomed to replace Loomis.

● **Dale Jarrett** has been reunited for the third time at Robert Yates Racing with his old crew chief **Todd Parrott** who moved over from the RYR Elliott Sadler team during September. In just his second race back with Parrott Jarrett won, giving Ford its first win at Taldega since 1998.

● Congratulations are due to *Racecar Engineering's* technical consultant **Peter Wright** who recently became a grandfather for the first time.

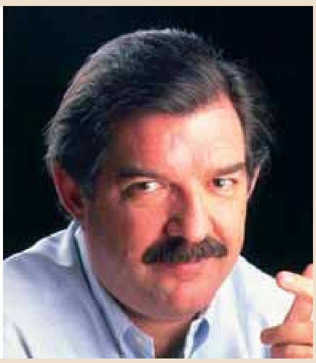
● The Quaife gearbox dynasty left its mark on motorsport again when **Adrian Quaife Hobbs** became the youngest ever winner of the BRSCC T-Cars Championship at 14 years and 8 months.

Send your company and personnel news direct to the *Racecar Engineering* team: tel: +44 (0)20 8726 8363; fax: +44 (0)20 8726 8399 or email racecar@ipcmedia.com

ON THE GAS...

SERGIO RINLAND
Managing director, Astauto Ltd.

A consultant for the Motorsport Industry, Rinland has worked at many levels of the sport, including as a technical director in Formula 1.



How did you first get involved in motorsport?

When I was born, I suppose. I always loved racing cars since I have memory. As a teen I was involved in slot cars, karting, motorbikes and finally cars. I studied Mechanical Engineering so I could design racing cars. I designed and built my first (a Formula Renault) in 1976 (two years before graduation). The rest is well documented.

What's the most interesting project you've ever worked on?

Every project has its own attraction for a variety of reasons at some point in time. To pick one it would be unfair on the others.

What achievements are you most proud of?

Few, but I would pick the Sauber C20 for the results it achieved and the Fondmetal GR02 F1 Car in 1992 because of the innovations it had, the way it was conceived and the people involved in it.

Can you name your favourite racing car of all time?

The Chaparral 2E and 2F, for its sheer amount of creative ideas well ahead of its time.

Who do you most admire in racecar engineering and why?

Two people – Jim Hall for his cutting-edge designs and Colin Chapman, also for his pioneering mind when it came to creating a racing car and his entrepreneurial approach to motorsports in general.

What racing era/formula would you have liked to work in and why?

Without sounding like 'old times were better', probably the '60s and '70s, when engineering innovation and ingenuity could make that winning difference, more than in modern times when ever-restricting rules promotes micro-development and conservatism.

What tool/instrument could you not work without?

The pencil, even though in today's world we could not work without computers.

What engineering innovation do you most admire?

Composite materials technology.

Is motorsport about engineering or entertainment?

Both. For us engineers, it is an engineering exercise with no hiding place, exciting and motivating like no other. For the public it is entertainment, so a good mix of both concepts is necessary. That is the huge task of the rule makers – to balance both without losing the essence of what this really is: motor-sports.

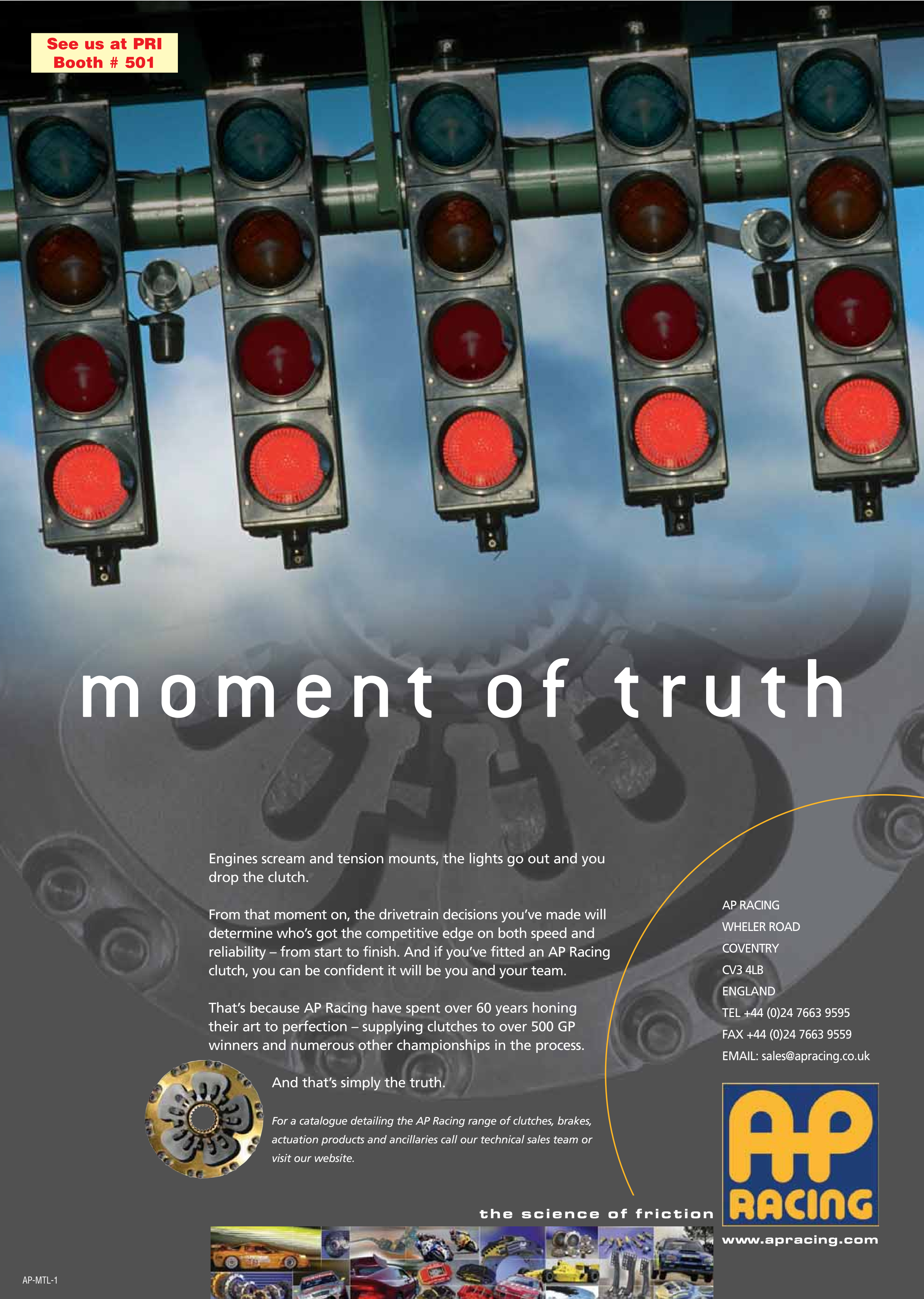
What new technologies in motorsport are you most excited about?

The rapid advancement of computing and simulation power which permits to 'test' cars and solutions while they are still only an idea in the engineers' mind. Also the alternative energy technologies which eventually have to find their way into motorsports.

Is there a future for high technology in motorsport?

Absolutely! Motorsport has to change rapidly in the world we are living today if it wants to sustain its growth, and can only do that with the help of what you call high technology.

The 'ostrich strategy' of most of the motorsport formulae and regulations of today in respect of technology and social responsibility will do more harm than good in the long term, both to the industry itself and to the fans.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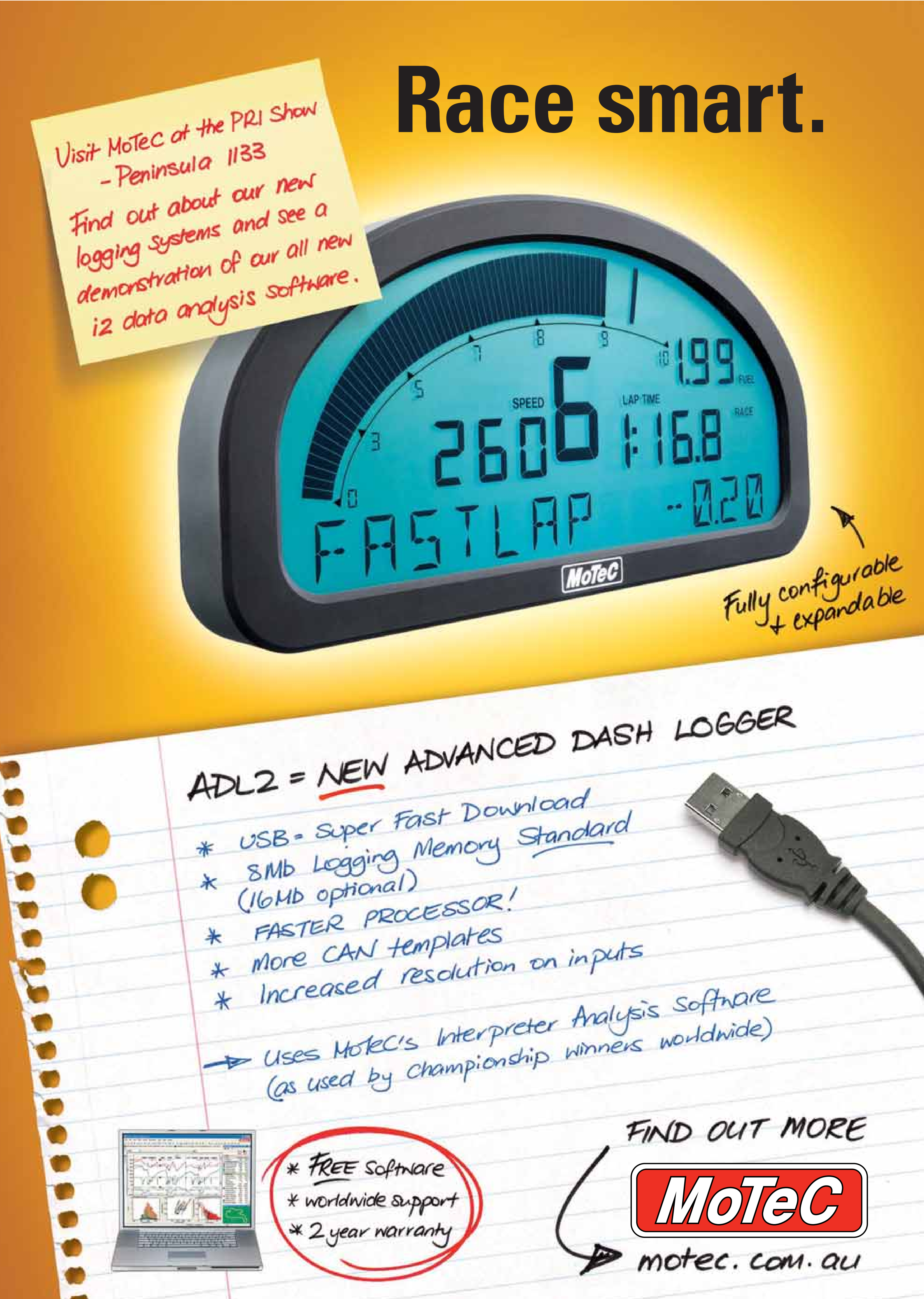
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Autosport INTERNATIONAL ENGINEERING SHOW

News

The International section of next year's Autosport Engineering show is set to play host to a surge of leading French engineering companies.

The Circuit de Nevers Magny-Cours and CS Consulting have joined forces to introduce a new French Pavilion into the International section which will be exhibiting a range of some of the top names in French engineering excellence.

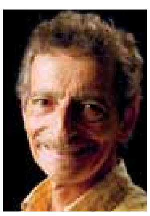
Eleven companies are currently signed up to showcase their specialist products and services. Rapid cylinder head prototype manufacturers Danielson Engineering is just one of the companies. Other names include Texys, famous for producing automotive sensors for F1, WRC, Indy and Champ Car teams; engine development specialists Sodemo; Apole; PRM Promo Racing; LSP and Fibre Active.

With Renault recently winning the F1 World Driver's Championship it seems only fitting therefore that some of the top French motorsport suppliers will be showcasing a range of their best suppliers products.

A number of other leading engineering companies will also be found exhibiting in the International section. Some of the names to expect include: Stack Data Acquisitions; MIRA; Aurora Bearings; Sadev Transmissions; Lifeline Fire Extinguishers; Pi Data Acquisition; Alcon Components; Quaife Transmissions; Aim Data Acquisitions; Tein Suspension and Venair Competition Hoses.

To make sure you secure a ticket of your own and to find out more information about the event visit www.autosport-international.com.

Talk to TT



If you are thinking of exhibiting at the show and would like to speak to someone about how to go about it, then contact *Racecar's* Tony Tobias. Email: expo@tonytobias.com or call him direct on: 07768 244 880.

Electronic expansion

Zica Consultancy Ltd is set to expand the newly formed business by making its first appearance at next year's Autosport Engineering show

Words | Katie Power

Specialising in the design and manufacture of high spec electrical harnesses, Zica supplies a number of leading clients in the motorsport, military and aerospace sectors with high performance electronic engineering components at competitive prices.

Zica Consultancy can be seen as a relatively youthful company within motorsport with its history only stretching back to its conception in July 2004. The Chief Executive and Senior Engineer Clive Candler was behind Zica's creation and brought several years of experience in electrical systems to the company, many from being an engineer on the Formula 1 circuit.

Candler believed that the market lacked the availability of affordable, quality products and needed to introduce more trained professionals. In an attempt to rectify this, Zica was created. Within four months of trading Zica had established accounts with some of motorsport's most pronounced names and are steadily becoming a pivotal player in the design and manufacture of harnesses and electrical systems.

Today Zica primarily concentrates on the design and manufacture of electrical systems, mechanical components and bespoke electronic modules. But it has also established various apprenticeship programs to, as Candler hoped, introduce more trained professionals into the field.

These apprenticeships have been set up in conjunction with a number of local colleges and universities, offering those wishing to work in the world of harness design and manufacture the skills they need. This opportunity is also profitable for those currently employed within the company as Zica constantly strives ensure their staff excel.

Zica is currently executing an extensive plan to branch out and promote the firm across a wide range of companies. So far this has returned successful results as many clients have been recruited from across Europe and the USA with many more predicted to be taken on in the next few months. Business Development Manager Steve Crabtree commented: 'this expansion enables Zica to have a presence in all the major motorsport arena's around the world and be able to handle enquiries on a local basis offering better customer support services'.

Zica makes harnesses for everything from Formula 1 downwards

Zica has recently confirmed that it will make its first appearance at the Autosport Engineering show in 2006 as the company considers it to be the perfect forum to publicly launch its ever-growing business.

Visitors will be offered the opportunity to discuss the company's plans for the future and speak to consultants directly about the services offered. Yet it is also an ideal time for Zica to promote the training programs and apprenticeships it provides. Anybody looking to start a career in harness design and manufacture should be sure to visit Zica Consultancy at next year's show.

Contact

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A new, bigger location and more events running alongside promise to make this year's PRI trade show the best event of its kind yet

Words	Charles Armstrong-Wilson
Photos	PRI

Bigger, better, faster, more

Following years being held at Indianapolis, the Performance Racing Industry Show has uprooted itself to move south for the first time. This year's show is being hosted by the Orange County Convention Centre in Orlando, Florida. Primarily, the move was forced by the show's success that made it outgrow its home of so many years and meant the event was being limited by the space available.

For 2005, the organisers have more than a million square feet of space to play with, allowing 3800 booths to be offered. The organisers are expecting 1300 exhibitors to sign up to create the biggest PRI show ever.

As ever, the show itself kicks off with the popular Industry Round Table on Wednesday afternoon between 1.30 and 3.30pm at the Convention Centre. It will be moderated by Jeff Hammond, the popular TV commentator and legendary NASCAR crew chief, and boasts a panel of distinguished experts. Together they will field questions from the floor on a broad range of subjects relating to motorsport and the industry.

A tradition of the show is the Grand Opening Breakfast that, like the round table, is free to all attendees. While enjoying a hot meal to fortify them for the day ahead, guests will be entertained by the notorious wit and energy of Busch driver Kenny Wallace. Food is served from 8.00am so be sure to get a seat early.

> **"THE ORGANISERS HAVE MORE THAN A MILLION SQUARE FEET OF SPACE TO PLAY WITH"**

For three days, the event showcases the best of the US motorsport industry supplying parts, equipment and services at all levels of the sport. It offers an unrivalled showcase of businesses that any customer serious about motorsport cannot afford to miss. From Formula 1 to amateur short track, you will see buyers from every area of the sport sourcing suppliers for the new season. →

PRI boasts 3800 booths and up to 1300 motorsport exhibitors displaying their products and services

The UK will be represented by the Motorsport Valley Zone comprising 68 booths of exhibitors from across the Atlantic. Directly opposite the international lounge, a prime position for visitors from outside the US, the area will see companies including Xtrac, MIRA and Altran demonstrating their abilities. Members of the MIA can also use the industry organisation's booth for meetings.

Motorsports Symposium

However, PRI is not the only event taking place at the Orange County Convention Centre during that week, others are taking advantage of the high concentration of motorsport people in one place.

The Society of Automotive Engineers is famous for its biannual Motorsports Engineering Conference, but this year it has broken with tradition by running a new event. Called the Motorsports Engineering Symposium, it will not only be held just a year after the last MSEC, but it will also have a shorter, slimmed-down format. It picks up on a relationship that worked well for MSEC in the past when it was run at the same venue as and just prior to the Performance Racing Industry Show. Last time that happened was up at Indianapolis in 2002. This year the show is in Orlando, Florida and that is where MSES will be held on the Tuesday and Wednesday prior to the show – 29 and 30 November.

The symposium format will feature industry and sanctioning body leaders in panel discussions and technical presentations discussing the latest technologies and how they are used. The theme of Change For Relevance from last year's MSEC will be revisited as a panel discusses the problems of striking a balance with technological innovation. Particularly, how this will impact on grass roots racing. It will address questions such as what is the value-added to the cost and complexity of the technology; will better, cheaper GPS-based data acquisition improve safety and reduce cost; and what is the next 'big hat' technology that will significantly alter the next generation of racing?

A two-part session plans to look at engine management in motorsport and specifically electronic versus mechanical engine management systems in motorsport. The sessions will look at how these systems operate, and how the technology affects the entertainment value.

The third subject to be dealt with at the seminar will be tyres. It will look at all aspects of how racing tyres work and present some guidance on how to get the most out of them.

For anyone planning to attend PRI, it represents a couple of extra days well-spent. See www.motorsportsengineeering.org for details.

Another event relocation to Florida to take advantage of the crowds is the Advanced Engineering Technology Conference that kicks off on Sunday night, 27 November with a reception. Transferred from Colorado, this is the 16th AETC and it attracts hundreds of race and performance engine builders. In three days, the organisers promise to tell you more about engine building than you could hope to find out in a whole season of racing. For details, visit www.aetconline.com.

"WHAT IS THE NEXT 'BIG HAT' TECHNOLOGY?"

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At a glance

Sunday, 27 November
Advanced Engineering Technology Conference welcome reception

Monday, 28 November
Advanced Engineering Technology Conference

Tuesday, 29 November
Advanced Engineering Technology Conference
SAE Motor Sport Engineering Seminar

Wednesday, 30 November
Advanced Engineering Technology Conference
SAE Motor Sport Engineering Seminar
1.30-3.30pm PRI Show Industry Round Table

Thursday, 1 December
8.00am PRI Show Grand Opening Breakfast
Performance Racing Industry Show

Friday, 2 December
Performance Racing Industry Show

Saturday, 3 December
Performance Racing Industry Show

The Motorsport Engineering Symposium promises to be a slimmed-down version of the biannual MSEC

To add a bit of spice to the week, attendees can take in two USAC Midget races at the Orlando Speed World Raceway on Friday, 2 December at 7.30pm. Tickets are just $20 and can be ordered in advance on +1 800 515 8445.

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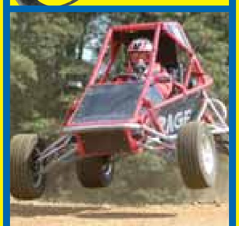

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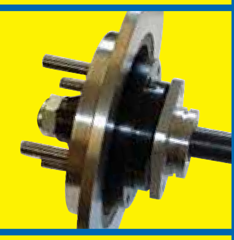




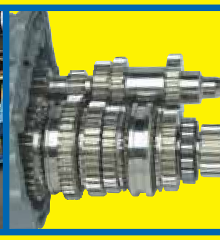


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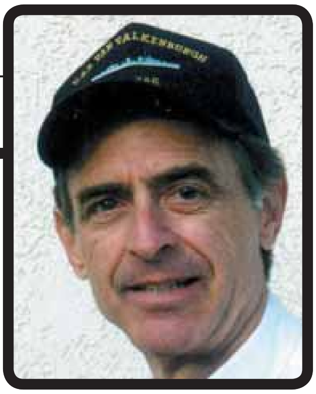
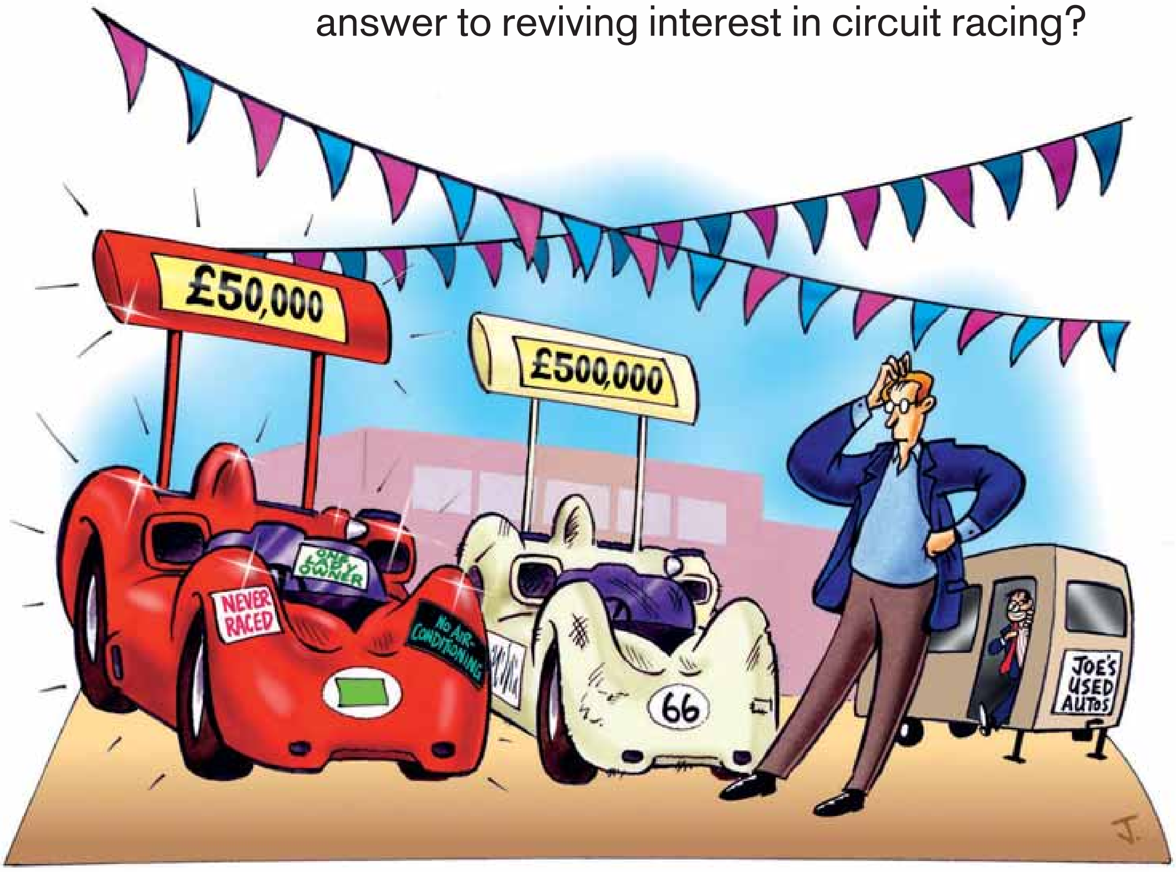
V-ANGLES

By Paul Van Valkenburgh



High Chaparral

Historic racing is big business, but is building continuation versions of innovative racecars the answer to reviving interest in circuit racing?



Last night I arrived home late from a weekend at the famous Monterey Rolex Historic races. As I opened the car door, a little light went on above my head. 'Sonnuva bitch!' I said, before the light went out again. There it is. The answer to a question I presented in my first editorial column in 1994. How to have interesting, affordable road racing again, with sexy shapes and technologies, instead of sanitised parades of boring spec-car billboards.

As I wrote about in 'Formula NONE', and later in 'Saving Racing', it might help to have less dependence on megabuck budgets from sponsors drawn in by television exposure, which creates spectacles rather than inherently interesting cars and drivers. I suggested a series with NO limits on technology and NO advertising on the cars. As I was reminded at Monterey, that's the way it used to be in Formula 1 and the legendary Can-Am, with wealthy individual innovator sportsmen and irreverently earthy drivers. And it never really went away, it just got a lower profile, as cars were restored and re-raced as historics.

I only go to Monterey when they feature the old big-bore Can-Am or Trans-Am cars, cars that roar (not whine). I love their high compression 'whanging' and their impossibly erratic idling that sounds like a 600 horsepower popcorn-popper, or like running a 6000 horsepower Top Fuel engine in a sedan.

This year, Chaparral was the featured marque at Monterey. Jim Hall brought the seven cars he restored for his museum collection, most famously the 2J 'sucker' car, and the first high-wing (mounted to the rear hubs) car, the 2E. The others were Hall's Fibreglass-tubbed 2A roadster, a 2D Lemans coupe, 2F coupe, 2H monocoque coupe, and his Indianapolis winner. The exhibition runs were so accurately nostalgic that even at a reduced pace, a couple of the cars suffered some traditional DNFs and DNS.

But there was an eighth Chaparral there – →

> **"HOW TO HAVE INTERESTING, AFFORDABLE ROAD RACING AGAIN"**

another 2E that has never been raced! In fact, it had not even been fully assembled yet. This is an interesting story for racecar engineers, which requires a flashback to a chapter I wrote in my '*Chevrolet – Racing?*' book about Chevrolet Engineering's contribution to these cars. (There are other books that present the Jim Hall/Chaparral viewpoint).

My boss at Chevrolet R&D in the '60s was a guy named Jim Musser, who was project engineer on the Chaparral consulting team. The Chevrolet GS-IIb (see exclusive photo at http://members.aol.com/racecartec/chevrolet.html) was his aluminium-tub prototype for the Chaparral 2C and 2E. Now retired, he decided he wanted to reconstruct a GS-IIb for his own enjoyment. Hall was willing to cooperate, but no one had any of the original body parts or moulds. So he suggested a compromise – build the latest 2E derivation, which he did have body moulds for. This was a landmark racecar by anyone's standards, and one of the most fun to drive, according to Hall. It was softly sprung, with the aero loads going directly into the suspension, and it was relatively easy to set up, being highly responsive to anti-roll bars and shocks.

"THIS MAY REVIVE INTEREST IN THE TRUE SPIRIT OF INNOVATION IN THE ORIGINAL CAN-AM"

As the project advanced, Hall and Musser started thinking, 'what about a limited production series?' Hall still had the original full-scale aluminium tub patterns, and the tubs and suspension are easily fabricated with ordinary shop tools – metal brakes, pop rivets, and adhesives. Some of the wheel and upright patterns and forgings still exist, and modern CNC machines can crank out the rest.

The 'secret' automatic transmission (which I explained in my book), turned out to be a limiting factor. Hall had one spare trans for Musser, and the original casting patterns, but the first estimate for new reproductions from today's racing trans companies was about $40,000 (£22,300) each. I recalled seeing a couple of spares in another Chevrolet engineer's shop about 15 years ago, which I tracked down and relayed to Musser. The torque converters aren't a problem, because of their popularity in drag racing today. You can specify whatever you want in diameter and stall or lockup characteristics, right off the shelf.

Likewise, today you can easily specify a Chevrolet engine off the shelf that will out-power the best the factory or any racing team could produce in that era. Yet to make it accurate, with the original Webers and manifold, only standard heads could be used.

If they do take orders and start producing copies, aside from a conversation piece, where can you race it? Vintage racing is hot. There are a bunch of magazines, and they list calendars of historic/vintage races held almost every weekend. In America alone, there are over 20 vintage racing organisations. I called Carl Jensen, competition director at SVRA (the largest) and asked about the acceptance of a 'continuation series' car like this. He replied: 'We deal with this all the time. It's a real controversy.' He reminded me that already there are nearly perfect copies of Cobra, GT-40, C-Jag, Lola T-70, and it's rumoured that McLaren has considered continuing their Can-Am cars. Although he only spoke for his own group, he generalised that kit cars are definitely out, but if a continuation car is associated with the original manufacturer, and if major components are interchangeable, and if the car is historically significant, then maybe... Musser has already contacted him, and the 2E will be accepted as long as, 'it isn't painted a different colour, and sponsored by Joe's Towing Service.' Owners of original cars don't want to be blown off by a relatively inexpensive copy. The bottom line is all cars are considered on a case-by-case basis.

Jim Hall (and a few lucky invitees) may occasionally make exhibition Chaparral runs, but the original museum-quality cars are irreplaceable. A continuation of production would allow the Chaparrals to actually be raced again. I put a lot of development miles on the GS-IIb, and a GT-40 test bed for the 2H radiators, and I both fabricated and test drove the suction-traction test mule for the Chaparral 2J, but I never actually drove any of Hall's cars. So what is it like to road race a 1600lb car with 5–600bhp on (relatively) narrow tyres? If I owned a totally original historic racecar, and wanted to race, I'd store it and buy a replica (with modern safety features) for competition.

I have to remember that these cars raced before many of today's racecar engineers were even born (considering the number of universities now offering racing degrees). The Chaparrals demonstrated features that have since been outlawed, and will otherwise never be raced professionally again – like the wings that could be trimmed out at speed, and patented loading of the wheels without loading the chassis (something UTA re-innovated in FSAE recently).

What a series this could become, with wealthy sportsmen again instead of corporations, rubbing elbows with famous (although now retired) driver celebrities who are not racing for millions, but for the joy of it. And see what four decades of advancements in engines, tyres, data acquisition and chassis set-up knowledge might contribute to making these 'continuation series' cars even faster.

This may revive interest in the true spirit of innovation in the original Can-Am, although in adhering tightly to the past, it does leave out the opportunity for any more *new* innovations. I think we still need a 'Formula NONE,' especially as a supplement to troubled Formula 1. Maybe we should make a movie about it, using special effects instead of real vehicles. Wait a minute, Spielberg already did that – with the pod race in *Star Wars* Episode One. RE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LAT

Turkish track at last proved a challenge for F1 drivers, with mistakes being penalised, just like the good old days…

Nice one Hermann

Well, wouldn't you know it, just after I submit my column lambasting the circuit designs of Hermann Tilke (RE V15N11), he comes up with an absolute cracker. I'm talking about the Istanbul Speed Park – or whatever they're calling it this week – of course, a circuit which has to be just about the best we could hope for from a new F1 track in this safety conscious age.

That said, many of the points I made still stand, and if you doubt it, just think: could anything that occurred at the boringly-named Turn 8 (rechristen it 'Ata Turk' please, it sounds like 'attack' and just about everything else in Turkey is named after the great man anyway) rival what we saw at Suzuka at the end of the season? Surely Alonso passing Schumacher round the outside of 130R would have been far less spectacular if there was an Ikea car park worth of paved run-off to play with?

Still, you can't blame Hermann for that, and the green strip of grass, or grasscrete, on the outside of 'Ata Turk' at least meant there was some sort of punishment for those overstepping the mark.

Mike Breslin
Llauo - y - Dos
Wales

Newton's legal man

Regarding Owen Brenton's 'Load of hot air' in V15N9, Owen seems to have confused his Newtons. Newton's first law states that a body remains at rest or in a state of uniform motion along a straight line unless acted upon by an external force. Newton's third law states that every action has an equal and opposite reaction. So the question of the month is what was Newton's second law? Also, energy can neither be created nor destroyed, only changed in form. So downforce and stability will always be at the expense of drag.

Ian Griffiths, by email

On the limit

I was originally responsible for penning the rules of a reasonably successful modified saloon car race series and at first we had a selling/buying plate in an effort to keep costs down but this was not really workable. I did at one time consider a selling plate on the engine alone but this was also seen to be impractical.

Well, it also occurred to me that revs are the real thing that cost money to achieve and also what destroys engines. If revs could be kept within feasible limits then the need for exotic (read: expensive) components such as steel rods, cranks and valve trains would be eliminated. I proposed something like a 500 or a 1000rpm limit over the model manufacturer's redline limit. Or if that was not possible, a limit for the class ie allowing smaller engines to rev higher.

This, at the time (it was eight or 10 years ago) was rubbished as being unenforceable, and maybe it is. However, with the recent strides in technology I was wondering if this idea was worth another look. Does anyone have any thoughts on this? Would it be possible to build an electronic device that could be set and sealed and checked by the scrutineer on a regular basis? It would have to be completely tamper proof of course but it would limit the revs to the set peak. This idea, if practical, has always appealed to me as I see it as a very effective way of cutting costs by eliminating the necessity of expensive components and expensive blow ups. If it worked it could be adapted to a variety of different championships with dividends in both performance and safety.

Al Weyman
Taken from the forum section of racecar-engineering.com

New!

Preview the online edition of The International Journal Racecar engineering in your browser

Go to 'This issue' at www.racecar-engineering.com

Words Dan Carney
Photos Chevrolet; Sam Collins; LAT

Yellow fever

If the Corvette racing programme was to promote the new C6 road car then a racing version was needed, but it presented some interesting challenges

Chevrolet netted a surprise GT win at Le Mans with its new C6-R racecar, despite the Aston Martins being tipped for victory. The British cars' reliability was no match for the Corvettes and the US team's endurance racing miles proved their worth. But the win with an all-new car was achieved in the face of a number of a number of problems to solve and improvements to be made.

The successful Corvette C5-R served as the development mule for the C6-R, while the race team also coordinated with the production team developing the new Corvette C6 in search of production changes that could yield racing advantages.

The Corvette production car team sent word to the racers that they'd like a list of items to consider when developing the design of the new car, and the racers responded with three specific requests, said Doug Fehan, C6-R programme manager. 'The design staff came to us and asked what they could do to make a better racecar,' he recalled.

The team's response was to ask for a single air intake at the front of the car in place of the split intakes on the C5, to replace the pop-up headlights with fixed lights, and to recontour the car's profile for more downforce. 'The C6 has a completely different angle in the roof and down the back,' Fehan observed.

The result is more downforce and less drag, with the trade-offs between the two adjusted to suit the needs of each track. The five-inch shorter C6 has a longer wheelbase than the C5, trimming front and rear overhangs – critical to developing downforce – away to almost nothing. 'The overall shape of the body has less drag, so the lift-to-drag ratio is very much the same,' observed Steve Wesoloski, GM Racing Road Racing manager.

However, the downforce reductions weren't the same front and rear, eroding the all-critical balance racers seek. 'What we were faced with was that the [C6] shifted the centre of aero pressure forward. The shorter rear overhang is more of a detriment then the shorter front overhang.'

A part of the solution to this problem has been to run with windows installed in the car. 'We run widows all the time now, where before we only ran them sometimes at tracks like Le Mans,' Wesoloski said. Racer's instinct said that the windows would trim drag by sealing off the turbulance-inducing window openings, but CFD modeling revealed that wasn't the real source of the benefit. 'We thought it would reduce drag, but that is not the case. It keeps the air attached over the body of the car, flowing air to the rear wing for more rear downforce.'

Making the rear wing more effective lets the team trim the angle of attack, typically by three or four degrees, for less drag. The range of operation now is between 11 degrees for a high-speed circuit like Le Mans and 15 degrees for a tighter, slower track like Lime Rock Park.

Of course, underbody aerodynamics also plays a crucial role. At the front, the revised bumper fascia is designed to flare outward ahead of the front wheel openings, creating low pressure areas outside the wheels that draws air from under the front of the car through the wheels, creating frontal downforce.

At the rear, the diffuser has taken on more of a cheese grater appearance, going from the typical three or four vertical strakes to a surprising 11. 'It creates little venturis [that] keep airflow in line, with more laminar flow through the back rather than having turbulence at the back where the diffuser meets the rear bumper fascia.'

The diffuser not only increased downforce, it improved the car's driveability, too, according to Wesoloski. 'It is not only overall downforce improvement, it reduces sensitivity to pitch and roll as well.'

'That has probably contributed to increasing downforce more than anything else,' confirmed driver Ron Fellows. 'We've messed with a number of different shapes and styles.' In the end, drivers could readily see the benefit of the new style of diffuser: 'you can feel it and it shows up on the stopwatch.'

With a factory programme backed by the world's largest automaker, surely such improvements were the result of countless hours tweaking prototypes in the wind tunnel, right? Wrong. Comparatively cheap CFD modelling points to the potential benefits, which are proven in straight-line speed testing at a defunct airport outside of Detroit, Wesoloski told Racecar.

'There aren't a lot of rolling road wind tunnels, and our car is very dependent on underbody ground effects,' he said.

“A PART OF THE SOLUTION TO THIS PROBLEM HAS BEEN TO RUN WITH WINDOWS INSTALLED”

Engine placement is limited by regulations mandating stock firewall location

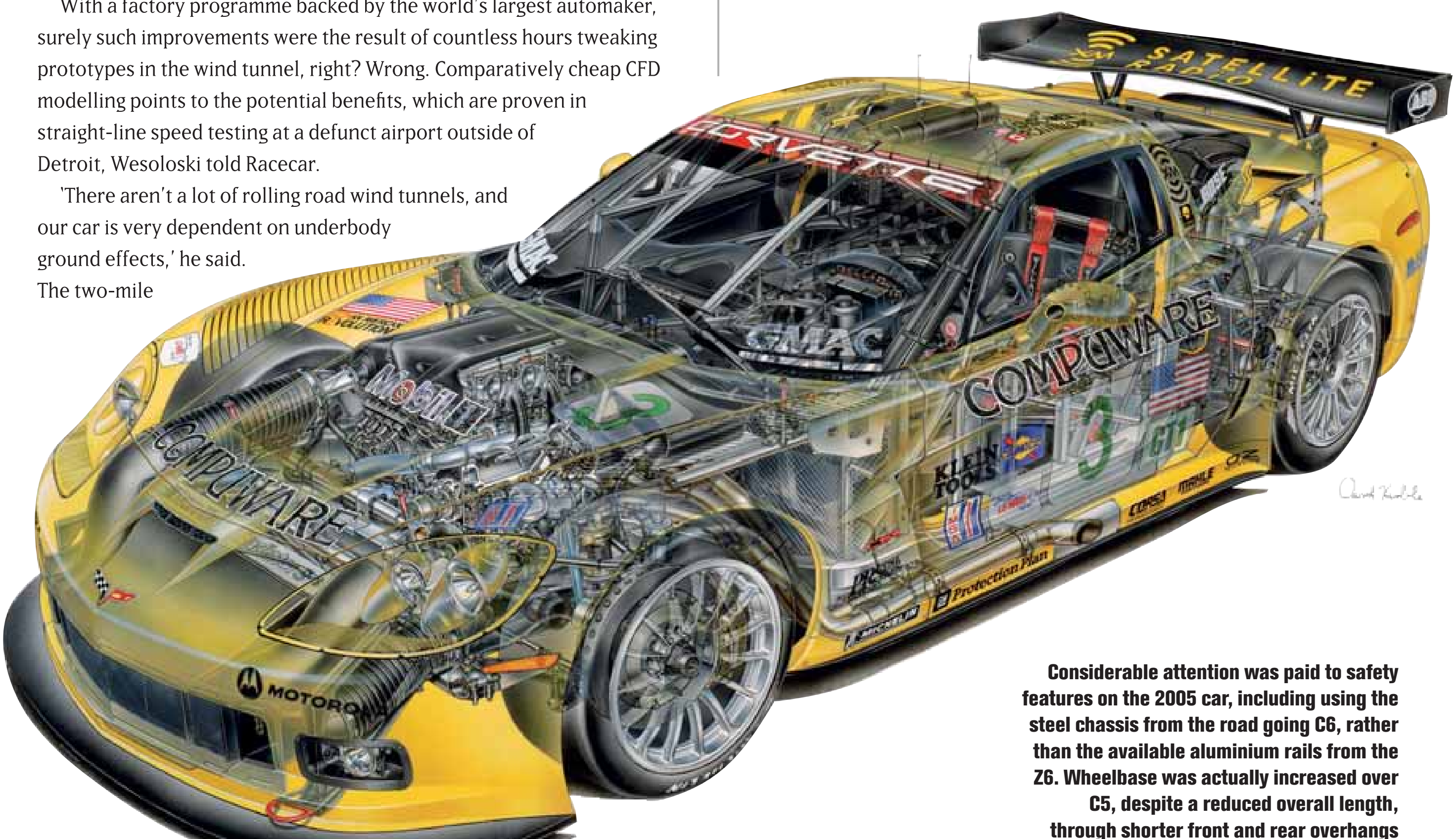
The two-mile runway provides plenty of space for the car to reach terminal velocity.

The diffuser didn't even have the benefit of that testing, but was rushed in prototype form to the track, where it quickly demonstrated its value.

CFD also let the team refine the design of its rear wing element. 'It took 15 iterations to find the optimised wing shape for the C6,' Wesoloski reported. 'The car has a pretty big wing, so you don't want to make 10 or 12 of them, you want to narrow that figure down.'

The cumulative result of all the aero improvements to the C6-R has been six per cent less drag with the same downforce, says Wesoloski. 'We're probably generating a maximum of 1800lbs of downforce.'

Such a downforce level makes itself felt in high-speed braking zones, as the downforce diminishes with speed, forcing drivers to ease off the brake pedal as the car slows. According to Wesoloski, the effect varies according to the available grip at the track. →



Considerable attention was paid to safety features on the 2005 car, including using the steel chassis from the road going C6, rather than the available aluminium rails from the Z6. Wheelbase was actually increased over C5, despite a reduced overall length, through shorter front and rear overhangs

Note in these two pictures the transverse beams running across the rear of the car connecting each hub to a third spring arrangement mounted on the rear of the diff housing

Rear suspension travel was increased, softer springs used (with conventional Sachs dampers) and new, smoother pressed ball joints utilised throughout

"WE REALLY CONCENTRATED ON REDUCING FRICTION IN A LOT OF THE SUSPENSION ATTACHMENTS"

That downforce at high speeds also has implications for suspension performance, hinting at the potential benefits of a third spring arrangement on the rear anti-roll bar visible on the car at Le Mans. While the set-up was in plain sight, the team still doesn't want to discuss its design and operation in any detail. However, with the team's cars going to privateer teams over the winter, presumably those secrets will soon be difficult to contain.

The suspension itself has been refined, front and rear, with different springs, shocks and sway bars, according to engineer Tadge Juechter. A critical improvement is increased suspension travel that keeps the car off its stops. 'We've got enough suspension travel now that you don't get into the jounce bumpers even at maximum lateral acceleration,' he said.

Also helping put the power down accelerating out of corners are softer rear springs, Juechter said. The C6-R's rear springs are in fact softer than those on the 2006 Z06 road car, he pointed out. This fact is another clue pointing to the use of a third spring arrangement on the rear sway bar that supports the car under high aerodynamic downforce at speed.

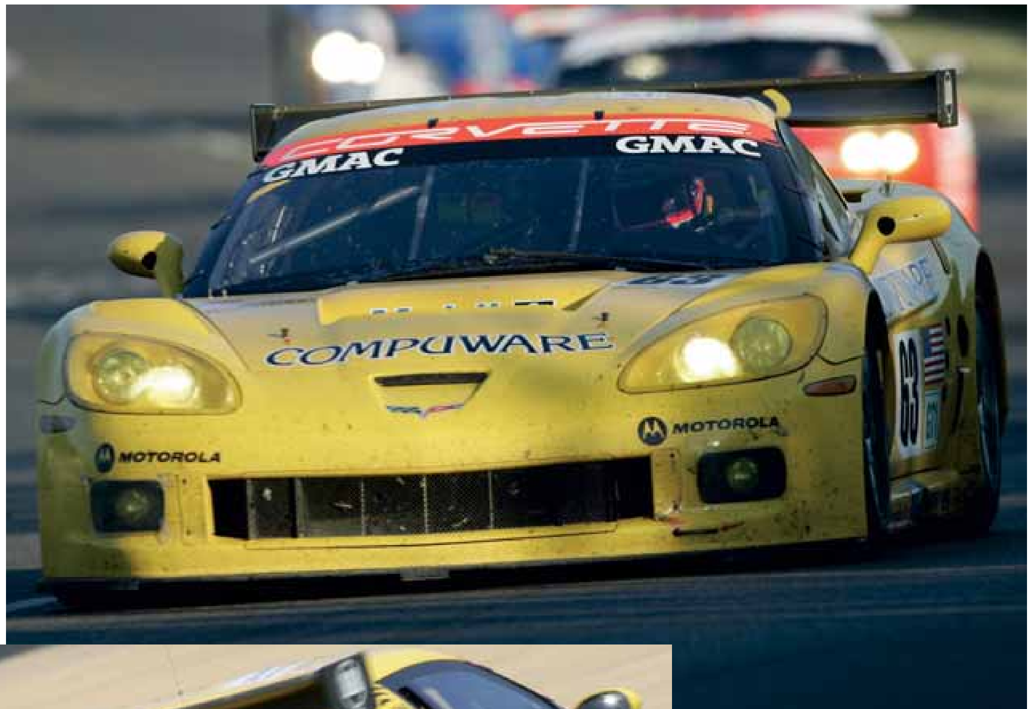
Conventional Sachs dampers are used on the racecar. The production car has high-tech, magneto-resistive shocks that are adjustable to suit conditions, but that technology is unsuitable for racing, said Juechter. 'It is just a bunch of extra mass, compared to conventional shocks. Further, heat dissipation under race conditions would be very difficult,' he added.

One of the simplest components of the suspension has seen special attention on the C6-R, according to Wesoloski. The rod ends that attach suspension arms are typically stiff and resistant to movement, which makes subtle suspension adjustments more difficult for drivers to discern. 'We really concentrated on reducing friction in a lot of the suspension attachments,' he said. Rather than a traditional spherical heim joint or rod end, 'it is like a pressed ball joint so it has a little more freedom of movement as it goes through its range of motion,' he said. 'You don't have any of the hysteresis as it goes through the range of motion, so the smaller changes to shocks and springs are more noticeable and reflected directly to the driver.'

During races, the primary tuning tool available to drivers is changing tyre pressure, said Fellows. So suspension that aids detection of subtle differences may be especially beneficial in this class of racing. While cockpit-adjustable anti-roll bars are not permitted, the team has installed a quick adjustment for the rear sway bar that mechanics can change during pit stops, said Fellows.

'The first time I really had to use it was at Petit Le Mans at Road Atlanta,'

"DRAWS AIR FROM UNDER THE FRONT OF THE CAR THROUGH THE WHEELS AND CREATING FRONT DOWNFORCE"



At the front the headlights were fixed upright and faired in, while a single air intake replaces the twin intakes seen on the C5-Rs

At the rear, the diffuser features 11 vertical fences rather than the usual two or three but returns a useful downforce increase

"MAKING THE REAR WING MORE EFFECTIVE LETS THE TEAM TRIM THE ANGLE OF ATTACK"

he said. 'The track changed dramatically when the weather changed from overcast to sun, and changing the sway bar during a pit stop eliminated the resulting oversteer.'

Safety in mind

Despite the road going Z6 having an aluminium chassis, for the racecar the team chose to stick with the steel version from the C6. 'We utilise the rollcage very heavily to add to the stiffness of the structure,' explains Wesoloski. 'Being a ladder frame, basically like a truck with the hydroform frame rails and some crossmembers, it is very tough to get the torsional stiffness. Had we gone to the aluminium chassis rails, crossmember and tunnel it would be very difficult to put a proper steel rollcage back in to reproduce that connection for the stiffness and the structural integrity from a durability standpoint over what we were able to do with a steel to steel connection.

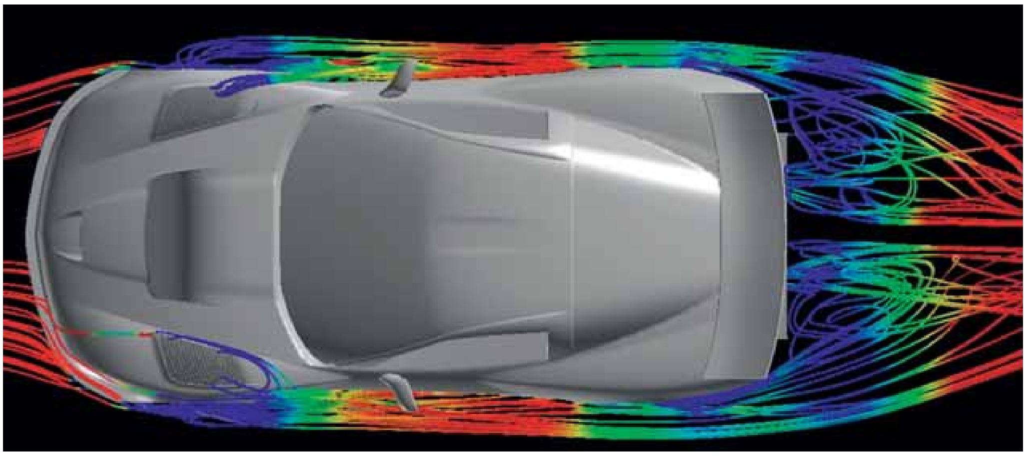
'Another reason that we felt was critical, we've had situations where we've had a crash and the hydroform steel frame rail designed for production is very predictable in its performance – it crushes very much like an accordian. You are then able to just cut off that crushed portion, butt weld and put a wrap around the joint to put a new extension on the rail and you are back in business. And you can do that at the racetrack if you really had to.'

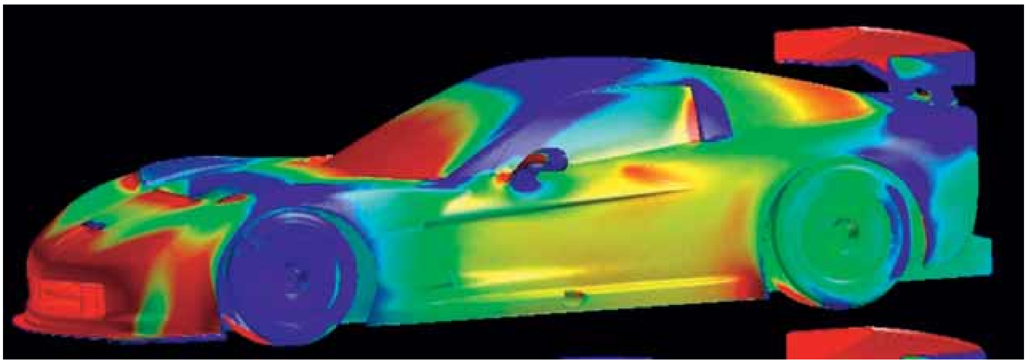
The new car has also been forced into a compromise over weight distribution. 'It has been a difference between the C5 and C6,' admits Wesoloski. 'For the C6 they were much more stringent in making sure you have production content in the car.' The team was obliged to keep the front and rear bumper beams and the production windscreen frame so you get that weight way up high where you don't really want it. So it has reduced the amount of ballast we have in the car that we put in the right rear corner. I would say it has cut 60 per cent of our ballast out of the car just by the content we've had to add back into the car.' The result is a higher centre of gravity and a greater raised polar moment.

The Corvette's engine has grown to 7.0 litres over the life of the programme, while maintaining reliability, according to Doug Duchart, director of GM Racing, but found 8.0 litres to be too far a stretch. 'We figured out how to make a 427 (cubic inches) with this programme,' he said. 'We tried to make an 8.0 litre too, but that didn't quite work out.'

But even within the 7.0-litre displacement, there has been room for improvement this season, said Fellows. 'Our engine guys continue to try to find more power,' he said. 'It is no secret that Aston Martin was faster →

Much of the 2005 car's development went into improving aerodynamics. The result was an improvement in downforce, less overall drag and improved (and adjustable) driveability





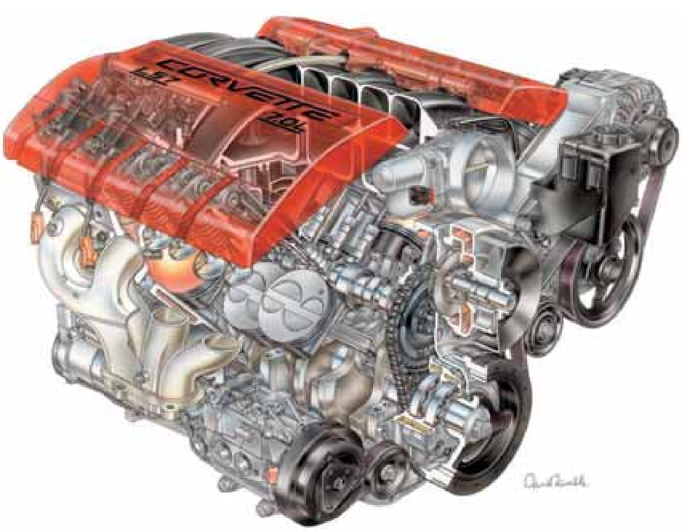
"CFD MODELING POINTS TO THE POTENTIAL BENEFITS, WHICH ARE PROVEN IN STRAIGHT-LINE SPEED TESTING"

than us on the straights at Le Mans but at Road Atlanta [for Petit Le Mans], I was pleased to see them running down the straight-away with these guys and that they weren't pulling away from us.' Fellows also said he wishes for another shot at Le Mans. 'If we could go back to Le Mans with what we had at Road Atlanta, I think we'd have done better.'

The C6-R was designed to incorporate side-impact crash absorption structures that were pioneered in the C5-R, and which Fehan credits with saving drivers' lives. 'We had two potentially fatal impacts in the C5-R – at Dallas and Miami – where the drivers unbuckled and then walked away,' he said proudly.

'The crash box that sits to the drivers' left replaces that bulbous cage that you see in NASCAR,' said Fellows. 'It is lighter, provides better protection and makes a nice ledge to help you get in and out of the car.'

Of course the most infamous C5-R crash was that of Dale Earnhardt Jr. at Infinion Raceway (nee Sears Point), wherein his heavily shunted car exploded into flames. In that case the fuel filler neck snapped off the fuel



GM tried an 8.0-litre motor for the C6-R but in the end went with the 7.0 (427ci)

cell and the suspension collapsed into the cell, expelling its contents.

To prevent that scenario from recurring, the C6-R eliminates the fuel filler neck between the bodywork and the fuel cell, said Fehan. Instead, the fuel filler has an extension that reaches inside to the fuel cell itself, eliminating one potential failure point from the fuel system. Similarly, the rear suspension mounts have been redesigned to direct collapsing suspension members away from the fuel cell,' he said.

Ongoing improvements

Another important safety factor is keeping the driver comfortable enough to concentrate, points out Fellows. 'We are continuing to improve the quality of the air we get into our helmets,' he said. 'That paid big dividends at Le Mans this year.' It was hotter even than in 2001, when a Corvette driver passed out after climbing out of the car, but drivers were more comfortable this time. 'It was hot, but it was not debilitating for us,' Fellows said. 'I heard the Aston Martin drivers were really suffering.'

Tyre testing, especially for LeMans, has proved to be a challenge for the team, because the tyres Michelin provides in Europe differ slightly from those in the US, and because European tracks tend to be smoother than those in America. 'We've been unable to find a racetrack where we can apply that tyre to get decent data in North America,' Fellows said. 'The tracks are enough different that it doesn't apply.'

However, with the expected sale of the 2005 C5-R cars to a European team, the factory hopes to gain valuable European tyre and track data from the new owners in preparation for Le Mans in 2006. 'It sets up some interesting potentials for us as far as collecting relevant data in Europe,' Wesoloski noted.

The team will evaluate the benefit of satellite operations when considering whether to build a number of C6-Rs for private customers, rather than just selling the team's old cars at season's end. The goal isn't to put the Corvette racer into limited production, but to potentially fulfill European demand for the iconic American racecar, while boosting the team's ability to gather further relevant information about the car's performance, said Wesoloski.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Lightweight 8

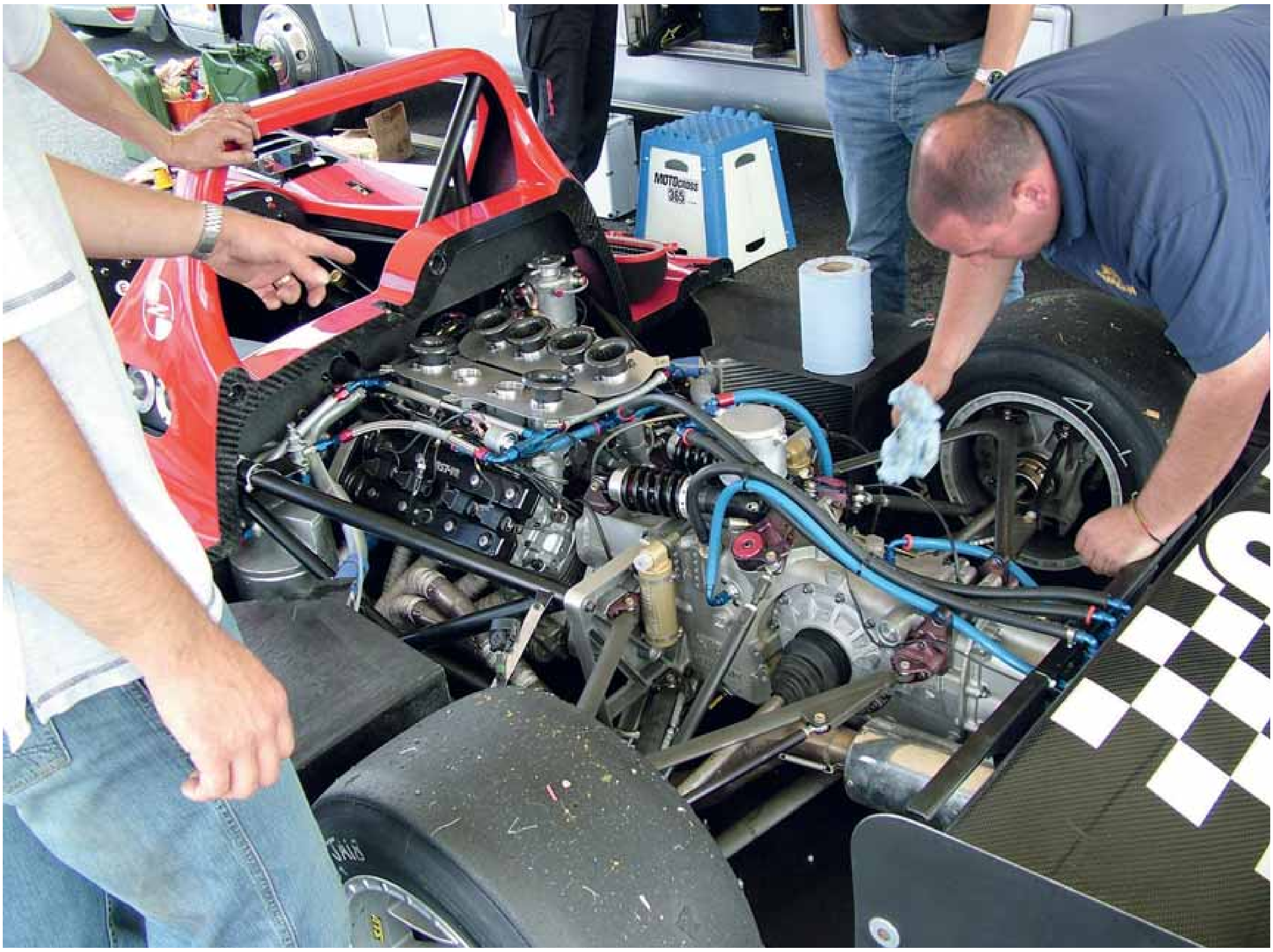
Interest in the new 'baby prototypes' has revived an old engine project with significant results – not least its application in the new F1 rulebook...

Words & photos | Sam Collins

'Where's the rest of it?' is the expression that comes to your lips when you first look at the tiny, lightweight unit that is the Motopower – Mountune RST-V8. Conceived just over 10 years ago by Russell Savoury, Simon Shaw and Tony Hart (hence RST) the V8 was first destined to appear in Gordon Murray's stillborn Lightning project. Back then it was quoted as producing 304bhp. However, Motopower was then running its own British Superbike team and the outfit's increasing demands saw the engine project sidelined.

But a few years ago the subject of creating an all-new V8 engine became a much-discussed topic and interest was such that Motopower decided to

"THE ENGINE WEIGHS IN AT A SHADE UNDER 74KG"



Sports racing cars seem a natural home for the RST V8, seen here and opposite in the Zeus chassis

resume work on the old RST. Savoury has completely reworked the engine since the project was revived, leaving only the motorcycle-derived cylinder head castings original to the first variant. The earliest version of the new RST was fitted to a Caterham SV – and has so far clocked up 20,000 miles, with no major problems.

The RST engine in its current configuration has belt driven cams, a change from its original design, and also that of the original Yamaha head design. However there is scope for chains to return, and future variants RST could either belt or chain driven. This switch left a cavity in the centre of the engine where the chain would have sat. If it wasn't for the stock head castings then the engine could be made at least 15mm shorter. 'On the drive there are pros and cons both ways – chains are narrower but can be noisy, belts are lighter, easy to tension and can drive ancillaries. They are both reliable and can handle the revs,' added Mountune's Roger Allen.

The only parts of the engine that are not bespoke are the cylinder head castings. These, and the basic layout of the block, are derived from a four-cylinder, in-line Yamaha motorcycle engine. Pistons, rods and crankshaft are made by Pistal, Arrow Precision and DKE respectively. In the quest for lightness, every component has →

Motopower/Mountune RST V8 tech specs

Number of cylinders:	8
Bank angle:	90-degree V
Bore:	75mm
Stroke:	56mm
Displacement:	2400cc
Spark plugs per cylinder:	1
Valves per cylinder:	5 (3 inlet)
Number of cams:	4
Compression ratio:	Classifiied
Injection/carburettor:	40mm twin injector port throttles
Power:	401bhp
Torque (est.):	190lb.ft at 7800rpm
Weight:	74kg
Dimensions:	
Length:	550mm
Width:	552mm
Height:	450mm

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been pared down to the minimum, and the engine weighs in at a shade under 74kg.

In February, Savoury turned to David Mountain, the principal of Mountune, for help. In collaboration with its parent company, Roush Technologies Ltd, Mountune brought the ability to productionise the engines, as well as providing servicing and road car certification from its base in Essex, England. Through Mountune the engine has gone into low volume production in a variety of guises, with the firms' one-man, one-engine building philosophy prevalent. Motopower itself continue to concentrate on further engine development and special projects.

When Racecar visited Mountune to inspect the prototype RST engines in build it was still being developed and 'productionised', each early prototype engine being bespoke. A hypothetical example is a follower that had been machined to fit one engine would not fit another apparently identical engine. This process was joint operation between Mountune and Motopower. As Racecar closed for press Mountune advised that this stage was complete and the production specification engines were ready for sale.

“POTENTIAL IS IN EXCESS OF 400BHP, AND WITH GOOD RELIABILITY”

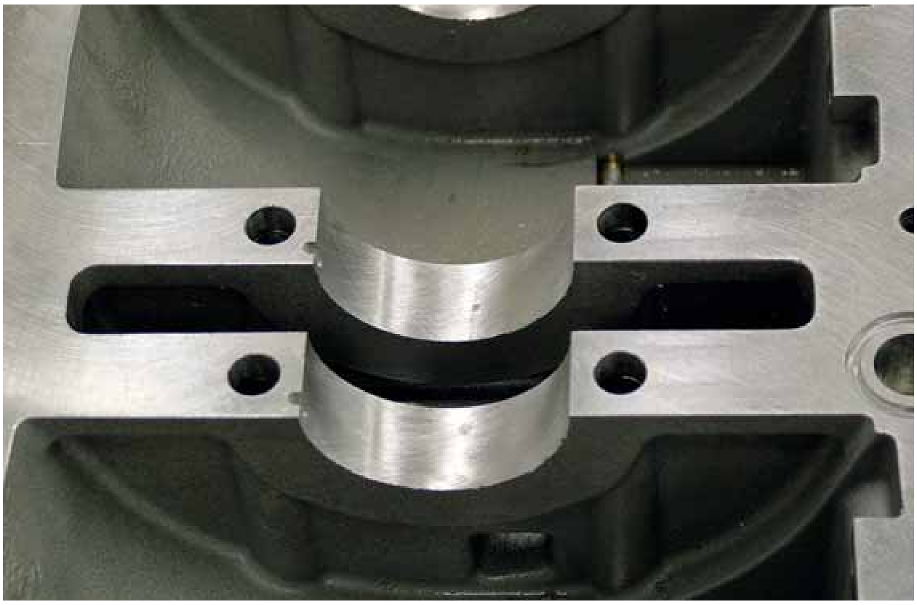
Currently the Motopower team is developing the engine and looking into titanium and other advanced materials to see how far the engine's capabilities can be pushed. It is, after all, a 2.4-litre V8 – the same capacity and configuration that will soon be used in the world's highest profile racing series.

'It's a mini F1 engine, but somewhat cheaper,' claims Allen. 'The target price for the race engines is between £23,000 and £25,000.' However, there is a smaller, cheaper option for those on a tighter budget – the 2.0-litre version. 'It gives a nominal 340bhp – more or less depending on application – a sprint race version can run higher rpm with more power and vice versa. The race applications for the 2.0-litre are essentially areas where there is a 2.0-litre capacity limit. The road applications are where there is a budget constraint, because the 2.4 will be more expensive.'

The RST doesn't quite have the performance of a 2006-spec F1 engine either. 'The road version revs to 10,500rpm and the race version should rev in excess of 12,000rpm and produce upwards of 380bhp.' The final brake horsepower figure is actually now thought to be around 400 on the competition spec unit. The estimated maximum torque is 190lb.ft at 7800rpm. →

The V8 is being productionised at Mountune's Essex HQ, the engine specialist will also market the engine

Cavity left in the centre of the engine where the timing chain would have sat, RST cams now belt driven



Mountune's unfinished business

'Le Mans is unfinished business for us,' claims Roger Allen. And the RST could be the first step back towards LMP racing. The new V8's first competitive outings were in sports prototypes, an area of the sport that Mountune feels is missing from its portfolio. But the firm still wants a proper attempt at Le Mans. On a number of occasions it has been all set to head down the N138 to La Sarthe, only to have its hopes dashed. The company's most successful recent attempt was in 2004 with the Taurus Sport VW/Caterpillar diesel engine.

However, the one attempt that really irks the firm was shortly before Reynard collapsed, when Mountune was in the late stages of development of the MT1 engine. It was destined to be fitted to the chassis now known as the DBA/Zytek, which has since proved to be one of the fastest prototypes currently racing. The half-finished prototype MT1 is now sat in a corner of Mountune's Essex HQ, its 2.0-litre turbocharged format clear for all to see, although a number of parts fitted to the engine are only rapid prototyped. Its build objective was to last 5500km of racing conditions or, in other words, the 24 Hours of Le Mans.

Two of the four LMP3 cars featured in last month's RE were powered by Mountune engines and both the firms behind those cars are looking at building LMPs. It is abundantly clear that Mountune has its eyes and heart set on racing prototypes at Le Mans again. Perhaps the RST is the start of a new era for Mountune in sportscar racing – after all, it already supplies the V6 engine used by Ewan Baldry's Juno racers and Baldry is known to be considering stepping up to LMP2...

There are provisional orders for 30 units so far – at least one of these has been fitted in the back of the reworked Zeus racecar, an LMP3-type chassis built around the RST (see RE V15N10). So-called 'LMP3s' or 'baby prototypes' such as the Zeus will probably account for a large proportion of the orders. 'We have an impressive list of clients already, and we know at least one of our engines will be competing in Britsports before the end of the season,' reveals Allen. 'We believe that the 2.4 will mainly end up in sports prototypes, and that's certainly where the interest is at the moment with three outfits having already bought engines. We have supplied the first to Zeus and the other two will have their initial engines in the next few weeks.'

The Zeus spoken of is that run by Alcon's Jonathan Edwards in Britsports – a small LMP3-style prototype featured in V11N4. 'I had read articles on it with interest when the test version was fitted to a Caterham,' Edwards recalled, obviously impressed by the concept of the RST. 'Clearly the engine has great potential. In dealing with Mountune for spares for our 2.3-litre Duratec engines which were to be fitted to the two Zeus cars we run we heard about the RST, so we got in touch with Russell Savory. Within three minutes

"THE ROAD VERSION REVS TO 10,500RPM AND THE RACE VERSION IN EXCESS OF 12,000RPM"

of discussing his powerplant and our cars I realised the combination would be perfect and we opened our cheque books.'

Edwards is certain that the engine is perfect for his 'baby prototype': 'Clearly, at just over 70kg, and producing well over 360bhp in mild tune whilst delivering a good flat torque curve, nothing else comes close. Potential is in excess of 400bhp, and with good reliability. The engine is a proper racing engine, utilising technology Russell learnt when running superbikes.' As mentioned, the engine is the same layout and capacity as a new spec grand prix engine, a fact that has not gone unnoticed by the first RST customers. 'It may sound daft, but this unit looks just like the pukka article. It is, as we call it, our little Swiss watch!'

It is also clear that the RST V8 is an engine full of potential, and *Racecar* will continue to track its progress, along with that of the Zeus, both of which promise to have some very exciting developments in the pipeline. RE

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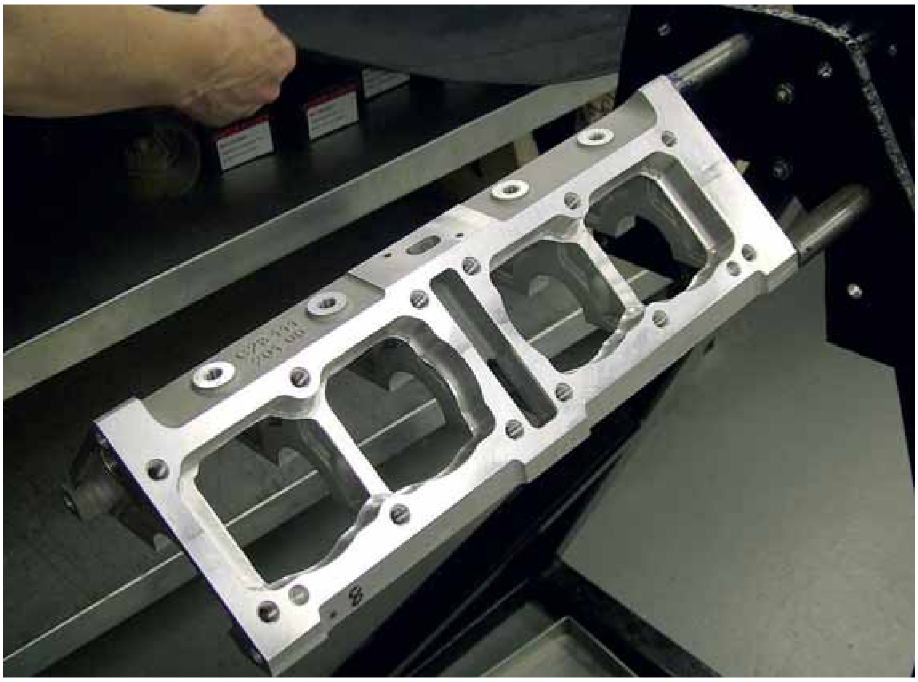

Everything on the RST is pared down to the minimum to make it lightweight, here the crankcase

Mountune

Mountune was founded in 1970 by David Mountain, and established its reputation building Mini engines. It started gathering pace and business in the 1980s when wins in the British Willhire 24 Hours race cemented the firm's reputation as one of the best in the business. Rallying gave the firm a further boost when in 1994 cars using Mountune engines won four rounds of the WRC. Since then, the firm has supplied rally engines to works teams such as Ford and done development work for a number of others. Sportscar racing and touring car racing yielded some successes as well. In 2003 the firm was bought out by Roush Technologies and moved into its current premises in Brentwood, Essex. Recent high profile projects include the LMP1 diesel engine used by Taurus Sport at Le Mans last year.

Because of the sheer breadth of projects undertaken, Mountune's parts department always has at least half a dozen engine types actively in stock and the types of engine are constantly changing. A Jaguar V6, the RST V8 and a Ford Super 1600 were all being worked on the day *Racecar* visited.


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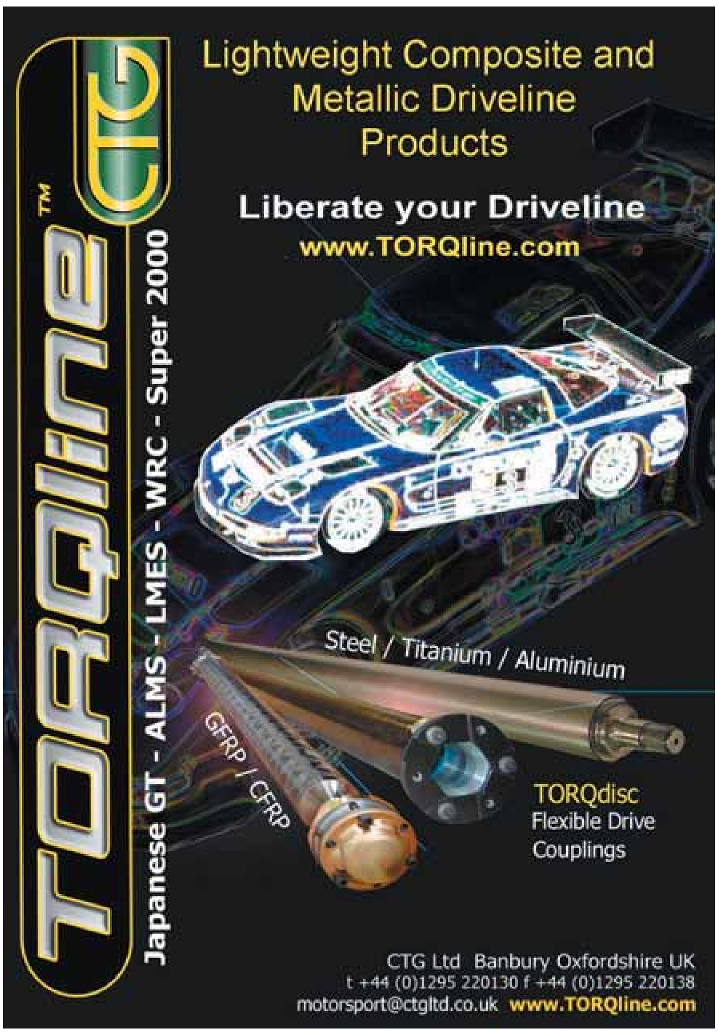
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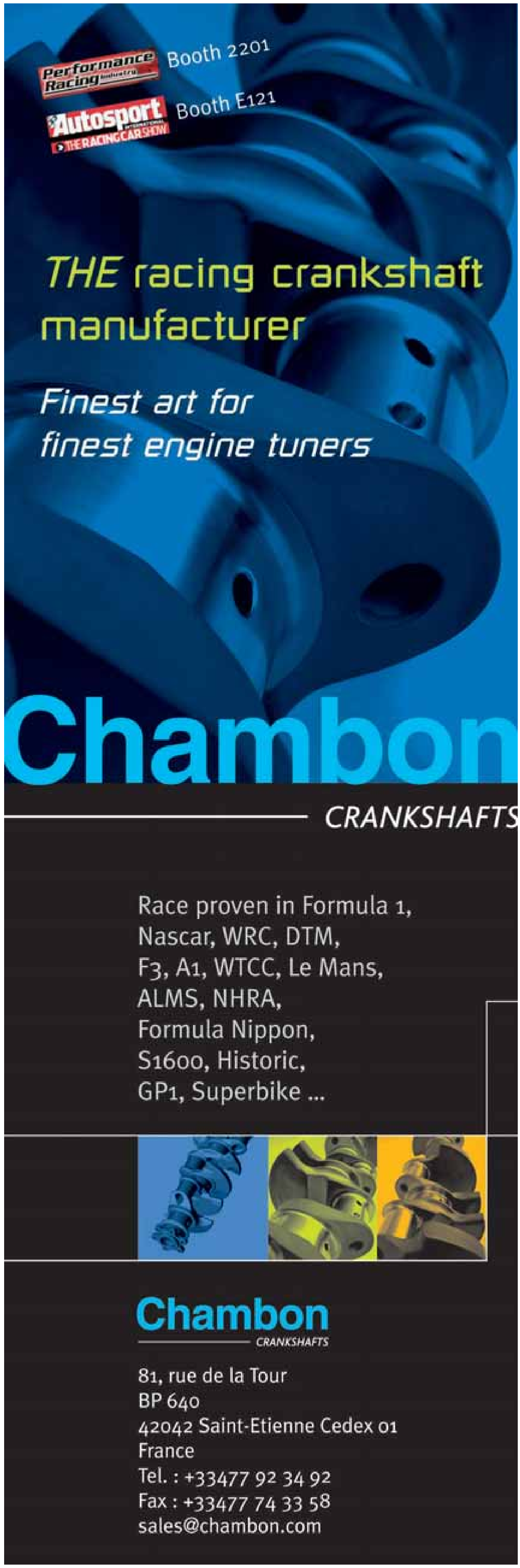
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Silver Crown jewel

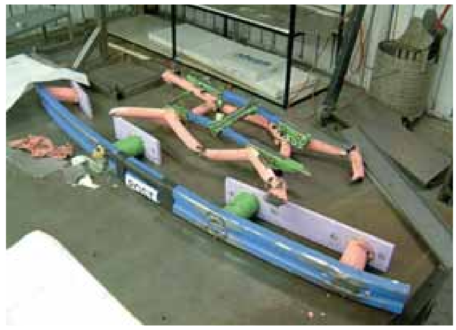
USAC's need for a new paved-oval racecar and ISC's search for more races for its newest tracks combined to create an exciting new class of US racers

Words & photos | Karl Ludvigsen

'What the hell's a Silver Crown car?' That's what Ron McMahon remembers NASCAR people asking when they found the Silver Crown series in the résumés of many of their top drivers. Tony Stewart, Jeff Gordon and Ryan Newman are former Silver Crown racers. So are Mike Bliss, Carl Edwards, Kasey Kahne, Jason Leffler and Ken Schrader. Fans, officials and Bill France Jnr himself were curious about USAC's (US Automobile Club) Silver Crown series, said McMahon, vice president and general manager of Riley Technologies in Indianapolis. The next thing McMahon knew he was building the prototype of a brand new car intended to take Silver Crown the next step to enhanced national recognition among America's oval-track series.

Silver Crown traces its origins to 1971. Until then, USAC's dirt-track cars competed on an equal basis with its longer-track racers on the Championship Trail. In 1971 the two series were split, the National Championship being the 'Gold Crown' and the dirt-track cars competing by analogy for the 'Silver Crown' Championship. Since then they've raced both on dirt ovals and on paved tracks ranging in length from $^5/_8$ of a mile to just over a mile.

Though at a glance Silver Crown cars look like sprint cars, in fact they're larger, heavier and carry enough methanol to complete a 100-mile race non stop. That's how long their races are, or 100 laps depending on the track. Powering them are ferrous-block American pushrod V8s of 355 cubic inches (5818cc). Derived from Chevrolet, Ford and Chrysler designs, the fuel-injected eights deliver some 750bhp between 7600 and 8800rpm. Minimum weight with water, oil and fuel is 1500lbs (680kg), while pavement sprint cars are only 1350lbs (612kg). Among traditional makers of



Crash testing of the mandatory, detachable front, rear and side structures has allowed a known level of driver protection to be incorporated into the cars

Silver Crown chassis are J&J Automotive, Stealth Motorsports and Beast.

Filling the void

The bright spotlight from the deep South on these robust racers has focused on more than just their role as a training ground for NASCAR drivers. Also part of the France empire is International Speedway Corporation, owner of 11 race tracks with a part interest in two more. A recent trend for ISC has been its building of paved one-mile ovals such as those at Homestead-Miami and its new Kansas City track. It also has a 37 per cent share of the one-mile Chicagoland Speedway. These are attractive facilities but, says ISC, it doesn't have enough races for them. Thus it eyeballed USAC's Silver Crown racers.

In the meantime USAC had been trying hard to enforce common Silver Crown car rules for dirt and paved ovals, but found it difficult to police the cheaters who knew that the two types of track demanded significantly different set-ups. USAC finally concluded that it would be best to accept the status quo and permit distinctly different cars for the two very different track conditions.

Having decided to establish a distinct Silver Crown design for paved ovals, USAC then found that there weren't enough of them to set up a good series for such cars. Paved ovals at its disposal were only four, ISC's Richmond and Phoenix plus Milwaukee and Indianapolis Raceway Park. With paved tracks in short supply, the idea of competing on ISC's one-mile tracks was appealing. So USAC president Rollie Helmling and technical director Mike Devin made the short stroll from their offices in Speedway, Indiana around the corner to Riley Technologies to talk racecar strategy.

Ron McMahon holds the worm and sector steering system with power assistance and detachable wheel

They had willing listeners in veteran designer and president Bob Riley, Riley Motorsports president Bill Riley and general manager Ron McMahon. This was right up the street of McMahon, a GM Institute engineering graduate who, after a score of years with GM, set up his own racecar building company, before joining Riley 10 years ago.

All were quick to grasp USAC's problem – that the existing Silver Crown cars would be way too fast and dangerous on a one-mile track. 'They already reach 167mph on the back stretch at Phoenix,' said Ron McMahon, 'and in tests ran 192 at Gateway in St Louis' – a one-mile oval. Without counter measures they'd easily be topping 200mph on the ISC tracks.

> **"MORE THAN JUST A TRAINING GROUND FOR NASCAR DRIVERS"**

Some two years ago USAC offered, and Riley accepted, a project to develop a new Silver Crown car that would remain true to the well-tried series format but would also be as safe as possible to run on these longer ovals. USAC's requirements for the work were as follows:

- Keep the look of the cars as little changed as possible.
- Carry over the same engine specification.
- Stay with the same type of solid axle, coil/shock suspension, already familiar to car owners who run Silver Crown cars more as a hobby than a profession.
- Maintain the present proportion of ready-made bought parts to keep cost down.
- Make the car 'safe' for running on one-mile tracks. McMahon: 'We decided to limit the maximum speed to 180, and we had to slow them in the corners, too.' →

The new Riley design for a Silver Crown car incorporates elements to reduce speeds and improve safety

USAC's assignment to Riley was to design, build and test a prototype. 'Rollie Helmling was very instrumental in getting the project started,' McMahon recalled, 'along with Mike Devin, who provided a lot of input. We worked very closely with them in the early stages, keeping them informed on the direction we were going so we didn't get too far outside the boundaries they had established.' Riley's task has now been completed. Based on its findings, USAC has promulgated new 2006 rules for Silver Crown cars for paved tracks. The existing cars will continue to race on dirt race tracks.

Bob Riley's design for the new car, computer detailed by Travis Jacobson, met its objectives right out of the box. 'Staring late in 2004 we tested it at the one-mile Kentucky tri-oval,' said McMahon. 'Jason McCord was the driver. On his seventh lap he was reaching 180mph with a lap speed of 162mph. We met the targets right away.' With Tony Ave as well the prototype was put through the wringer at Phoenix and Homestead in

"AT A GLANCE SILVER CROWN CARS LOOK LIKE SPRINT CARS"

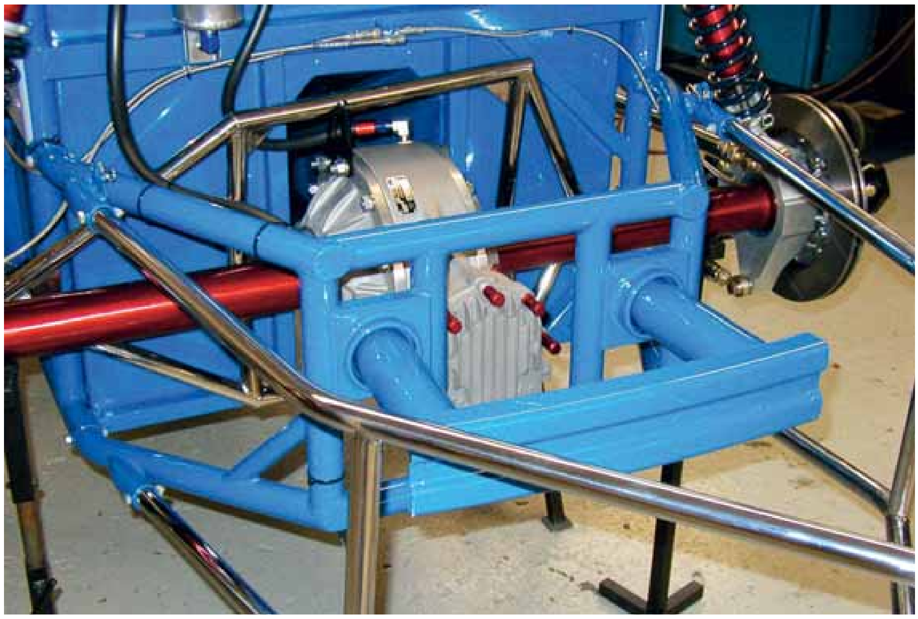
addition to Kentucky. 'We ran it as hard and fast as we could at Homestead,' McMahon recalled of the test session. 'We adjusted ride heights and spring rates to make it as fast as possible. We had 65 gallons of methanol, and after 100 miles we had 15 gallons left.'

New for 2006

For 2006 USAC has more than doubled the purses for these cars and expects 10 races for them. Interest was sparked by the prototype's display at the Performance Racing Industry show in December 2004. Cars are being built by Joey Martin's Stealth Motorsports, Joe Devin's Devin Racing Chassis and Keith Kunz Motorsports. Riley has jumped on the bandwagon as well. 'We weren't planning on being a producer,' McMahon said, 'but as time went on this started to look interesting. It's hitting home that this is really going to happen.'

Cars are being bought and built in spite of the scepticism that inevitably attends any effort to tinker with an established racing category. Riley's Silver Crown prototype attracted just such doubts at first. A major change, for example, was moving the fuel cell from a plastic housing in the extreme tail to an SAE 4130 sheet-steel container, integral with the frame and forward of the rear axle. The aim was three-fold: to move the cell well out of harm's way, give it better protection and to keep the fuel mass within the wheelbase where its consumption during a race has less effect on →

Front crush structure is removable and feeds loads into the chassis at rigid nodes dispersing forces



A similarly replaceable crush structure is used at the rear inside the removable tail supporting frame

The side-mounted crush structures locate in hard points along the side of the chassis preventing intrusion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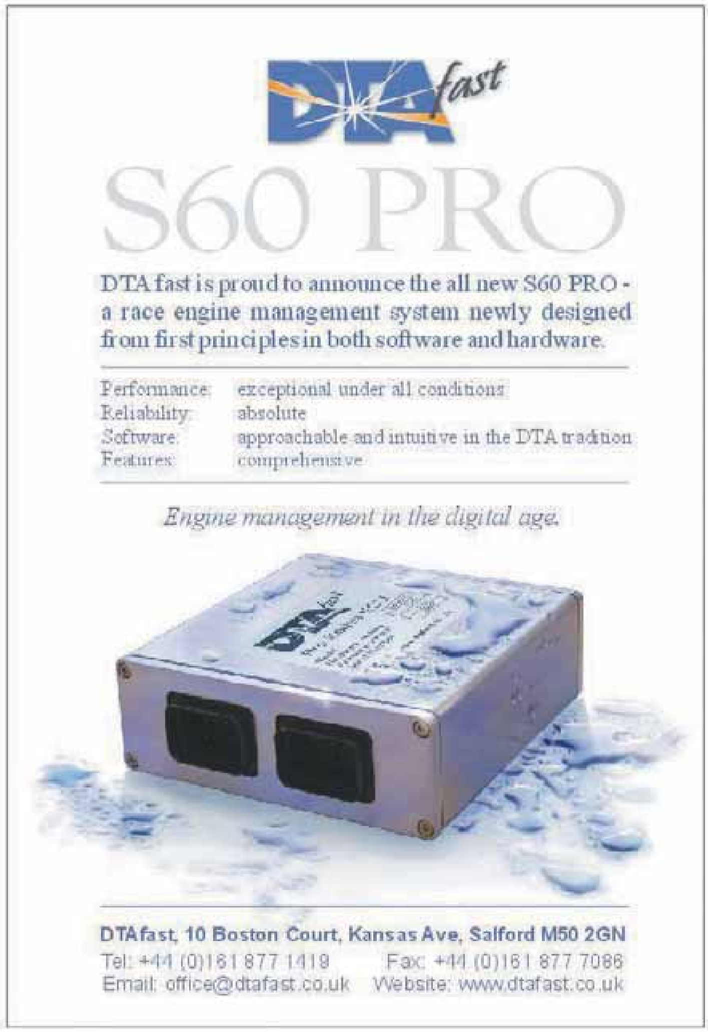
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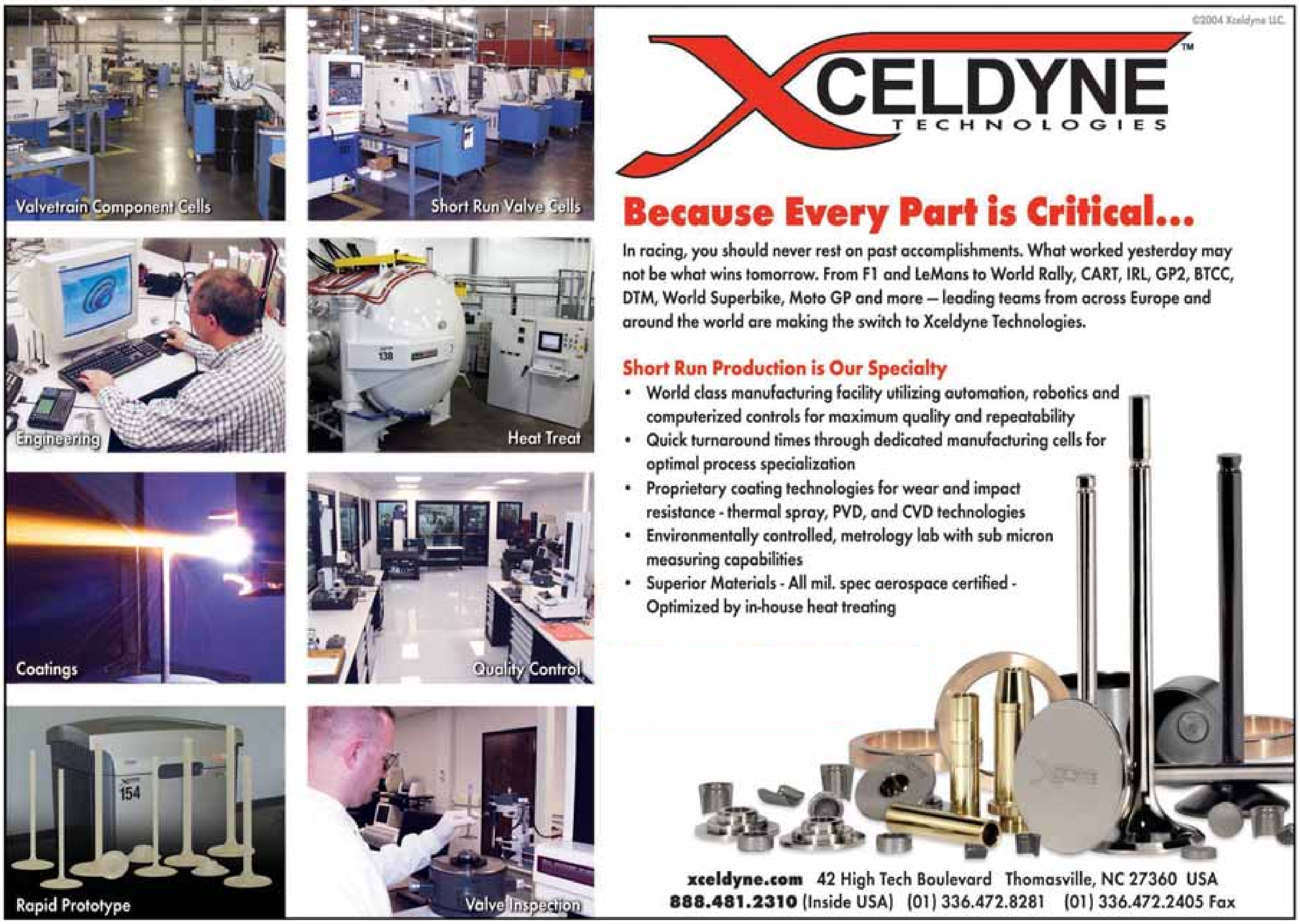
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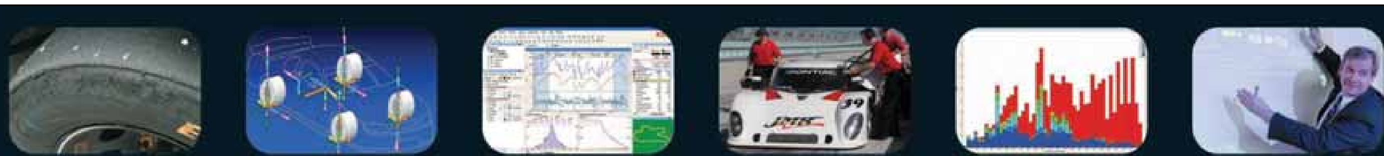

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All-embracing seats were a mandatory requirement of the new Silver Crown cockpit specifications

Crash testing for safety

Along both sides of the Silver Crown frame are four mounting points for a crash-absorbing structure, within side pods of a design that's standardised for all cars. On each side is a rugged guard beam with four tubular mountings that are designed to be crushable. The nose piece and tail cone, also standard for all cars, encloses crash-impact structures. The provision of a crash structure at the rear became feasible only after the fuel tank was moved forward.

All structures have been crash tested at the Center for Advanced Product Evaluation (CAPE) in Westfield, Indianapolis. Set up in 1998, CAPE is a division of IMMI, which made its reputation in seatbelt design and production. IMMI established CAPE mainly to work on crash improvements to trucks and coaches, but its capabilities and experience have met Riley's needs well.

With its crash-test facilities CAPE has evaluated Riley's proposals for Silver Crown crush structures at impacts of up to 25g, using the same 31mph impact speed as the FIA's tests for sports prototypes. So far, nine actual crash tests have been undertaken, in addition to several simulations.

The various structures have been developed by Riley through simulation, test and redesign with the help of CAPE's engineers and the staff of Shape Corporation in Grand Haven, Michigan – the company who makes the energy-management tubes (EMT) that are at the heart of the driver-protection impact packages. Shape's manager of research and development, Dave Heatherington, worked closely with Riley to match his EMTs to their crush requirements. The actual fabrication of the system was up to Riley.

Computer simulation was used by Shape to arrive at the final designs for the crush structures. Initially a triangular structure was posited for the rear of the Silver Crown, but this was changed during development to a crash bumper mounted on two EMTs, illustrating well the mutual benefits of both simulation and testing.

Other inputs to the final driver-protection configuration of the 2006 Silver Crown came from acknowledged experts in the field. Both Tom Gideon of GM Racing and Dr. John Melvin of Tandelta Inc. provided advice on the design of the crushable structures and other safety aspects of the car such as seat design, seat mounting and placement of driver safety nets.

More comprehensive simulation of the whole vehicle crash performance will be possible with the use of finite element analysis (FEA). 'We do some FEA here,' said Riley's McMahon, 'but we haven't yet simulated crashes. We're working on it with a computer company but at the moment it takes 36 hours to simulate a half-second crash. We may well be able to make use of FEA in the future.'

By exploiting in full the available techniques, USAC and Riley have advanced the state-of-the-art driver protection in the new Silver Crown racer. The next step, inevitably, will be to see how these structures perform in the real world. To enable full analysis of their performance the cars will need to carry on-board recorders of *g*-force impacts.

the overall weight distribution of the car.

A consequence of the new location was that the bottom of the tank is split by the drive torque tube. Critics were sure it would never drain properly to the pump on the left-hand side, especially at high lateral gs. 'It drained absolutely equally on both sides,' said Ron McMahon. One objection was overcome.

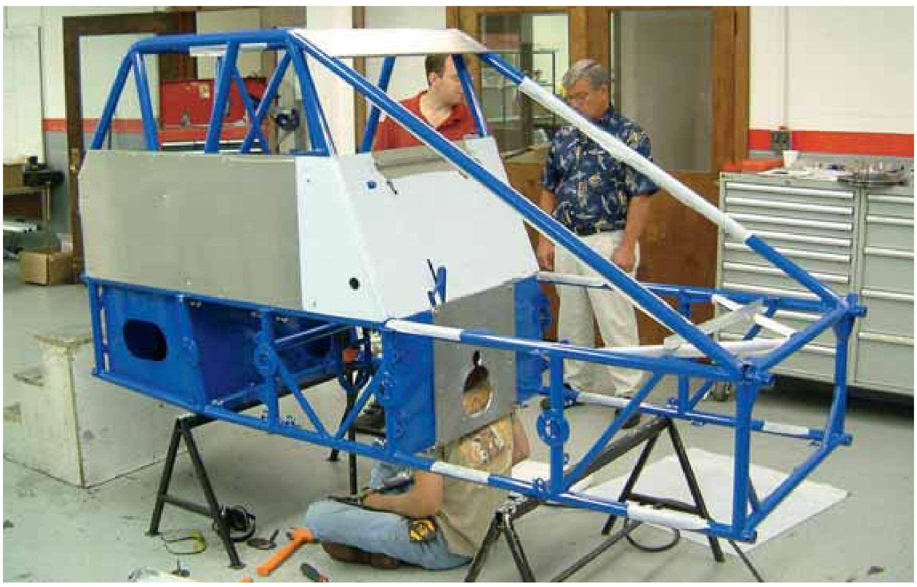
Another important change is that the new car is completely symmetrical. Previously Silver Crown cars were offset by as much as seven inches, giving left/right weight distribution around 57/43 per cent. Now the new design is balanced side-to-side to reduce

"WITHOUT COUNTER MEASURES THEY'D EASILY BE TOPPING 200MPH"

cornering grip. With the same aim in view the width of the outside rear wheel was cut back from 18 to 14in. Widths of the front rims, like the rears of 15in diameter, are 10in and all wheels for all cars are supplied by Weld Wheels. Solid front axles must be tubular and of SAE 4130 or equivalent steel. Made by Winters Performance Products, the rear axle is an open tube with a quickchange centre section.

Tremendous final drive ratio choice is available from several different ring and pinion pairs, plus 60 quickchange gearsets that can be used on either top or bottom shafts, resulting in 120 ratios in all. In contrast, the series spec two-speed Emco transmission is designed so that its low ratio cannot be changed.

The use of a two-speed is an innovation for



Basic chassis is a simple triangulated frame with a roll structure design dictated by USAC's regulations

Silver Crown cars, which as a rule dispensed with them before. Riley decided to recommend a low gear in view of the cars' need to have a good starting ratio when geared to suit the faster tracks. The driver's doing around 40mph when he shifts up at 4000rpm, using the lever at his left with its motorcycle-type squeeze handle to throw out the clutch.

America's brass-balled oval trackers were also dubious about the safety provisions that Riley built into the pavement-racing Silver Crown. Such effete notions weren't their style, but they soon came to appreciate that, on the 1.5-mile tracks, a little extra protection wouldn't go amiss. In achieving the aim of better crash protection, Riley reckons it's given the new Silver Crown more actual crash testing, from all directions, than any other formula car has ever experienced. See the sidebar for details.

Pilot protection begins with the series-spec →

New rules mandate a symmetrical chassis to reduce adhesion on paved ovals

Transmission is a two-speed unit, unusually for a Silver Crown racecar

Panhard rod is a truss-like structure located above and below the differential

At 34 inches the cockpit is some 5 inches wider than previous Silver Crown cars

4130 steel tube frame, which makes more room for the driver with an interior width of 34in. Lateral strength is aided by three steel bulkheads, one at the firewall and two enclosing the fuel tank. Main frame rails are one-inch 4130 steel tubes, which may be either round or square.

Clear specs are given on USAC's website for the roll cage, an area in which some builders hope to improve on the prototype's angular structure. A tubular bumper structure outside the body at the rear is mandatory. All-embracing racing seats are required, as are harnesses with a minimum of six mounting points. An on-board fire extinguishing system is also mandated.

Exterior Silver Crown body panels are to a standard spec as established by Riley. They're made of e-glass with Kevlar in Twin Lakes, Wisconsin by Five Star Bodies, under contract to Riley. A feature of the nosepiece is the way its upper surface slopes up to the horizontal air filter above the injectors. 'At speed that produces a negative pressure above the engine, starving it of air,' McMahon explained. 'That's another Riley/USAC trick to slow down the paved-track Silver Crowns, which are no longer allowed to have big forward-facing anteater air scoops that pack extra air into the engine.

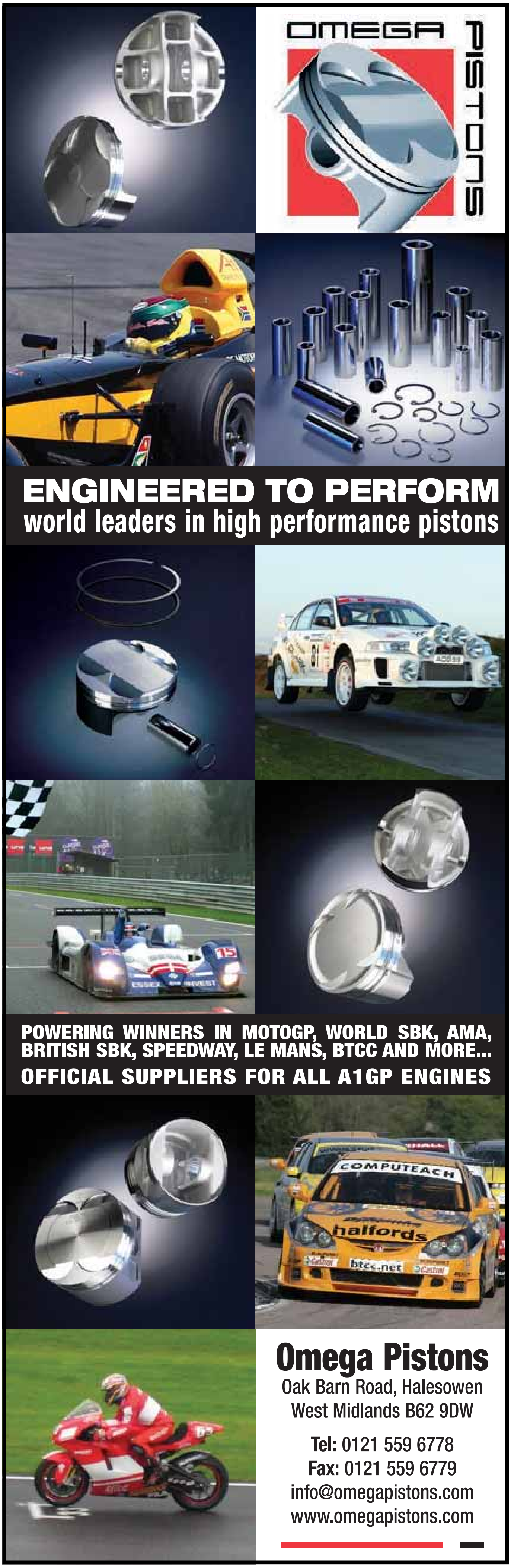
Among other chassis features is a cockpit-mounted worm and sector steering gear with hydraulic power boost and a detachable steering wheel. Riley's design has four mounting holes in the pitman arm for the drag link to allow quick steering ratio variation. A combination of parallel radius rods and panhard rods guide the axles. The rear panhard rod of Riley's car is designed as a truss structure so it can pass above and below the differential. Brakes are by Wilwood with mandatory ferrous discs.

"WELL WITHIN THE REACH OF THE PRIVATE ENTHUSIASTS"

For improved stability on the fast paved ovals the 2006 Silver Crown may have a wheelbase of between 101 and 104in, increased from the previous legal minimum of 96in. The Riley car has a 102in (2590mm) wheelbase. Width is set as 75in (1905mm) between the outer surfaces of the side pods while length is unchanged from 2005 at 15ft (4.57m). To take account of its added safety equipment the minimum weight is raised by 150lbs to 1650lb (748kg).

The new paved-track Silver Crown has the look of a robust racer with the rough, tough cockpit beloved of American drivers. As a kit Riley is charging $16,000 (£8870) with $61,500 (£34,000) the tab for a car complete less engine. Even at an increase of around $7000 from the 2005-style car this is very reasonable for a professional racecar, well within the reach of the private enthusiasts who are the backbone of the car owners in the popular Silver Crown series.

The first chance to see the new cars on the track will have been in exhibition races at Kansas City over the weekend of 8-9 October, while the 2006 season itself kicks off with its first championship race at the end of January. With multiple cars under way from multiple builders, the outlook is good. Silver Crown is stepping up a gear, ready to nurture even more fine drivers for both USAC and NASCAR. RE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Time team

An innovative approach to a design exercise lead to the rapid development of a racecar concept and turned up some unexpected ideas in the process

Words	Sam Collins
Images	Aston University

Technology transfer is part of motorsport, with aircraft technology being perhaps the most obvious exponent of this, but what about agricultural machinery? Well, a group of students based at Aston University in England thought that applying hydrostatic drive technology – as found in snow blowers, tractors and road planers – to racecars was a hitherto unexplored avenue.

A highly innovative project known as the Global Design Initiative (GDI) saw the hydrostatic racer designed in just five days in the summer of 2002. The result formed Aston's class three entry in the following years IMechE Formula Student competition. And it won.

Five days is not a very long period of time to create something from scratch, yet the GDI project found a very simple way of maximising time. 'I was intrigued by some articles in engineering magazines that focused on collaborative development in the design phase of new product development,' states Chris Evans, the man behind GDI. 'The key element being the creation of a continuous design capability by locating design teams around the globe. Each team worked in local time but passed the design work on to the next team at the end of their day. My thought was that if industry was doing it, then we should be developing the skills and expertise with our own design and engineering students. All I needed was a suitable project, willing collaborators and time. Having persuaded my colleagues to help, enthusiasm for the project grew quickly.

'Of course I had many concerns. But I wanted to create a continuous working environment inspired by an exciting concept. The few similar collaborations I was aware of tended to look at individual elements rather than a complete product. By involving each team in generating the overall concept we aimed to create a sharper focus on the technologies needed to achieve a working outcome.

"A HIGHLY INNOVATIVE PROJECT KNOWN AS THE GLOBAL DESIGN INITIATIVE"

'The question I was asked often was "what if you fail?" My response was that there is no failure, just learning. The risk of not completing, the teams not gelling or not having compatible ideas were minor compared with ensuring the technologies worked and the information flowed between the teams.'

There were of course teething troubles, such as finding willing teams in the US and Singapore prepared to take the risk of being involved in the project, getting compatibility in the CAD systems and selecting a parts data management package (in the end PDMworks was chosen).

However, since an early flurry of interest after the Formula Student success the project has been somewhat forgotten. A few elements of it have found their way onto Aston's current Formula Student car, mainly in the CVT system. But the car itself was never actually constructed – and it remains as a set of plans and renderings, somewhere in the archives of the Aston University School of Engineering.

Solidworks was the program that made GDI possible, effectively allowing students to construct a variety of designs and evolve them on screen rather than in the workshop. The students were tasked with the design of a 'radical' racecar and given just five days to do it. But leaving students alone for too long can have unexpected results – in this case four-wheel drive, four-wheel steering, regenerative braking, four motors and a lot of hydraulics.

The chassis itself was a fairly conventional affair, being a steel spaceframe mated to a 600cc motorcycle engine. Nothing exciting there. In fact, at first glance, it could be just another of the current breed of identikit student racers. But things start to get interesting when you investigate the pedals – there are none, no accelerator or brake, instead a pivoting bar in the centre of the footwell, one side of which would be pressed to accelerate, the other to brake. You certainly cannot describe this as any sort of throttle control because the 'pedal' has no direct bearing on the behaviour of the engine.

Power comes from the omnipresent Honda CBR 600 F3 (the staple engine of FSAE teams) but, unlike any other car in its class, it is coupled to a variable displacement hydraulic pump. The hydraulic system incorporates large piston accumulators that act to pressurise nitrogen in a storage area in the car's floor. In this initial design

"A VERY SIMPLE WAY OF MAXIMISING TIME"

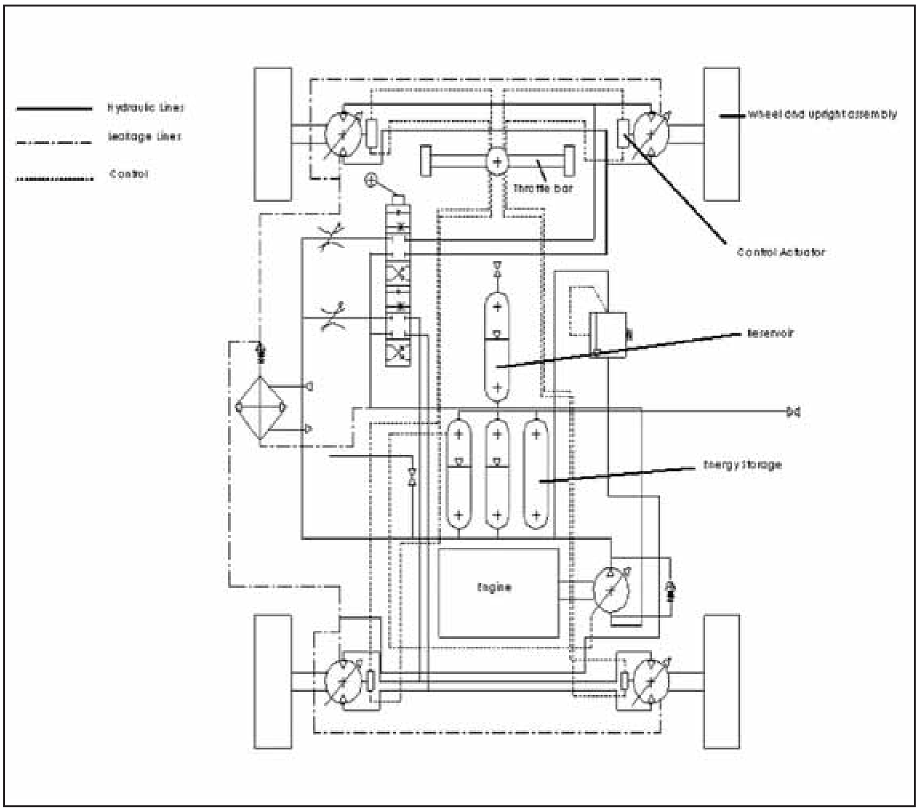
the storage area is set to allow complete storage of all energy dissipated when braking hard from 40mph to a dead stop.

The system serves variable displacement motors on each corner that drive the wheels through fixed 2.5:1 epicyclic gearboxes to achieve the required top speed (in the case of Formula Student, the target speed was 65mph). These gearboxes could easily be changed to obtain higher speed in other racing applications.

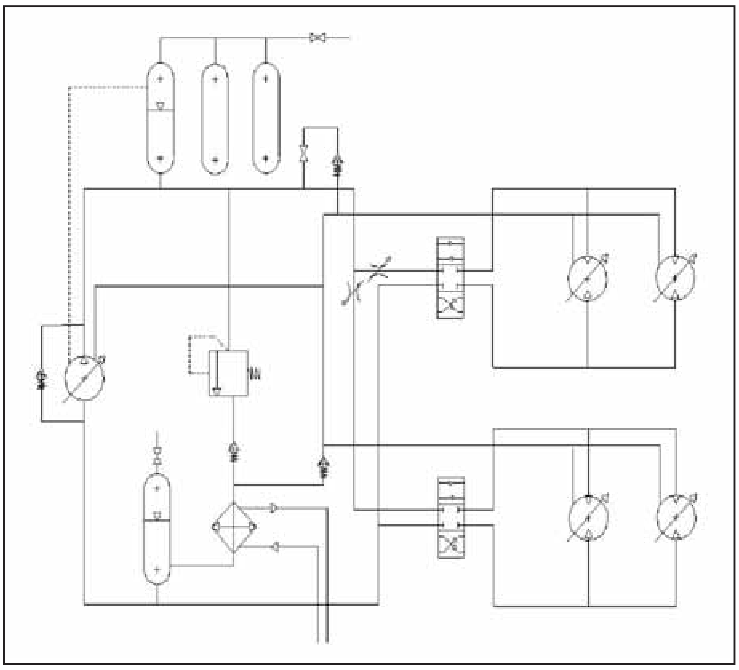
Stop and go

The Honda engine is set to idle at 8000rpm, giving maximum torque. The throttle is controlled by pressure in the storage system. Below 280bar the engine runs at full throttle until the pressure has built up again and it returns to its 8000rpm idle.

As mentioned earlier, a sway bar takes the place of pedals in the footwell and this bar controls motor displacements. In the neutral inert position the car is stopped or coasting. With the bias on the bar pushed to the right it increases the torque of the motors and accelerates the car. With the bias to the left the car decelerates, →

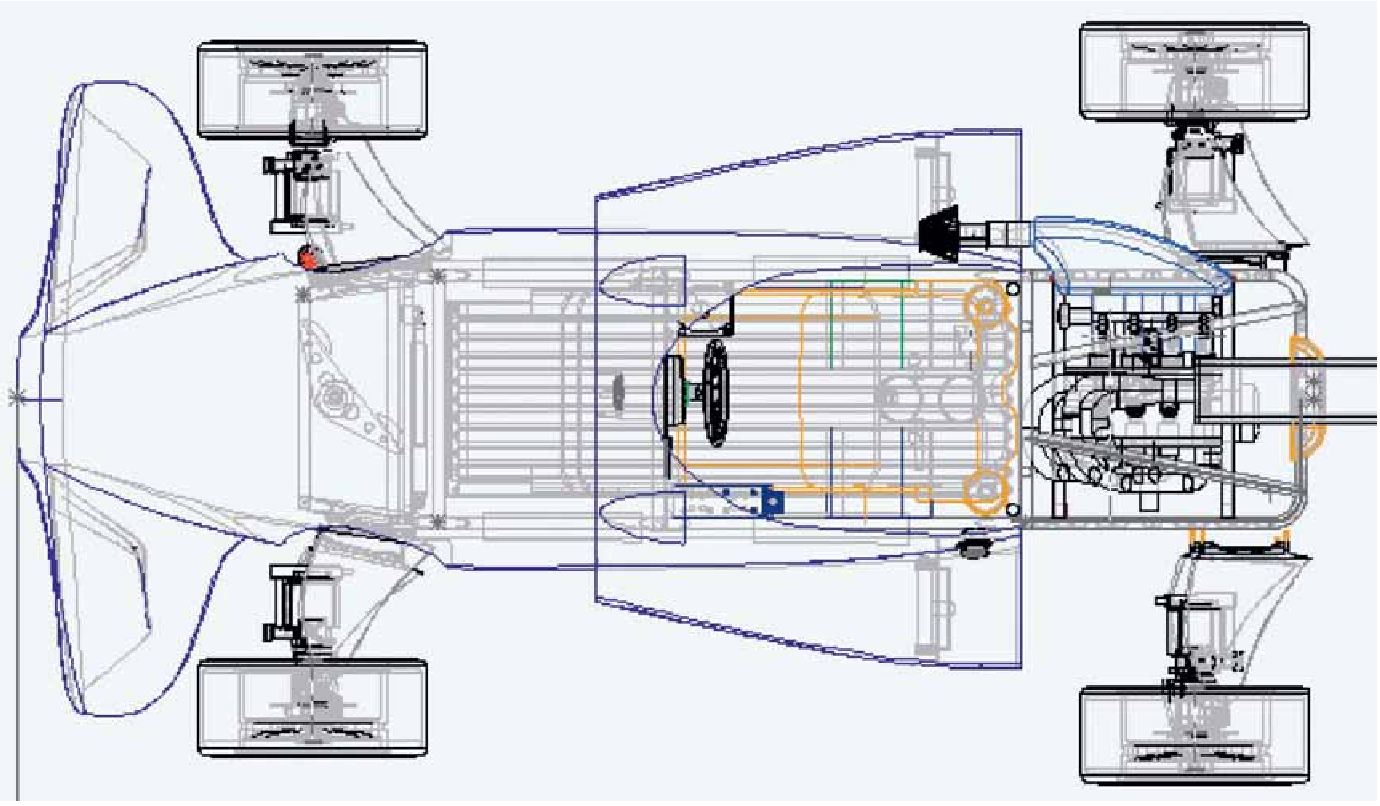


Above: diagrammatic representation of the hydraulic system featuring four wheel-mounted reversible motors which control acceleration and braking



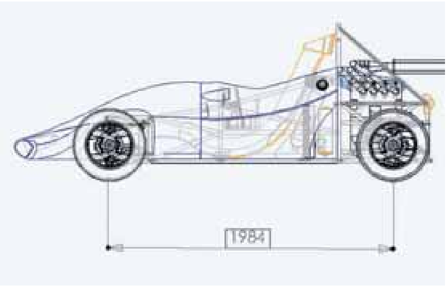
600cc Honda engine is coupled to a variable displacement hydraulic motor with full energy storage facility

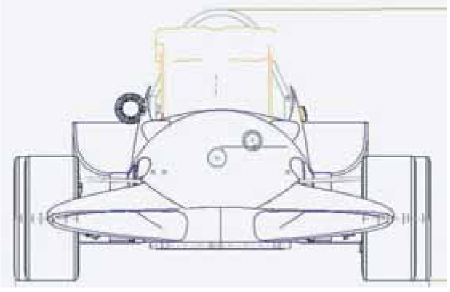
All design work on the hydrostatic racecar was executed in Solidworks



Plan view of hydrostatic racecar, showing wheel location and 'wing' suspension arms. Note the final design was for an MSA legal car, hence drivers' foot position

Using GDI meant students around the world worked continually for 120 hours on the design project





Side profile and front view of the concept showing body style, cockpit and seat arrangement, chassis and rear subframe design and in-line engine location. Note full height back to composite seat acting as firewall

effectively braking. In actual fact braking comes by way of the motors producing negative torque or, in other words, running backwards.

In this state the wheel motors act as pumps and pressurise the under floor storage area up to a maximum pressure of 350bar. As the system is designed to operate at 280bar, the extra pressure built up under braking is used up first before the engine has to replenish the pressure in the system again. This is effectively fully regenerative braking. An additional inboard disc brake is fitted to stop the car in the event of a failure.

The front and rear motors are controlled by separate hydraulic circuits allowing the driver to adjust the power bias front to rear, and this can be adjusted whilst the car is in motion. It is possible for the driver to demand more power than the system is capable of sustaining, and this will deplete the storage system until it reaches its minimum design pressure of 220bar. At this point the accumulator piston bottoms out and the storage system becomes ineffective. To prevent the motors from locking up the wheels in this scenario a 'freewheel' valve is fitted.

Four-wheel steering is also controlled by hydraulics. When the driver turns the wheel a multi-stage rotary actuator on the steering column activates linear actuators on each wheel, eliminating the need for a steering rack (the hydraulic actuators acting on the steering arms). These can be adjusted to suit conditions, circuit, and driving style. It is unclear how this system will affect the 'feel' of the car for the driver.

The anticipated performance of the car predicts that it will be able to travel 75m from a standing start in 4.3 seconds, going on to achieve a maximum speed of 58.4mph. 'This would not be a light car because of the regenerative braking/energy system but its four-wheel drive system would transfer this to the road very effectively,' explains Evans.

> **"BASED ON IDEAS THAT COULD BE ENGINEERED AND MANUFACTURED"**

It seems increasing unlikely that these claims will ever be proven though as there are currently no plans to build and test the car. It was only ever constructed in Solidworks and there was no funding available to the team when there was a will to construct it. Evans, on building the car: 'The final concept was based on ideas that could be engineered and manufactured. However, a concept like this would need the interest and support of the manufacturing and business sector if it were to become a reality.'

The implications of the project however are more obvious. Racecar design firms could set up offices around the world and be able to complete design work in a fraction of the time. No longer will the oft-used phrase 'not enough hours in the day' be valid because using the GDI concept there are 24 working daylight hours in every day. RE

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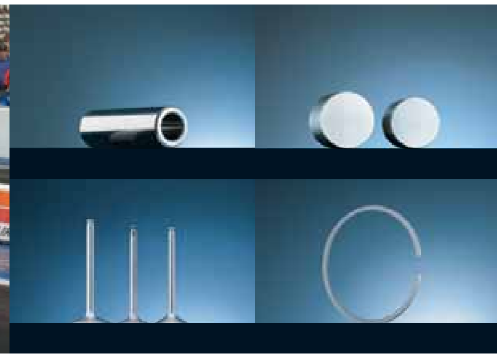

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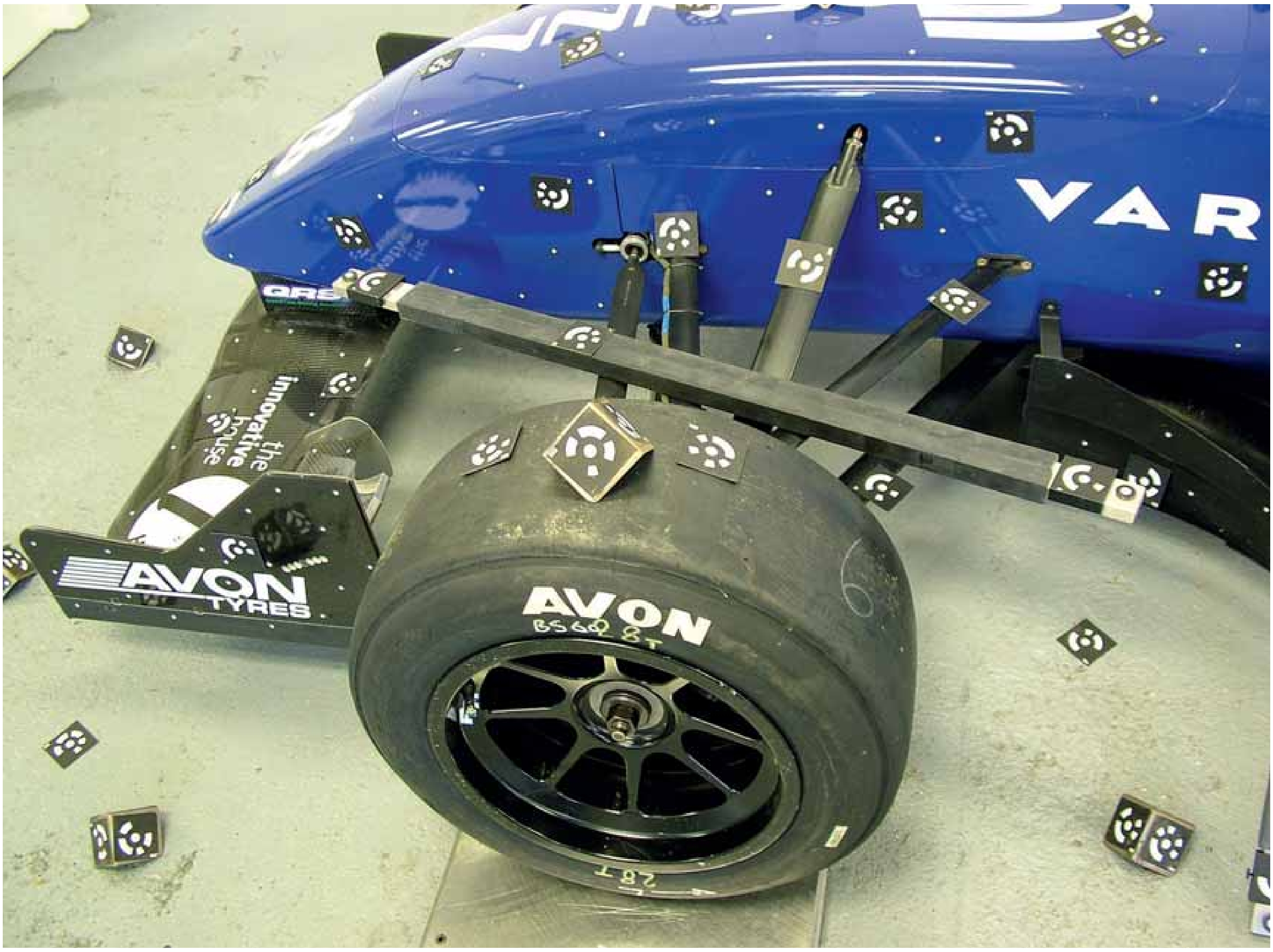

Measure for measure

Mobile, highly accurate, non-intrusive, zero wear and tear, and fast, too. What more could you require of a 3D measurement system?

Words	Simon McBeath
Photos	GOM UK; McBeath; PhysicalDigital

Various forms of non-contact 3D coordinate measurement systems have been in use throughout industrial and other sectors for some while, including laser and optical scanning. The latter has principally been the preserve of the large manufacturers in the automotive and aerospace worlds, and a number of academic bodies. In motorsport one of very few organisations thus equipped was McLaren, but until recently the capability was simply not accessible to a wider potential user base. Now former McLaren employee Tim Rapley has set up Physical Digital Ltd, the first independent company in the UK to provide a mobile, high-accuracy, 3D optical digitisation service. Once potential users are aware of the benefits of such a service and the company's presence becomes established it seems likely that Physical Digital's services will be in great demand. Some of those potential benefits that could accrue will become apparent shortly, but first we need to understand a little more about optical 3D scanning.

All forms of 3D coordinate measuring – tactile or otherwise – have similar fundamental uses that could be grouped more or less as follows: quality assurance inspection against known 3D (CAD) data; object duplication where no CAD data exists; digital archiving (for example of ancient artefacts); and reverse engineering to generate or update 3D CAD data. The latter could possibly be used for gauging competitors' products, or performing other computer-aided functions such as computational fluid dynamics (CFD) or structural finite element analysis (FEA). Deformation measurement is also available.

Optical measurement methods such as those we'll examine here have additional and very significant advantages over tactile methods. These include the ability to take the measuring equipment to the job and to measure objects as large as an aircraft or as small as a suspension mounting bracket. Furthermore much reduced

Left: The TRITOP system applied to an RR Racing Formula 3 car

Figure 1: Tim Rapley shows the first stage of optical measurement using the TRITOP photogrammetry system (McBeath)

Reference points are identified by barcodes placed on the car's surfaces

measurement times generating higher numbers of data points and higher levels of accuracy compared to tactile coordinate methods are on offer. As such these techniques are finding wide applications, and not just in engineering – the film and computer games industries have been optically scanning objects to provide the basis for computer-generated animations, which perhaps hints at the high level of surface detail possible.

So how can motorsport gain from optical scanning? Take one example scenario. CAD/CAM processes are sometimes thought of as infallible – there can be an underlying assumption that because the design, and perhaps also the tooling, have been aided by computer that post-manufacture geometry checking is unnecessary. Or where there is the desire to perform post-checks, there may be insufficient time to carry them out. That may be because of schedules, or more likely because of the complexity of shape of the parts, which makes tactile measuring prohibitively slow with currently available

"OPTICAL MEASUREMENT METHODS HAVE SIGNIFICANT ADVANTAGES OVER TACTILE METHODS"

techniques. The fast moving world of top-line motorsport may sometimes be guilty of these faults, where the prerequisites of zero time to delivery and geometric perfection – for example of new aerodynamic parts – are bound from time to time to be at odds. How many 'new aero packages' have failed to work as well as the simulations and wind tunnel programmes predicted because the 'as made' geometry was not what was designed, modelled and tested? Only disciplined process control procedures such as root cause analysis would enable these problems to be identified. Now though, with the speed and portability offered by 3D optical measurement, this and other questions can be answered and, if necessary, pre-empted with suitable improvements following process development programmes.

Some relatively simple motorsport-related projects highlight further benefits of the mobile optical scanning service now being offered by Physical Digital. For example, the main element of a rear wing set was scanned so that comparisons with the original CAD data could be made. A further example was a full size historic racecar (the precise identity of which we are obliged to keep secret but which is housed at the Brooklands Museum in the UK) that was completely digitised. And the early stages of a job on the Formula 3 Dallara of RR Racing have been included to illustrate some aspects of the measurement process. More on these projects later, first let's take a glimpse at the technology involved.

Data acquisition and analysis

Physical Digital uses equipment supplied by GOM mbH, a company based in Braunschweig, Germany, which was founded in 1990 as a spin-off from the Technical University Braunschweig. GOM employs over 100 people in Germany, Switzerland, France and Great Britain, and specialises in the development of optical 3D measurement technology for industrial use. It says its equipment is used mainly in product development and quality assurance, and its reference list includes many of the OE automotive manufacturers, but few motorsport related companies, yet. Perhaps Tim Rapley's wide experience in motorsport will see changes here.

Two principal items of GOM's systems comprise the Physical Digital armoury – TRITOP and ATOS. TRITOP is described as a digital photogrammetry system that comprises a high-resolution digital →

Physical Digital's ATOS optical scanner in operation at RR Racing's Woking headquarters camera, a laptop computer with potent image processing software, plus some crucial scale and marker aids that we'll look at in more detail shortly. ATOS is an acronym for Advanced Topometric Optical Sensor – a dual camera optical scanner combined with a projector that uses the principle of triangulation and 'fringe projection' to gather data on the surfaces it scans. By interfacing with the image processing software it then converts that data to a point cloud or mesh that defines the surfaces and surface features. It can be complemented on larger objects with TRITOP which pre-measures key reference points. The combination of these two systems produces a high-accuracy measurement of the free form shape of the work piece.

Measurement trials

The aforementioned wing element was set up for measurement using both TRITOP and ATOS. TRITOP utilises scale bars and two types of reference markers – known as coded and uncoded markers – that are placed on or around the object being measured. These are used by the image processing software to determine scale and orientation. Small self-adhesive discs with a white circle on a black background that are placed randomly on the object's surfaces are referred to as uncoded points. In addition, larger reference markers known as coded points are also placed on and around the object – these can be seen in figure 1 as the larger white on black markers on square backgrounds. Also visible in this shot are the scale bars, these being exactly 1 metre long and traceable to the international standard of length. Optical recognition markers are also visible on the ends of the scale bars, and the bars are placed at an angle to each other and in different planes.

The data gathering process then begins with an initial set of photographs that include the scale bars, taken at 90 degrees to each other, that allow the software to take account of any lens distortions. Then further photographs are taken from random positions around the object to provide a set of overlapping images to be analysed by the TRITOPCMM software. The software then computes a model based on camera positions, 'ray intersections' (rays being the lines joining the camera positions to the markers), lens distortion and object coordinates, and takes into account the various views of the scale bars, and the coded and uncoded markers. Figure 2 is one of the TRITOP camera's views of the upper surface of the wing, showing how it has recognised these features. Figure 3 shows a screen grab of the computed information from the Formula 3 car, with the ray intersections from two camera positions highlighted. The green points are the computed locations of the reference markers, and can be seen to roughly mark out the shape of the F3 car. The TRITOP measurement is relatively quick, depending on the size of the object, its complexity and the level of detail required. Once this image data has been gathered, if TRITOP is used independently of ATOS then the object is no longer required.

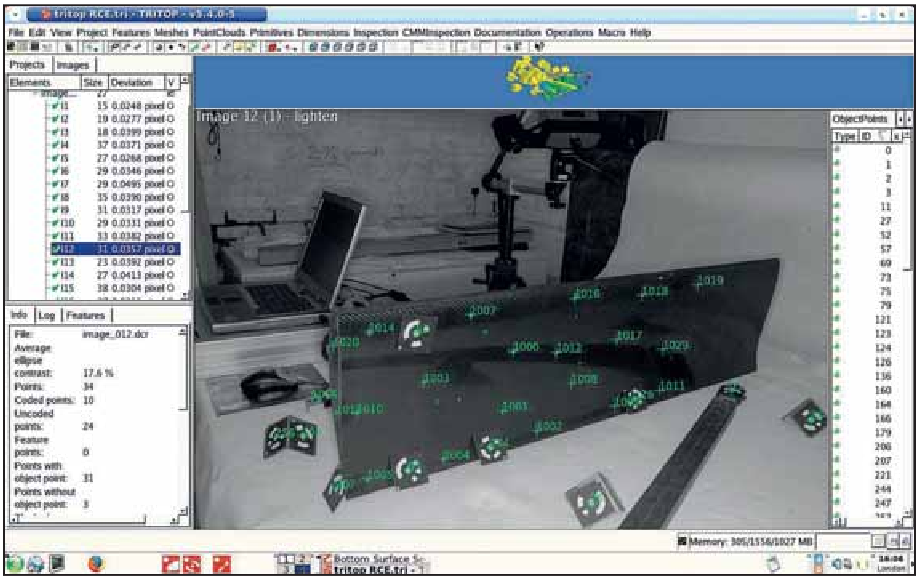

Figure 2: TRITOP's view of the wing being scanned, with reference point recognition visible (courtesy: PhysicalDigital Ltd)

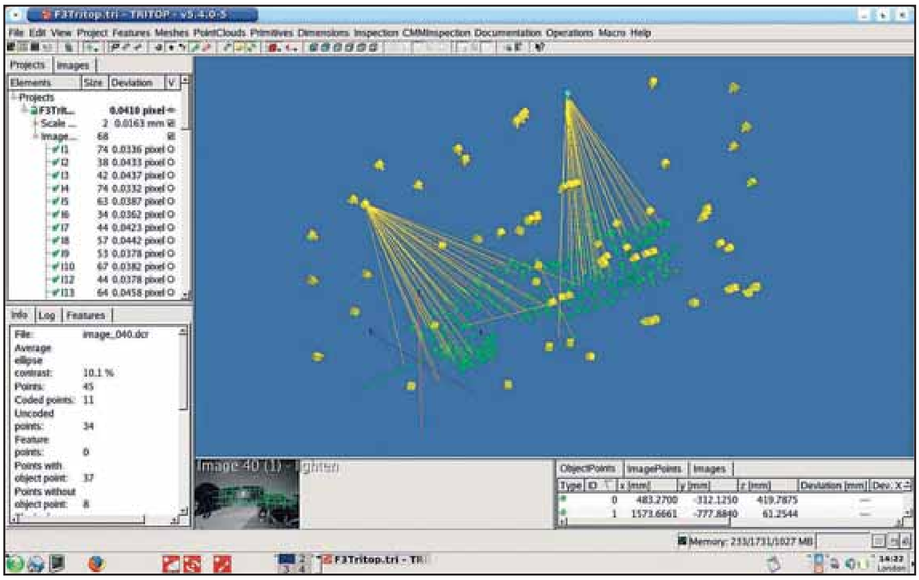

Figure 3: camera positions, and ray intersections from two such positions, plotted around the reference point locations that have been computed on the Formula 3 car (courtesy: PhysicalDigital Ltd)

At this point the software can be invoked to perform its image processing and triangulation algorithms to enable three-dimensional coordinate determination of surface control points, holes and so forth. CAD data can be imported into the window on display to enable access to dimensions, distances, angles, and to display deviations from the original CAD data on a colour error map. Display labels or sections can also indicate numerical values of deviations at selected locations, and measurement reports may be exported or printed.

> **"THE MEASURING PRINCIPLE [OF ATOS] IS BASED ON TRIANGULATION"**

To provide further detail refinement of the scanned surfaces, ATOS then comes into play. Using the data determined by TRITOP that defined the locations of the uncoded points placed on the surface, ATOS then uses a 'fringe projection' technique to scan surface details. The area of each scan is determined by the resolution required and by the object's size. A set of scans is built up by successively moving the scanner head around the object and scanning from various locations until the required detail has been captured. Where specific details are required from the ATOS scan, the coordinate system defined by TRITOP maintains everything in the correct relative positions. Figure 4 shows the →

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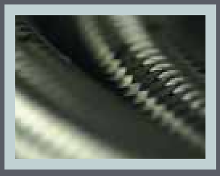

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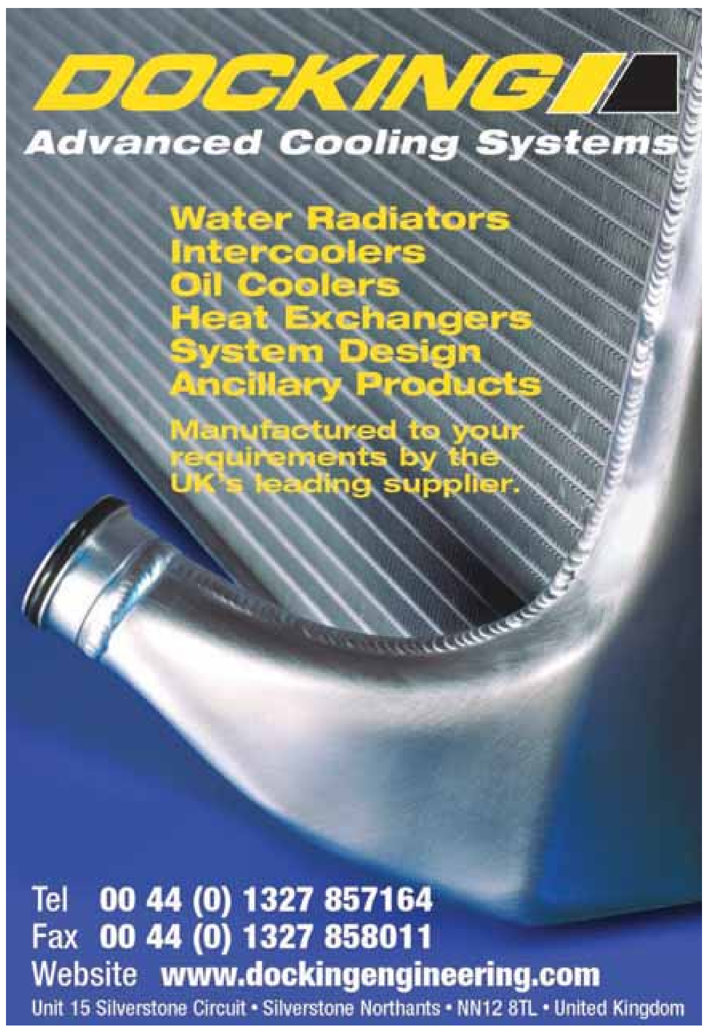
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scanning head, comprising two cameras and a central projector, being aligned for a scan of the upper surface of the wing, and figure 5 shows the striped 'fringe' pattern projected onto the wing's surface. The visible powdery surface of the wing is from talc spray, applied to minimise optical interference from the striped carbon finish.

The measuring principle of ATOS is also based on triangulation. The scanner projects the fringe patterns onto the object during each scan, and the patterns are recorded by two high-resolution digital cameras. By taking this data into account along with the previously recorded information gathered using TRITOP, the software is able to calculate the 3D coordinates mapped by each of the four million image pixels recorded during each scan. The various views and measurements taken as the scanner is moved around the object are automatically merged into the 'global coordinate system'. This can be done using ATOS alone on small objects, but TRITOP is required where larger objects are measured.

Following scanning, the software then calculates a high-resolution polygonal surface

"FOUR MILLION IMAGE PIXELS RECORDED DURING EACH SCAN"

mesh of the surface, with small triangles on areas of curvature and larger triangles on flat areas. Features like holes, slots, cut-outs and edges are identified by virtue of their contrast with surrounding areas and, by intersecting with the surface mesh, coordinates and dimensions for these features are defined.

To enable comparison with CAD data, the scanned data, which is in effect in its own arbitrary coordinate system, is mathematically aligned with the CAD coordinate system using one of three possible methods: best fit, which minimises the average deviation from the CAD surface; RPS (reference point system), which aligns characteristic features such as holes; or 3-2-1 transformation, which would be used if the component is mounted on a gauge.

Having once performed the most appropriate alignment it is then possible to use the software to generate colour deviation plots and labels, and also evaluation along sections 'cut' through the data. The scale of deviation plots can be altered to assess if surfaces are within tolerance, or can be adjusted to provide a simple go/no-go (pass/fail) readout.

If scanning has been performed simply to create a digital model of the object, the 3D data sets can be exported for use in typical CAD formats. If the object in question is symmetrical then scanning half the object and using the software's mirror command to replicate the data for the other half can reduce the time required for data acquisition. It is also possible to increase the data resolution where needed – around fine detail for example – and to reduce resolution where it is not needed. In fact, according to Tim Rapley, 'you can spend a lot less time and produce a lot more points than comparable [tactile] coordinate measurement methods.'

So a brief look at the output on this wing reveals the types of deviation plots available, and also that the wing did indeed deviate slightly from its original CAD profile (not unexpected, given →

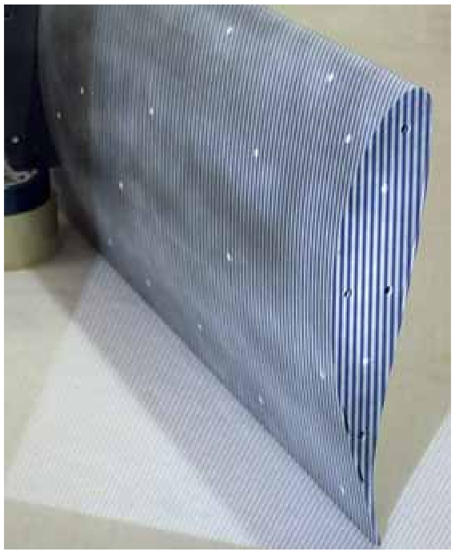

Figure 4: setting up the ATOS optical scanner to measure a wing mainplane (McBeath)

Figure 5: the fringe pattern projected onto the object being scanned by ATOS (McBeath)

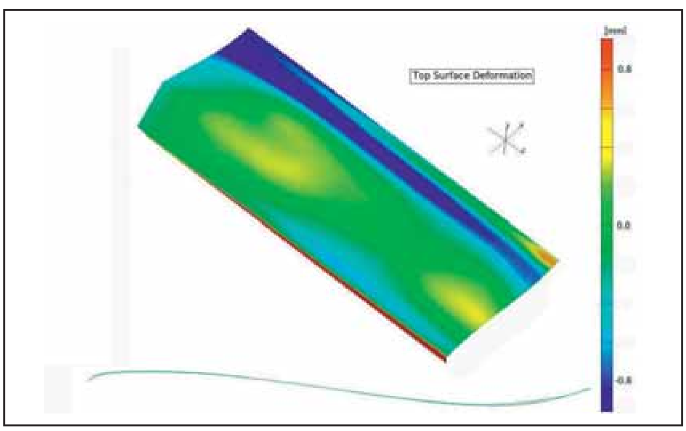

Figure 6: surface deviation plot, and sectional deviation superimposed, for the upper surface of the wing (courtesy: PhysicalDigital Ltd)

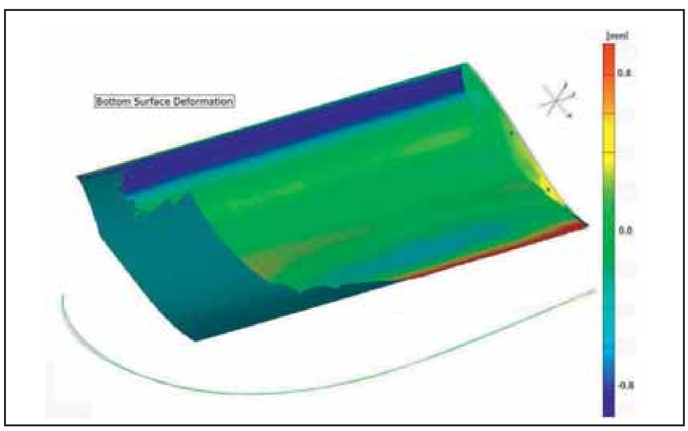

Figure 7: surface deviation and sectional deviation plots for the wing's lower surface (courtesy: PhysicalDigital Ltd)

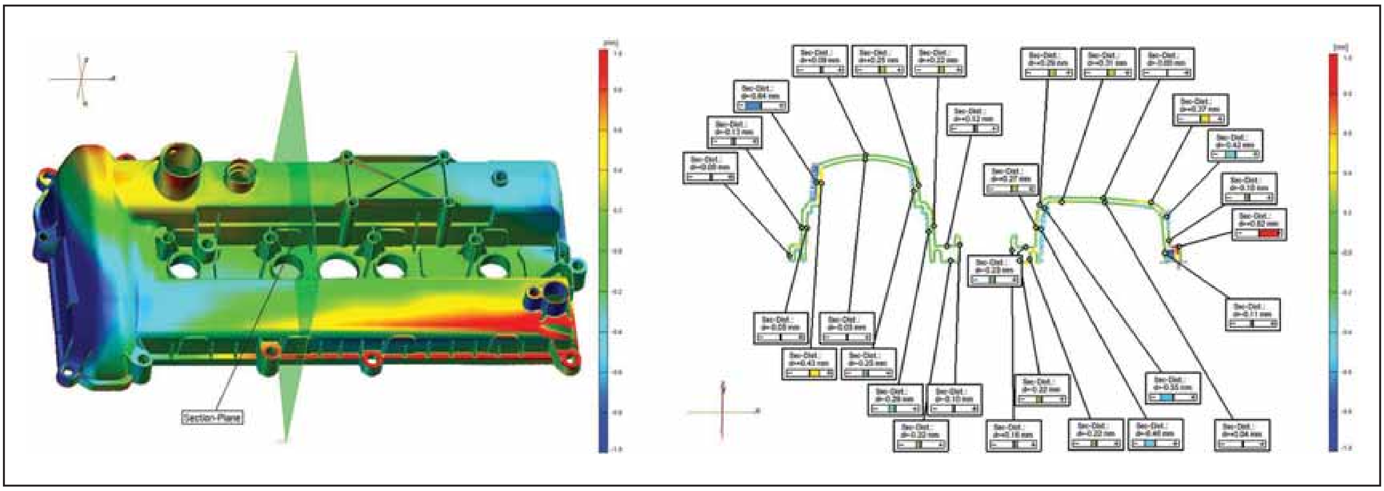

Figure 8: surface deviation and sectional plot, with discrete point reports (courtesy: GOM UK Ltd)

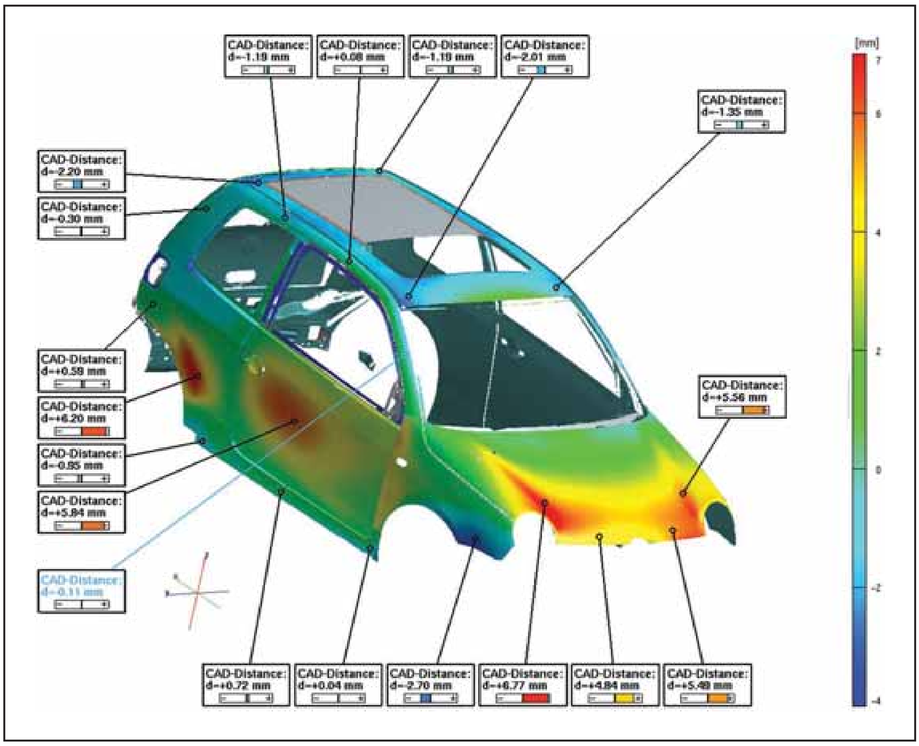

Figure 9: deviation of a sheet metal car body from nominal data (courtesy: GOM UK Ltd)

that the pattern was hand made). Figures 6 and 7 show surface deviations from the original CAD profile, with sectional reports – which can be taken at any designated station across an object – superimposed on these plots. If desired the ATOS output can be in .stl format, which would permit a CFD analysis of the 'as built' wing to be compared to the 'as designed' wing. It is also possible to perform repeat scanning on an object placed under mechanical load so that deformations and deflections can be accurately measured. (GOM provides tailor-made systems for this purpose, and also for the measurement of deformation under thermal load.) Figure 8 shows an example of a sectional report on an engine cam cover.

The previously mentioned historic racing car project is worth bringing up for a number of reasons, even though we cannot reveal any images for reasons of confidentiality. Optical measurement methods were chosen for this project because more accurate data could be obtained in less time than using traditional measuring techniques. In fact, scanning the entire car apparently took just five hours. Scanning also faithfully recorded undulations in the original sheet metalwork, but smoothing functions enabled some of those undulations to be removed (although no doubt subsequent manipulation in CAD would also have enabled this). The car was not quite symmetrical in shape, so although some extra scanning was needed around the non-symmetrical areas of the cockpit surround, normally a digital model could be built up after scanning just half the car. Figure 9 shows the type of report that can be generated, using an example of a more modern passenger car 'shell.

Another motorsport-related application involved scanning some hand bent stainless steel pipes. This was to enable inspection jigs to be quickly manufactured using stereolithographic rapid prototyping techniques so that subsequent hand-made pipe sets could be made to match and fit like the first set. And it is easy to imagine many similar applications, such as replicating a previously manufactured exhaust system, or indeed a great many other possible components.

Such a brief encounter with this optical measurement technique can barely scratch the surface (to a depth easily measurable, presumably) of potential applications. It seems likely that one of Physical Digital's principle sources of work is going to be enabling new clients to build 3D digital models of objects that were not originally drawn digitally in 3D. Already one small racecar constructor that was carrying out a feasibility study on fitting an engine for which there were apparently no digital models available to its existing chassis has contacted Rapley with a view to scanning the engine.

Optical scanning means it is now possible to measure and analyse an existing object without the need for a pre-existing 3D CAD model. And crucially, you don't have to spend a large sum on capital equipment because a mobile digitisation service is now available. It's as if some of the digital analysis methods mentioned in the introduction have just been waiting for optical scanning to surface into the wider world... RE

"MORE ACCURATE DATA COULD BE OBTAINED IN LESS TIME"

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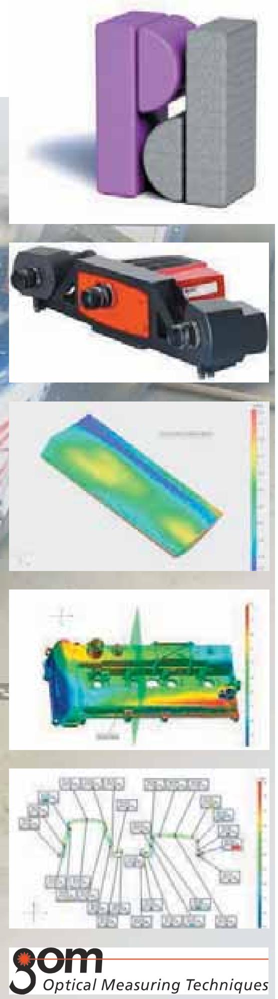

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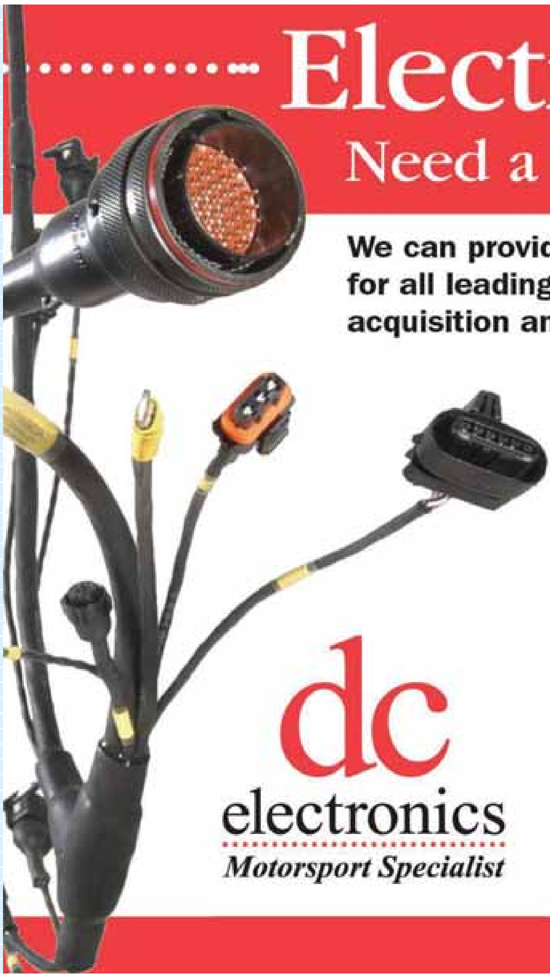

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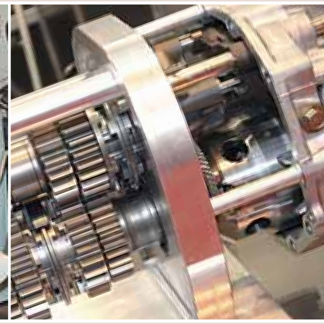

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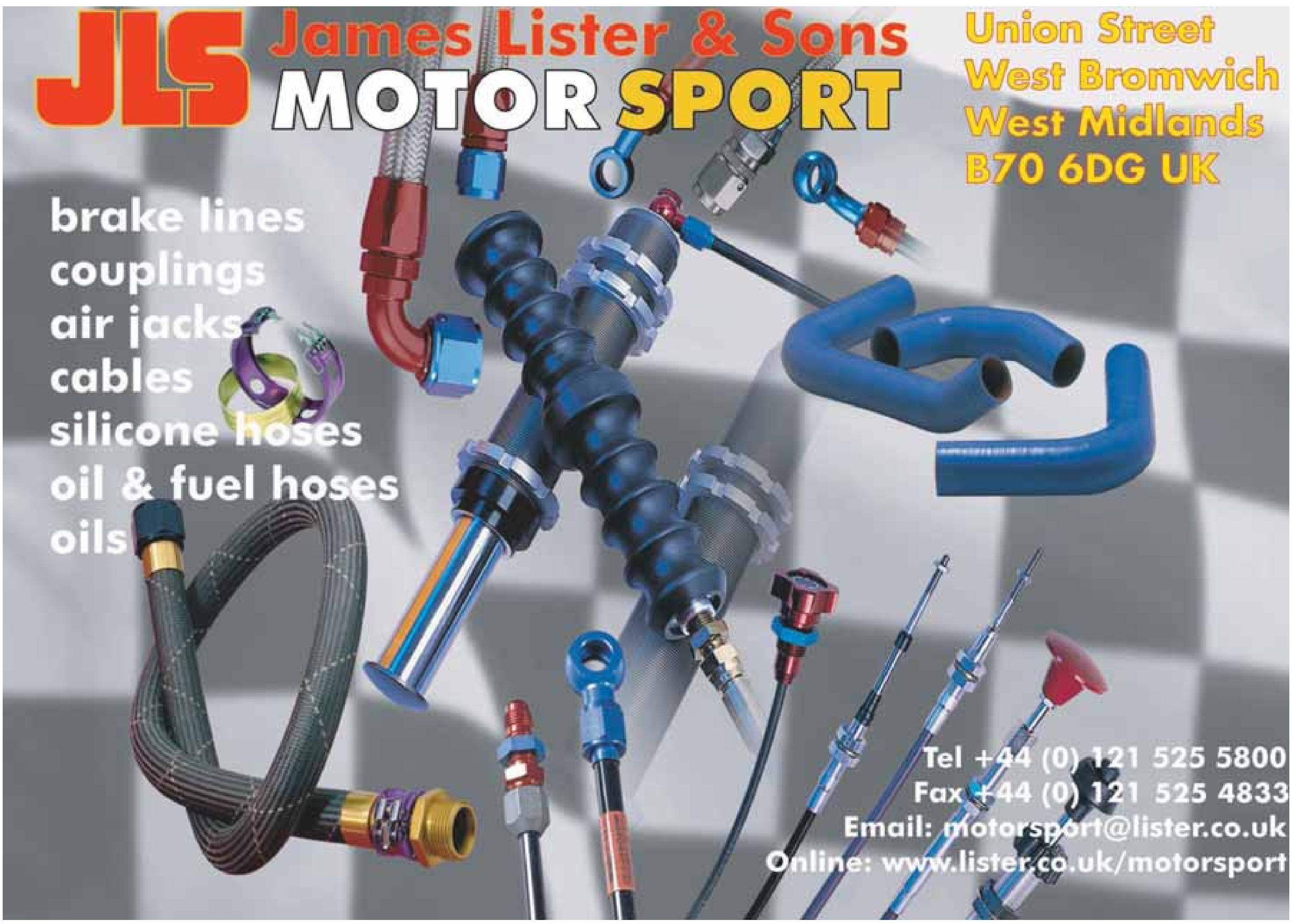

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Raceshop

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

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

Racegear: racecar@ipcmedia.com

Database: Tony Tobias
tony_tobias@ipcmedia.com

The Consultant: Mark Ortiz
markortiz@vnet.net

Aerobytes: Simon McBeath
via: racecar@ipcmedia.com

Management training

LAT

Hi-tech engine management systems are found in almost every area of motorsport these days. **Racecar** looks at the main players in this increasingly complex and competitive field

Words | Ian Wagstaff

According to Magneti Marelli, even with the reduction in electronics dictated by current regulations, the overall capacity for calculation of a Formula 1 car's on-board computer is equivalent to a top-range professional computer, and its level of sophistication is the same as a fighter aircraft's electronics, with an even higher level of component integration. The Italian company currently supplies complete engine management systems to Ferrari, Minardi, Renault, Sauber and Toyota – half of the grand prix field. Magneti Marelli points out that the most important part of a Formula 1 cars' management system is controlling the injection and ignition systems. It has accordingly made improvements in both these areas for 2005.

Its unit also contains gear change management that is closely linked to the engine management system. One of the company's main innovations for this year has been its 'step 11' version. This has a faster calculation time, giving response times of a thousandth of a second. It also sees the integration of the control system and the telemetry in the same 'box'. To formulate data in such a short time five calculation units are used. An important part of the system is that which manages the throttle bodies and the accelerator pedal, which are not connected directly, but through an electronic control that activates the throttle opening according to the characteristics of the circuit and the different styles of each driver. Electronic management also governs the length of the air inlets to maximise the volume of air entering the engine under different driving conditions.

"PRODUCTION-LINE TARGETS CAN ALSO BE APPLIED TO MOTOR RACING TECHNOLOGY"

According to Bosch Motorsport, its Motronic technology was started in production line manufacturing at the same time as it was introduced into racecars. Now though, it is the subject of an independent manufacturing →


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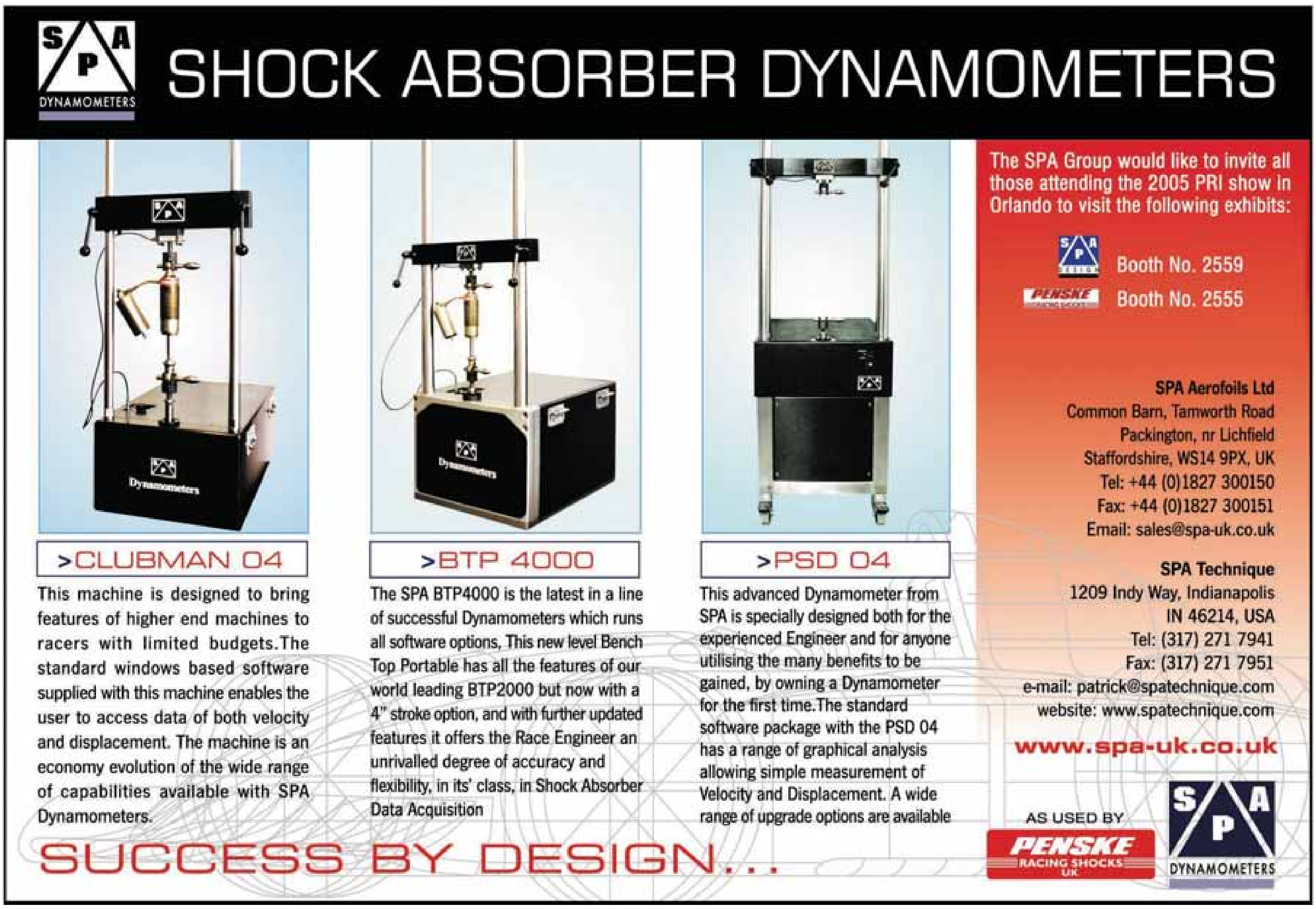
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DYNAMOMETERS

Pectel's SQ6 was developed to replace the company's stalwart T6 in Formula Nippon

process that has hardly anything to do with road cars. Engineers working on the latter have to focus on issues such as comfort, safety, long life, fulfilling emissions standards and fuel consumption. Those involved in motorsport have just one focus – tuning the cars to maximum short-term performance. That said, production-line targets can also be applied to motor racing technology. The obvious example is fuel economy, where a reduction in the number of pit stops can be a winning factor.

The casing of racecar electronic control units will be made from carbon fibre or aluminium, with extra protection against dust, moisture and shock. The significantly higher number of entries and exits for sensors, actuators and communication interfaces can provide a wide variety of set-up possibilities. Depending upon customers' wishes, the electronic control unit can even receive data in an individual and tailor-made way. The ever-increasing volume of processed data can often be handled by linking several processors to generate the required computing performance. Such power can allow a driver to influence the electronic control unit while driving. One could, for instance, change the moment of ignition or adjust the volume of injected fuel to suit the driving style, circuit and weather.

Bosch MS 3 is a popular unit in Formula 3 and Porsche Cup

Here the unit is installed on the Lola Formula 3 car

The new T10s-F from Pectel is an upgrade of the unit used in the Aston Martin DBR9s

The Bosch range of motor racing electronic control units covers most classes. The basic unit was developed from the serial production MS 3 hybrid model family and is claimed to be popular for Formula 3 and Porsche Cup. The MS 2 has had to prove its reliability in endurance sportscar racing. At the top of the range is the MS 1 unit family, which is available on request. This is designed for 12-cylinder engines with up to 20,000 revolutions. Finally, the MS 4 unit family has been developed for the specific requirements of various North American motor racing classes.

With the same ownership as Cosworth it is not surprising that Pi Research supplies the engine management for its Formula 1 engines. For all other formulae the company offers products under its Pectel brand. Pectel commenced business in the early 1990s, initially assisting Ford Motorsport at Boreham in reworking Magneti Marelli hardware and software. The company designed its own engine management system, the T6, in 1995 and the product was tested by Gwyndaf Evans a few days prior to the RAC Rally. The Welshman's comment was that, unless he was able to use the T6 in the event itself, he did not want to start. He believed it was worth a second a kilometre. The company still sells the T6 to this day as a mid-range, professional offering. It is seen as the mainstay of the product range and is used in everything from LMP2 to Toyota Atlantic, with 80 per cent of the current Formula Nippon field currently using the T6. However, with this formulae about to use old IRL engines, the need arose for a new engine management system to keep the costs down. The result has been the SQ6, which has about 10 times the performance of a T6 ECU and embraces →

MoTeC's M880 ECU installed in the WTCC Chevrolet Lacetti

This is the company's top of the range unit designed to interface with the vehicle's standard wiring

modern technology with built-in Ethernet. The SQ6 has been the first Pi-funded project since Pectel was acquired by what was then part of Ford. It has been designed to cope with any combination of sensors and actuators on the market. It is expected that it will also be used in the Cosworth-engined replacement for the Toyota Atlantic series. An SQ6M variant will also be available – the same as the SQ6 but with military-style connectors. Pectel reports that the first batch of SQ6s has already been sold, with the initial track test expected a couple weeks after the time of writing.

Formula Ford had problems with the road car ECU that was being used prior to 1997. As a result, Pectel designed its T2, which became the spec for the formula. Pectel founder Stephen Phillips says that over 1000 of these have now been delivered (the same as the number of T6s so far sold).

At around the same time Pectel also brought in its T10 high-end model for use by Nissan in the British Touring Car Championship. This has since been replaced by the powerful 32-bit, two microprocessor T10S, which can control both engine and gearbox from one ECU. This is now used in the Chevrolet IRL engine, as well as the M-Sport WRC Ford Focus. Prodrive has also used the T10 for the Aston Martin DBR9 and Ferrari 550 GT cars (the considerably less expensive DBRS9 understandably uses the latest SQ6). A new version – the T10S-F – has recently been produced, as an evolution with a slightly faster processor.

Low-level motorsport

Companies such as Webcon fulfil an important role at the other end of the spectrum. The company was involved with dedicated motorsport engine management in the 1990s and, indeed, John Cleland won the British Touring Car Championship in 1995 using one of its systems in his Vauxhall Cavalier. However, Webcon's sales director, Martin Eva, says that high-level motorsport was moving on and not in the way in which the company wanted to develop the product.

The main customer for its current Alpha system has instead become the kit car market, concentrating much of its efforts in this area and offering a turn-key, pre-calibrated kit for most of the kit car OEMs, including Westfield and Tiger. This means that it is still involved in motorsport though, supplying the spec system for the Westfield Challenge and product for Tiger's ERA racing cars. The company also has a network of dealers who may fit the system in motorsport applications. Webcon believes that it is important that end users do not map the product themselves. This, believes Eva, enables the company to 'preserve reliability and to offer a solution.'

"ITS T2 BECAME THE SPEC FOR THE FORMULA"

The Australian company MoTeC, which specialises in both engine management and data acquisition, covers a whole raft of requirements with its systems. However, regardless of the level of the customer, its ECUs are built to the same standard, using a Motorola 32-bit processor. Included are the M4, M48, M400, M600 and the latest M800 plug and play ECU for the Mitsubishi Evolution VIII and the Subaru WRX STi VIII. Like earlier MoTeC 'plug and play' units for previous Evo and STi models, these are based on the company's M800 ECU and are designed to use vehicles' existing wiring, with no need to remove or add sensors. The firm has said that it intends to expand its range of plug and play products to extend to other models.

There is only one company that is racecar manufacturer, engine manufacturer and produces its own engine management systems, too, and that is Zytek. Bill Gibson was an electronics engineer with Lucas before establishing Zytek, and his company can lay claim to having supplied the first full digital engine management system (to Toleman in 1984). Within a few races Bosch, Delco and Magneti Marelli were all supplying such units.

Significantly, one of Zytek's current divisions is MZ Technologies, an alliance with Motorola. Much of Zytek's business is in the passenger car world, the company having been the first to introduce 32-bit integrated powertrain control in this sector. It also supplies dedicated engine management systems for motor racing, where its own engines have been used from the old Formula 3000 through to the LMP1 car that has won this year at both Spa and the Nürburgring. Topically, its systems are to be found on all the Zytek-engined A1 GP series cars, and are always supported by its own PC-hosted calibration tool. RE

Webcon's Alpha-managed throttle bodies on a Ford Duratec-R engine

Zytek's management unit on its own race winning LMP1 sportscar, the 04S


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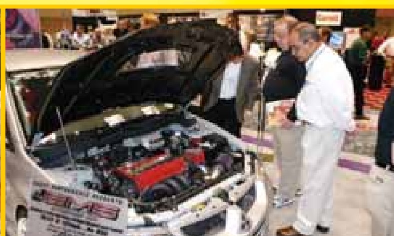

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Core value

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

Complex shapes can be produced affordably as one-offs

Words | Charles Armstrong-Wilson

Unsintered sand is poured away leaving the shape of the cores

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

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

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

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

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

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

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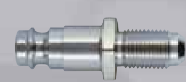

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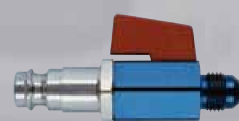

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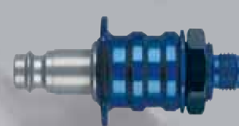

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Cutting it

Facom's complete range of cutters and pliers has been improved creating better results. By changing its manufacturing procedure and investing in new grinding equipment, Facom is now able to cut edges and mate jaws after the heat treatment has taken place.

It is common practice for manufacturers to machine their tools before the heat treatment as, in this state, the metal is easier to work with. Yet this can cause distortion and as a result many manufacturers refrain from using heat treatment at all, losing out on the added strength and resilience they could gain.

By manipulating the metal after the heat treatment, Facom has managed to provide its products with increased precision, strength and durability.

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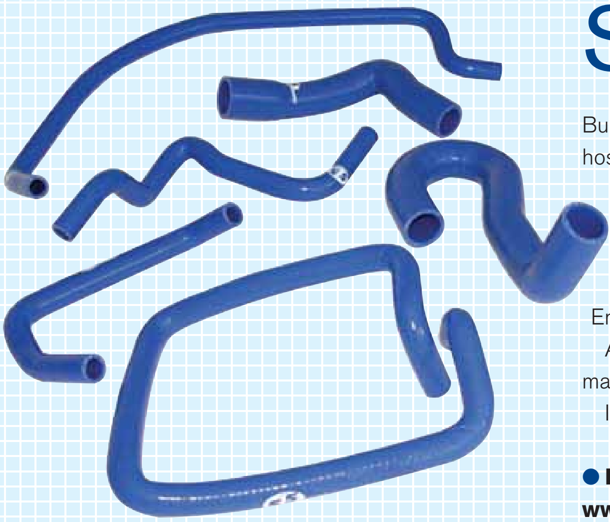


Silicon hoses

Burton Power in the UK has partnered with SFS Performance to provide silicon coolant hoses for the Escort Mk1 and 2.

All the hose sets for the crossflow and Pinto engines are available and individual items can be purchased if required.

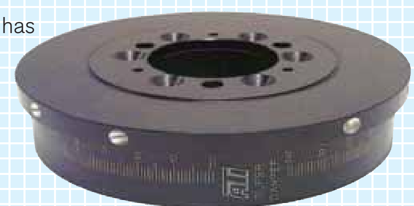
A complete set of hoses for the Pinto engine, with either DGAV or DCOE carbs, is priced at £104.99 (US$183.90). A complete five hose set for the Kent Crossflow Engine is priced at £105.75 (US$185.26).

A previously unavailable hose running from the RS2000 heater to the DCOE inlet manifold has also been manufactured.

Individual hoses are priced £13.95 (US$24.44) including VAT.

● For more information call +44 (0)208 554 2281 or visit www.burtonpower.com

Super Dampers



ATI Performance Products has manufactured a new damper shell that removes the need for added pulleys being bolted to the front of the damper.

The new ATI Crank Trigger Shell allows magnets of any quantity to be placed on the damper shell in any position. It is available for most popular models and works with 'Flying Magnet' pick-ups alongside various other trigger sources.

The ATI Super Dampers are the only dampers to be specifically designed for rebuildable and tunable high performance engines and ATI also offers to customise each shell to be compatible with specific engine requirements.

● For more information call +1 800 284 3433 or visit www.atiperformanceproducts.com

Groovy brakes

Italian brake specialist Tarox is now providing a cheaper alternative to its machined billet upgrade.

The new cast brake disc upgrade has been designed for the Subaru STi version 7 onward. Although the discs are outwardly similar, Tarox is able to sell the new cast discs at a much more competitive price due to the less expensive manufacturing processes.

Measuring 324mm (12.76in), the fully vented cast discs can be purchased with the familiar Tarox G88 or Sport Japan facings. Pictured here, the G88 removes dust and gases from the brake surface by a series of radiating grooves. The Sport Japan is drilled and grooved.

The discs are priced at £265 (US$464.61) per pair including VAT.

● For more information call +44 (0)870 777 2727 or visit www.tarox.com

RACEGEAR

New products and services for racecar engineers

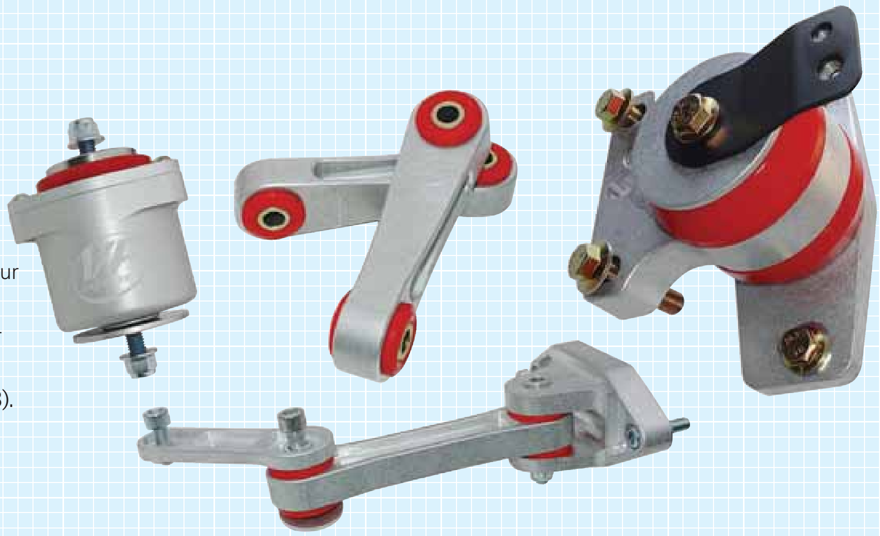
Heavy duty mounts

VF Engineering is offering a new range of high performance engine and transmission mounts for VW/Audis, Seats and Skodas.

The improved mount range has been designed to aid front-to-rear engine and gearbox movement restriction as well as absorb more unwanted vibration from the engine.

Various heavy duty mounts are available for VW/Audi models including pendulum mounts, six or four cylinder engine offside mounts, four and six cylinder transmission universal offside mounts and front or rear engine mounts.

Prices range from £45 to £130 (US$79 to US$228).



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Cool water

The newly launched Generation II Water Circulator from C&R Racing has been designed to cool hot race engines more effectively.

Designed for race conditions and with practice and qualifying in mind, the new water circulator hosts a 43-Gallon tank (195ltr) and prevents engine and radiator thermo shock by having a diverter valve with three cooling positions: radiator only, radiator/tank, and tank only.

The circulator measures 34" x 25" x 36" tall (86cm x 64cm x 91cm), providing more laps per session. It is fitted with a 40 GPM Pump and 220 Volt system that draws 8.2 amps with a heater and 18.75 amps without.

● **For more information call +1 317 293 4100 or visit www.crracing.com**

Long-life filters

Leading performance air filter manufacturer K&N Filters has added a series of new panel filters to its range.

Ranging from £34 to £50, (US$59.60 to US$87.66) the new filters are available for a number of Audi, BMW, Ford, Honda, Skoda, Vauxhall and Volkswagen models.

K&N filters are manufactured to last the duration of the vehicle's lifetime whilst being reusable and washable. Each filter has been designed to be compatible with the original vehicle's components and only needs cleaning after 50,000 miles of travelling under normal road conditions.

K&N's extensive range of air filters are compatible for most vehicles.

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RACEGEAR

New products and services for racecar engineers

Cooler by design

US company 10,000 RPM has developed a new Nitrous Plate that provides optimum cooling effort.

The 10,000 RPM plate design ignores the common practice of including injector tubes and jets. Instead, the nitrous is plumbed directly into the plate achieving increased cooling results.

The billet plate being machined 100 per cent flat also achieves improved cooling effort. Doing so extinguishes the need for a gasket, as the plate can be set up as a Flat manifold.

The four-hole design of the new 10,000 RPM increases the airflow, keeping it higher in the carburation. The CFM of the carburettor is also raised and a more beneficial Nitrous to Fuel mixture is provided.

● **For more information call +1 661 942 1312 or visit www.10000RPM.com**

Slimline sensor

A new slimline linear transducer has been designed from Variohm EuroSensor.

Following 18 months of research, Variohm has developed the new transducer in accordance with its proven track and wiper technology to prolong life expectancy. It is capable of withstanding some of the harshest environments and temperatures of up to 175deg C.

The sensor has a diameter of 9.5mm (0.7in) and, by using mounted rod end bearings, is compatible with a number of applications. It is supplied with a lightweight housing and with stroke lengths from 12.5mm to 150mm (0.49in to 5.91in).

Variohm also offers custom designed sensors to meet the exact requirements of its customers.

● **For more information call +44 (0)1327 351 004 or visit www.variohm.com**

Protective synthetics

Millers Oils, the leading oil and lubricant manufacturer, has introduced a new range of fully synthetic competition diesel oils onto the market.

Optimal engine performance has been achieved by using recent additive technology to produce fully formulated synthetic based fluids.

The three new oils can withstand a higher carrying load and high film strength for definitive protection. The incorporation of new triple ester technology helps to guard against start-up wear, as the fluids have superior cold flow properties, resulting in enhanced thermal stability for oxidation resistance. Due to this, engine friction losses are also reduced to a minimum, causing the oils to achieve a higher output compared to equivalent non-ester oil.

● **For more information call +44 (0)1484 713 201 or visit www.millersoils.net**

Speedy top-up

Sykes-Pickavant's new Cooling System Speed Filler tops up and fills cooling systems quickly and efficiently without the need for bleeding.

The air-operated filler creates a vacuum through standard workshop compressed air to enable the system to then be filled with a coolant. Wastage and spillages are therefore reduced by this new method whilst airlocks are even eradicated. Airlocks are normally created through traditional gravity filling methods. Vacuum filling eliminates this problem and is a quicker, cleaner and more effective means to fill the cooling system.

The Speed Filler is simple to operate and is priced at £107.33 (US$188.22) plus VAT.

● **For more information call +44 (0)1922 702 000 or visit www.sptools.co.uk**


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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

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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

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Flli Barrelli, Via La Spezia 5, 20156 Milan, Italy

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Bodin ChassiTeknik, Skalbygatan 8, 745 37 Enkoping, Sweden

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Lower College, Hothersall Lane, Longridge, Preston, Lancashire PR3 2XB

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Cheek Racing Cars, Flatebyvn 3, 1792 Tistedal, Norway

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CHEVRON — **Tel 01300 348499**
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DON FOSTER RACING **France**
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DYNAMIC SUSPENSIONS 01842 755744
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2.6 Braking Systems

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2.7 Brake Components

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

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ALCON COMPS	**01827 312500**
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ATE	020 8654 8836
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CARBONE INDUSTRIE	France (33) 0472 355700

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CASTROL	Malaysia (603) 245 2642
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PERFORMANCE FRICTION	USA (1) 803 222 2141 01280 843390
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FGR	01885 400639
MINTEX	01274 854000
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RAYBESTOS	USA (1) 815 363 9000
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TILTON	**USA (1) 805 688 2353**
WILWOOD	USA (1) 805 388 1188

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WILWOOD USA	(1) 805 388 1188

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Database 3
ENGINE & TRANSMISSION COMPONENTS

3.1 Engine Components

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CONNAUGHT	01795 843802
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RESB	0121 520 8271
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QUAIFE ENGINEERING	01732 353747
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PIPER CAMS	01233 500200
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VALVE SPRING RETAINERS
G&S VALVES LTD 01483 415444

VALVE GUIDES
ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 01455 234200
Fax +44 (0) 01455 233545
KAITEN PRODUCTS USA (1) 714 220 2227
SERDI 01895 232215

3.2 Engine Ancillaries

AIR FILTERS
INDUCTION TECH GROUP Tel 02476 305386
Fax 02476 307999
Unit B, Quinn Close, Seven Stars Industrial Estate, Whitley, Coventry CV3 4LH
K&N ENGINEERING USA 800 858 3333
K&N FILTERS (EUROPE) UK 01925 636950
KINSLER USA (1) 248 362 1145
PIPERCROSS 01604 671100

CARBURETTORS
BG FUEL SYSTEMS USA (1) 706 864 8544
CARBURETOR SHOP USA (1) 909 481 5816
SOLEX France (33) 14 729 7171
WEBER Italy (39) 51 417995
WEBCON 01932 787100

EXHAUST SYSTEMS
ACTIVE ENGINEERING USA (1) 714 637 1155
BURNS STAINLESS USA (1) 949 631 5120
GDS EXHAUSTS Tel: 01280 702510 / Fax: 01280 705225
Email: sales@gds-exhausts.co.uk
Website: www.gds-exhausts.co.uk
Unit 8C Boundary Road, Brackley NN13 7ES
GOOD FABRICATIONS LTD
Tel: +44 (0)1844 202850 / Fax:(0)1844 202833
Email: info@goodfabs.com www.goodfabs.com
Unit 3a, Drakes Farm, Drakes Drive, Long Crendon, Aylesbury, Bucks HP18 9BA England
FLOWMASTER USA (1) 616 463 4113
JETEX EXHAUSTS 01789 298989
MARK ORTIZ USA (1) 715 835 3292
PIPER CAMS 01233 500200
SPECIALISED EXHAUST 0208 648 4786

FUEL FILTERS
AN MOTORSPORT DESIGN 01628 776320
CONNAUGHT 01795 843802
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 (1) 217 324 3737
FRAM EUROPE 01443 223000
KINSLER USA (1) 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 287100

FUEL INJECTION
AC ROCHESTER USA (1) 716 359 6361
ASNU Tel 0208 420 4494
BGC MOTORSPORT 0208 880 4205
BOSCH 01895 834466
Germany (49) 711 8111
USA (1) 312 865 5200
CONNAUGHT 01795 843802
SBD MOTORSPORT 0208 391 0121
FLUID CONTROL PRODUCTS Tel (1) 314 291 7223
GENESIS ELECTRONIC SYSTEMS 01635 582255
INDUCTION TECHNOLOGY 02476 305386
JENVEY DYNAMICS 01746 768810
JOHN WILCOX COMPETITION 01455 230576
KINSLER FUEL INJECTION Tel: USA (1) 248 362 1145
Fax: USA (1) 248 362 1032
Email: kinsler@kinsler.com Website: www.kinsler.com
LINGENFELTER USA (1) 219 724 2552
MAGNETI MARELLI Italy (39) 2 618 351
MM COMPETITION SYSTEMS 08707 444666
MARREN USA (1) 203 732 4565
MILLINGTON 01746 789268
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
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 (1) 805 967 9478

FUEL LINES
AEROQUIP USA (1) 419 238 1190
AN MOTORSPORT DESIGN 01628 776320
ATL USA (1) 201 825 1400
Fax (1) 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 84380
EXACT ENGINEERING 01803 866464
FAE MACHINE USA 317 243 3092
FLEXOLITE 01684 891898
FUEL SAFE UK 01799 541955
USA (1) 714 842 2211
GOODRIDGE CA USA (1) 310 533 1924
GOODRIDGE INDY USA (1) 317 244 1000
GOODRIDGE EAST USA (1) 704 662 9095
GOODRIDGE UK Tel 01392 369090 / Fax 01392 441780
Exeter Airport Business Park, Exeter, EX5 2UP
HENRY'S ENG USA (1) 410 535 3142
JLS MOTORSPORT Tel 0121 525 7733
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 (1) 216 232 2282
XRP INC Tel USA (1) 562 861 4765
FAX USA (1) 562 861 5503
5630 Imperial Highway, South Gate, CA 90280, USA

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

HOSES & HOSE-ENDS
AEROQUIP USA (1) 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 (1) 310 609 1602
EXACT ENG 01803 866464
FASTENER FACTORY 01327 311018
FHS MOTOR RACING 01753 570863
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
GOODRIDGE UK 01392 369090
GOODRIDGE CA USA (1) 310 533 1924
GOODRIDGE INDY USA (1) 317 244 1000
GOODRIDGE EAST USA (1) 704 662 9095
HCL FASTENERS 01282 411992
HENRY'S ENG USA (1) 410 435 3142
JLS MOTORSPORT 0121 525 7733
KINSLER USA (1) 248 362 1145
SAMCO SPORT 01443 238464
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 355277
XRP INC USA (1) 562 861 4765

INTERCOOLERS
AH FABRICATIONS 01432 354704
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
PACE PRODUCTS 01440 760960
SERCK MARSTON 0208 965 2151
SFS PERFORMANCE 01582 412 697

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

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

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

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

OIL SUMPS
AH FABRICATIONS 01432 354704
A.R.E DRY SUMP SYSTEMS
USA: (1) 916 987 7629
www.drysump.com
CONNAUGHT 01795 843802
JENVEY DYNAMICS 01746 768810
MILODON USA (1) 818 407 1211
PACE PRODUCTS 01440 760960
STONE FOUNDRIES 0208 853 4648
SWINDON RACING ENGINES 01793 531321
TITAN MOTORSPORT 01480 474402
TREVOR MORRIS ENG 01547 530289

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

RUBBER & ELASTOMERIC COMPONENTS
BUTSER RUBBER LTD Tel: 01730 894034

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

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

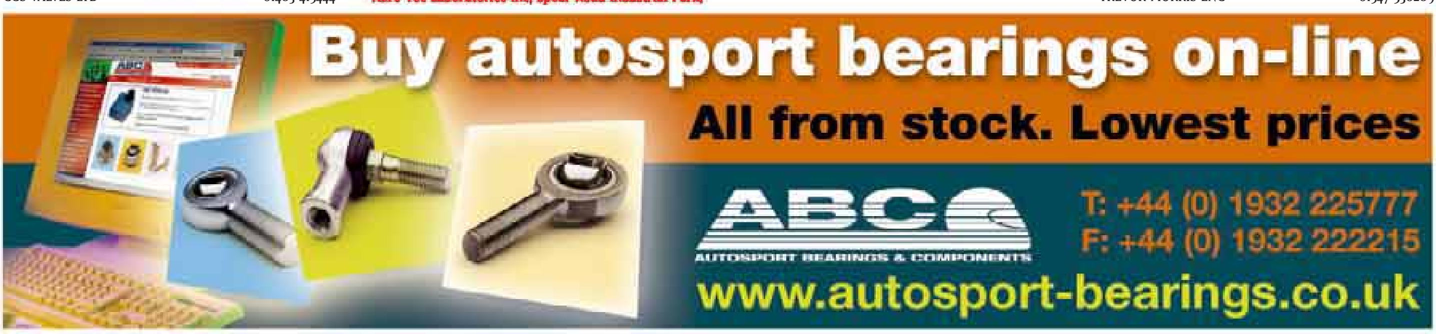
THROTTLE VALVES
JENVEY DYNAMICS 01746 768810
KINSLER USA (1) 248 362 1145
LUMENITION 0207 403 4334
TREVOR MORRIS ENG 01547 530289
TWM INDUCTION USA (1) 805 967 9478

TURBOCHARGERS
GARRETT AUTOMOTIVE 01695 22391
HOLSET ENG 01484 422244
INTERPRO ENGINEERING 01454 412777
QINETIQ 08700 100942
TURBO TECHNICS 01604 764005

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

WATER INJECTION
ERL 01273 581007

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



3.3 Engine Electronics

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

DATA-ACQUISITION
ACTIVE SENSORS Tel 01202 480620
Fax 0120 2480664
ADVANCED AUTOMOTIVE 01753 642019
B&G RACING USA (1) 602 274 2537
BOSCH 01895 834466
Germany (49) 711 8111
USA (1) 312 865 5200
COMPETITION DATA SYS USA (1) 716 631 2880
COMPUTECH SYSTEMS USA 800 870 8383
COMPUTERACE TIMING 01905 796090
CORSA INSTRUMENTS USA (1) 313 761 1545
2D DEBUS Germany (49) 721 944850
DATASPARES ACQUISITION 0208 463 9222
DATRON TECHNOLOGY 01908 261655
DIGICON ENGINEERING Canada (1) 604 984 9437
FOREFRONT USA (1) 404 448 9550
INTERCOMP USA Tel (1) 763 476 2531
Fax (1) 763 476 2613
14465 23rd Avenue N, Minneapolis, MN 55447, USA
ISAAC INSTRUMENTS INC. Tel: (450) 658 7520
Fax: (450) 658 3322
Email: isaac@isaac.ca
Website www.isaac.ca
25 Robert, Chamby, Quebec, Canada J3L 1S2
LONGACRE USA (1) 425 485 0620
McCLAREN ELECTRONICS 01483 261400
MM COMPETITION SYSTEMS 08707 444666
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
MOTECH USA (1) 804 973 1399
MOTOR SPORT ELEC Australia (61) 7 3290 1309
MOTORSPORTS INTERFACE 01327 311011
MTS Powertrain Tech Tel 01932 351516
Fax 01932 351517
7 Glen Court, Canada Road, Byfleet, Surrey KT14 7JL
NIPPON DENSO Japan (81) 56 625 6951
PECTEL CONTROL SYSTEMS +44 (0)1954 253610
PENNY & GILES 01202 409409
PERFORMANCE TRENDS USA (1) 248 473 9230
PI RESEARCH 01954 253600
POLY LOGIC 01462 621066
QINETIQ 08700 100942
QUANTUM SUSPENSION 01243 865058
RACE DATA ENGINEERING USA (1) 714 449 1445
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
STACK Tel 01869 240404
Fax 01869 245500
email: sales@stackltd.com
Wedgewood Road, Bicester Oxfordshire, OX26 4UL
STEVE BUNKHALL 01223 303025
VARIOHM 01327 351004

ENGINE MANAGEMENT SYSTEMS
ADVANCED AUTOMOTIVE 01753 642019
ASNU 0208 420 4494
BOSCH 01895 834466
Germany (49) 711 8111
USA (1) 312 865 5200
CONNAUGHT 01795 843802
DATASPARES 0208 463 9229
SBD MOTORSPORT 0208 391 0121
McCLAREN ELECTRONICS 01483 261400
MM COMPETITION 08707 444666
MOTEC PTY LTD Aus Tel: 613 9761 5050
Aus Fax: 613 9761 5051
Japan +81 489 461 734
121 Merringdale Drive
Croydon South Victoria Australia
UK: +44 8700 119100
USA +1 714 895 7001
PECTEL CONTROL SYSTEMS +44 (0)1954 253610
PRECISION RACE SERVICES USA (1) 248 844 1060
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
STACK 01869 240404
SUPERCHIPS 01280 816781
TERRY SHEPHERD TUNING 01695 574454
WALBRO ENGINE MANAGEMENT USA (1)989 872 7091
ZYTEK SYSTEMS 0121 323 2323

ENGINE SENSORS
ACTIVE SENSORS Tel 01202 480620
Fax 01202 480664
Unit 12, Wilverley Rd, Christchurch, Dorset, BH23 3RU England
AVL DEUTSCHLAND (49) 6134 7179-0
Gmbh Germany
DATASPARES 0208 463 9229
ENTRAN 01923 893 999
KISTLER INSTRUMENTS 01420 544477
KULITE SENSORS Tel 01256 461646
Kulite House, Stroudley Road, Basingstoke, RG24 8UG, England

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

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

3.4 Transmission Components

CLUTCHES
ALCON 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 (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 GmbH Tel +49 9721-984300
Fax +49 9721-984299
Email service.sre@sachs.de
Website www.sachs-race-engineering.de
Ernst-Sachs-Strasse 62, 97424 Schweinfurt, Germany
SACHS BOGE UK 01788 822353
TILTON ENGINEERING USA (1) 805 688 2353
Fax (1) 805 688 2745
25 Easy Street, Buellton, CA 93427 USA
WILWOOD ENGINEERING Fax (1) 805 388 4938
USA (1) 805 388 1188
416 Calle San Pablo, Camarillo, CA 93012, USA

COMPLETE TRANSMISSIONS
RICARDO MIDLANDS TECHNICAL CENTRE Tel: 01926 319399
Fax: 01926 319352
Email: rasimmonds@mtc.ricardo.com
Website: www.ricardo.com
Southam Road, Radford Semele, Leamington Spa CV31 1FQ

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

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

DRIVESHAFTS
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 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 001 818 882 6422
www.bmracing.com
Chatsworth CA 91311 USA
COLLEDGE & MORLEY 02476 462328
COMPTECH USA USA (1) 916 933 1080
DAVID BROWN 01484 422180
GEARACE LIMITED 01869 277563
HEWLAND ENG 01628 827600
JCM TRANSAXLES USA (1) 303 695 6093
KERSCHBAUMER Ger (49) 6074 47 663
MARK BAILEY RACING 01380 850130
PANKL 0043 3862 33999
TEX RACING USA (1) 910 428 9522
RICARDO MIDLANDS TECHNICAL CENTRE 01926 319399
TRAN-X GEARS LTD 02476 659061
XTRAC LTD 01635 293800

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

Database 4
FACTORY EQUIPMENT

4.1 Factory Hardware

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

AIR TOOLS
DESOUTTER AUTOMOTIVE 0208 205 4884
DINO PAOLI S.R.L. Tel: +390 522 300828
Fax: +390 522 304864
email: info@dinopaoli.com
Website: www.dinopaoli.com
Via Guido Dorso, 542100, Reggio Emilia, Italy
FACOM 01932 566099
INGERSOLL RAND 01204 690690
JLS MOTORSPORT 0121 525 7733

CNC MACHINING CENTRES
ABSOLUTE MACHINE TOOL USA (1) 440 324 5133
BOSTON DIGITAL USA (1) 508 473 4561
BRIDGEPORT MACHINE USA (1) 248 299 1750
DEREK ROBINSON 0116 266 2222
DEWCO USA (1) 765 962 7201
MACHINERY SALES USA (1) 510 490 4000
MAKINO USA (1) 800 552 3288
MEDDINGS MACHINES 01752 893277
MILLS ENGINEERING 01603 745531
MILLSITE ENGINEERING USA (1) 304 273 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
TGS USA (1) 940 668 1002
TOYODA EUROPE 02476 547200

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

CRYOGENIC TEMPERING
FROZEN SOLID 01449 674914

DUST EXTRACTION EQUIP
DENCER 01789 470198

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

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

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

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

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

ENGINE HOISTS
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SILVER SEAL USA (1) 800 521 2936

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BLUEBIRD USA (1) 800 808 2473
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DYNAMIC TEST SYSTEMS USA (1) 800 243 3966
GOODSON USA (1) 507 452 1830
JEGS USA (1) 614 294 5451
MOROSO PERFORMANCE USA (1) 203 453 6571
MR GASKET PERFORMANCE USA (1) 216 398 8300
RACER COMPONENTS USA (1) 903 581 5976
SCRIBNER USA (1) 916 638 1515

FLOW BENCHES
ASNU 0208 420 4494
AUDIE TECHNOLOGY USA (1) 610 630 5895
CV PRODUCTS USA (1) 800 448 1223
CLO-FLOW South Africa (27) 11 963128
DEPAC DYNO SYSTEMS USA (1) 315 339 1265
FLOWDATA USA (1) 714 632 7828
HODGE MFG USA (1) 800 262 4634
PERFORMANCE TRENDS USA (1) 248 473 9230
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RMT MECHATRONICS — 01565 650411
LOCK-N-STITCH — USA (1) 800 736 8261
MAGNAFLUX — USA (1) 847 657 5300
THE STRAIN GAUGING CO — 01256 320666

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

TOOL CABINETS
DURA — 01295 712800

GWS Systems Oy — **Tel: 01403 276445**
Fax: 01403 276434
Email: sales@gwssystems.co.uk
Website: gwssystems.co.uk
Units 10-12 Horsham Court, City Business Centre, 6 Brighton Road, Horsham, West Sussex RH13 5BA
LISTA — 01908 222333
MAC TOOLS — USA (1) 614 755 7000

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

4.2 Factory Software

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

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LIFECHECK — 01285 720665
KINETIC RACING TECHNOLOGIES — USA (1) 248 245 2330
NOSKECOMP — Australia 07 32 88 3895

PERF SIMULATION
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PI RESEARCH — 01954 253600
PERFORMANCE TRENDS — USA (1) 248 473 9230
RICARDO — USA (1) 734 397 6666
SERVOTEST — 0208 707 1400
VEHICLE DYNAMICS PERFORMANCE — USA (1) 512 450 1035

Database 5
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5.1 Pits Equipment

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COMPAIR UK — 01473 602222
ROTOTEST — Sweden 46 8532 55 890

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

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

CAMBER GAUGES
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75 Ash Road South, Wrexham Industrial Estate, Wrexham, Clwyd LL13 9UG, Wales

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

REDLINE MOTORSPORT — **Tel 01606 737500**
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk
TRIDENT — 01327 857822

CHASSIS STANDS
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SMR COMPONENTS — USA (1) 708 949 9100

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CALEX INSTRUMENTATION — 01525 373128
CRANFIELD — 01234 751361
DYNOLAB — USA (1) 206 243 8877
FASTER SYSTEMS — USA (1) 415 332 6064
FUELTRONICS — Australia (61) 0883632199
FUJITSU — 0208 573 4444
GENESIS — 01635 582255
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NOVA — USA (1) 615 832 6355
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STACK — 01869 240404

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LONGACRE RACING — USA (1) 206 885 3823
NOVATECH — 01424 852744
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EAR DEFENDERS
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REDLINE MOTORSPORT — Tel 01606 737500

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SPA TECHNIQUE — USA (1)317 271 7941
TRIDENT — 01327 857822

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NOISE METERS
CIRRUS RESEARCH — 01723 891655

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PIT BOARDS
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AUTOTEL RACE RADIO — 01508 528837
MRTC — 0150 981 2610
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GRAND PRIX PROMOTIONS — 01474 879524
JAYBRAND — 01733 68247
REDLINE MOTORSPORT — Tel 01606 737500

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EXACT ENGINEERING — 01803 866464
GTC COMPETITION — 01483 272151
KRONTEC — Germany (49) 9401 703062
PREMIER FUEL SYSTEMS — 01332 850515
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4-PATCH — 01376 348246
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ME MOTORSPORT — 01884 253070
RML — 01933 402440
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DEMON TWEEKS — 01978 664466
ILONGACRE RACING — USA (1) 206 885 3823
ME MOTORSPORT — 01884 253070

REDLINE MOTORSPORT — Tel 01606 737500
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SPACE HEATERS
FASTENER FACTORY — 01327 311018

STOPWATCHES
CASIO — 0208 450 9131
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GRAND PRIX RACEWEAR — 020 8987 5500
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TRIDENT — 01327 857822

STORAGE SYSTEMS
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POLSTORE STORAGE — 01403 750000
PRONALS — France (33) 3201 997510

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DRC RACE CAR — USA (1) 609 397 4455
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RALLY DESIGN — 01795 531871
REDLINE MOTORSPORT — Tel 01606 737500
TRIDENT — 01327 857822

TIMING SYSTEMS
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MOTEC SYSTEMS USA — USA (1) 714 897 6804
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STACK — 01869 240404
UNISYS — 0208 453 5562
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KAISER & KRAFT — 01923 233312
POLSTORE STORAGE — 01403 750000
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GMD COMPUTRACK — Austra (61) 2 9644 1946
REDLINE MOTORSPORT — Tel 01606 737500
THE STRAIN GAUGING CO — 01256 320666

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GRAND PRIX RACEWEAR — 0208 987 5500
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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
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ALRESFORD TECTONICS — 01962 736316
AWNING COMPANY — 01204 363463
BARKERS — 020 8653 1988
DEANS AWNINGS — 01942 241399
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TOP MARQUEES — 01623 740777

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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
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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

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GRAND PRIX RACEWEAR 0208 987 5500
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REDLINE MOTORSPORT Tel 01606 737500

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DEMON TWEEKS 01978 664466
GRAND PRIX RACEWEAR 020 8987 5500
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GRAND PRIX RACEWEAR 020 8987 5500
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Ively Road , Farnborough, Hampshire, GU14 OLX

Database 7
CHASSIS ENGINEERING SERVICES

7.1 Chassis Services

BODYWORK SPECIALISTS

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ADVANCED COMPOSITES 01773 763441
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AERO APPLICATIONS USA (1) 562 597 0001
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ASQUITH BROTHERS 01924 402001
C&B Consultants Aerodynamics 01202 617 1707
CML GROUP 0151 647 5531
COMPOSITE DESIGN USA (1) 727 539 0605
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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

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ÆOLUS TECHNOLOGY USA (1) 970 472 1288
AERODINE COMPOSITES USA (1) 317 271 1207
APPLIED FIBREGLASS 01842 765339
ASTEC 01332 875451
B&K RESINS 0208 464 7734
C&B CONSULTANT AERODYNAMICS 01202 661707
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COMPOSITE DESIGN USA (1) 727 539 0605
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DU PONT UK 01438 734000
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USA (1) 302 774 1000
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NERO 01254 202085
PANKL Austria (43) 3862 512500
PODIUM DESIGN 07000 763486
PRONAL'S France (33) 320 99 75 10
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RICHARD HINTON RACING 01279 771667
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SAMCO sport 01443 238 464
SECART USA (1) 203 798 6698
SCOTT BADER 01933 663100
SPA COMPOSITES 01543 432904
SQUARE ONE MOTORSPORT 01825 723425
STRAND GLASSFIBRE 0208 568 7191
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DESIGN AND ANALYSIS

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FABRICATION

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

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1027 Levee Street Dallas, Texas 75207

ASTEC 01332 875451
AZTEK 01509 261299
BBW 01483 722 713
BOB SPARSHOTT ENGINEERING 01908 618080
BRADY FABRICATIONS 01869 252750
BRISE ALLOY FABRICATIONS 01322 222343
BSS PARTS 01772 601602
CHEVRON RACING 01565 777395
CHIP GANASSI RACING 01243 544192
CML GROUP 0151 647 5531
COLMET PRECISION 01296 681658
COMPOSITE DESIGN USA (1) 727 539 0605
COMPETITION FABRICATIONS 01953 454573
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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
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LOTUS ENGINEERING 01953 608000
LYNX MOTORS 01424 851277
MACDONALD RACE ENG 0208 889 1633
MATRIX ENGINEERING USA (1) 888 249 0013
MASON ENGINEERING USA (1) 805 527 6624
MICRO CRAFT USA (1) 909 947 1843
MIKE TAYLOR DEVELOPMENTS 01609 780123
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PREMIER AEROSPACE 01332 850515
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SNAPDRAGON MOTORSPORTS USA (1) 413 2560861
SPA AEROFOILS LTD 01827 260026
SOUTH CERNEY ENGINEERING 01285 860295
UNICLIP AUTOMOTIVE 01932 355277
VAN DYNE ENGINEERING USA (1) 714 847 4417
VIN MALKIE RACING 01565 777395

MOULDING

ADVANCED COMPOSITES 01773 763441
AERODINE COMPOSITES USA (1) 317 271 1207
ASTEC 01332 875451
BENTLEY CHEMICAL TRADING 01562 515121
BUTSER RUBBER 01730 894034
CML GROUP 0151 647 5531
COMPOSITE DESIGN USA (1) 727 539 0605
COMPOSITE WINGS 01953 885478
CROSBY GRP 01327 857042
CROMPTON TECH GROUP 01295 220130
CTG +44 (0)1295 220130
G FORCE COMPOSITES 01243 544192
GRIFFITHS ENGINEERING 01582 600629
JANUS TECHNOLOGY 01753 869996
MICRO CRAFT USA (1) 909 947 1843

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

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

SPACEFRAME DESIGN

ÆOLUS TECHNOLOGY USA (1) 970 472 1288
ENABLING TECHNOLOGIES LTD 01983 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

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DRIVETRAIN & SUSPENSION ENGINEERING SERVICES

8.1 Engine Services

RACE PREPARATION

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

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

DJ RACECARS 01663 734518
DTM POWER 01865 407726
DUNNELL ENGINES 01449 677726
EARS MOTORSPORT 01625 433773
EDS 01708 857108
ELABORAZIONE COLASUNO 0207 738 8331
ENGINE DATA ANALYSIS 01977 516622
ENGINE SHOP 01280 812199
FISCHER ENGINEERING USA (1) 818 767 8840
FORWARD ENGINEERING 01676 523526
GEMINI ENGINEERING 01474 534779
GEOFF RICHARDSON ENGINEERING 01480 861599
GF BECK MOTORSPORT PREPARATION 01646 621184
GOLDFLOW 01491 875554
GOODMAN RACING ENGINES 01327 300422
GRAHAM HATHAWAY RACING 01621 856956
GRIFFIN MOTORSPORT 01793 771802
HARPERS PERFORMANCE 01642 818188
HARTWELL 01202 556566
HAUS OF PERFORMANCE USA (1) 714 545 2755
HT RACING 01474 872888
IRMSCHER 01543 414466
IVAN DUTTON 01923 816277
JANSPEED MOTORSPORT 01722 321833
J MATTIS ENGINETECH Greece 003 019 512 761
JOHN WILCOX COMPETITION ENG 01455 230576
JONDEL 01933 411993
KENT AUTO DEVELOPMENTS 01303 874082
KREMER RACING Germany (49) 221 171025
LE SPORT France (33) 14 582 4400
LIGHTNING PERFORMANCE USA (1) 904 439 5283
LINGENFELTER USA (1) 219 724 2552
MARDI GRAS MOTORSPORTS 01327 858 006
MATHWALL ENGINEERING 01252 703191
MATRIX ENGINEERING USA (1) 888 249 0013
MAXSYM ENGINE TECH 01608 685155
MERLIN DEVELOPMENTS 01283 511184
MILLINGTON 01746 789268
MINERVA MOTORSPORT 01509 233970
MINISTER RACING ENGINES 01634 682577
MIRKO RACING USA (1) 408 776 0073
MIS M/SPORTTECHNIK GERMANY (49)263680394
MOUNTUNE RACE ENGINES 01621 854029
NEIL BROWN ENGINEERING 01775 723052
PHIL JONES ENGINE DEV 01454 310936
PHIL MARKS ENGINE DEV 01564 824869
PRICE MOTORSPORT USA (1) 812 546 4220
PRIMA RACING 0115 9491903
PRODRIVE 01295 273355
QUICKSILVER RACE USA (1) 301698 9009
QUORN ENGINE DEVELOPMENTS 01509 412317
RACE ENGINE DEVELOPMENT USA (1) 760 630 0450
RACESPEC 01925 636959
RACE TECHNIQUES 01242 245640
RACING BENT USA (1) 714 779 8677
RANDLINGER Germany (49) 761 16373
ROAD & STAGE MOTORSPORT 01524 844066
ROADSPEED PERFORMANCE 01453 750864
RPM FRANCE (33) 3 86 66 00 08
SCARBOROUGH Canada (1) 416 759 9309
SEARLE 0208 305 2250
STEVE CARBONE RACING USA (1) 918 835 6596
SWAYMAR 01932 868377
SWINDON RACING ENGINES 01793 531321
TECNO 01268 764047
TERRY SHEPHERD TUNING 01695 574454
THINK AUTOMOTIVE Tel 0208 568 1172
Fax 0208 847 5338
Email matt@thinkauto.co.uk
292 Worton Road, Isleworth, Middlesex, TW7 6EI
THUNDERBIRD RACING INT LTD 01623 622848
VAN DYNE ENGINEERING USA (1) 714 847 4417
WARRIOR 01825 764833
ZYTEK ENGINEERING 01332 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

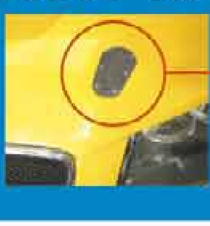
ANDREASON RACING 01300 348499
ANEX SYSTEMS 01869 345038
BTR PREPARATIONS 01977 522348
EARS MOTORSPORT 01625 433773
GTC COMPETITION 01483 272151
HAUS OF PERFORMANCE USA (1) 714 545 2755

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

JACK KNIGHT 01483 764326
JP RACE CENTRE 01327 858151
KREMSPEED EQUIPMENT INC. USA (1)814 724 4086
MARK BAILEY RACING 01380 850130
MATRIX ENGINEERING USA (1) 888 249 0013
ME MOTORSPORTS 01884 253070

QUAIFE ENGINEERING Tel 01732 741144
Fax 01732 741555
Email info@quaife.co.uk
www.quaife.co.uk
Vestry Road, Sevenoaks, Kent, TN14 5EL

ROADSPEED PERFORMANCE 01453 750864
TONY THOMPSON RACING 01664 812454d
ZF Germany (49) 7541 77 2543
UK 0115 9869211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www.aerocatch.com

8.3 Suspension Services

SETUP SPECIALISTS

ACTIVE ENGINEERING	USA (1) 714 637 1155
ANDREASON RACING	01300 348499
ATHON MOTORSPORT	0114 2490 272
AZTEK	01509 261299
BEAUFORT RESTORATION	**01795 830288**
DAVID POTTER CONSULTING	0033(0)494 339090
BRADY FABRICATIONS	01869 252750
CRANFIELD UNIVERSITY	01234 754152
DON FOSTER	France (33) 470 580308
EARS MOTORSPORT	01625 433773
GEOSCAN (G.I.L. Design)	01225 790568
LOLA	**Tel 01480 451301**
	Fax 01480 456722
HAUS OF PERFORMANCE	USA (1) 714 545 2755
INTERPRO ENGINEERING	01454 412777
LOTUS ENGINEERING	01953 608000
MARDI GRAS MOTORSPORT	01327 858006
MARK ORTIZ	USA (1) 704 933 8876
PILBEAM RACING DESIGNS	**01778 424838**
PODIUM DESIGNS	07000 763 486
Ray Mallock LTD (RML)	**Tel 01933 402440**
	Fax 01933 676519
	www.rmlmallock.co.uk
	6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
FSUSPENSION TECHNOLOGY	01327 858558
SHOCKBOX DAMPER SERVICES	**Tel: 07919 340550**
	Website: www.shockbox.co.uk
	Email: ghbj@compuserve.com
	67 Blackthorn Road, Attleborough, Norfolk, NR17 1YJ UK
THE STRAIN GAUGING CO	**01256 320666**
UNIVERSITY OF HERTFORDSHIRE	01707 284270

ENGINEERING SERVICES

RACING INDUSTRY TECHNICAL SERVICES	USA (1) 248 645 1724

8.4 Metal Services

BEAD & SAND BLASTING

BLAST-IT-ALL	USA (1) 800 353 2612
CAMCOAT PERFORMANCE COATINGS	**01925 445003**
COMPAIR AUTOPOWER	01494 465000
HANKOE MOTORSPORT	01753 522779
MACDONALD RACE ENG	**0208 889 1633**
SWAYMAR CASTING	01932 868377
AEROMET	01795 415000
GM DESIGN	0117 985 9964
GRIFFITHS ENGINEERING	01582 600629
HILLGARD	Sweden (46) 300 60590
JENVEY DYNAMICS	01746 768810
KENT AEROSPACE CASTINGS	01795 476333
PANKL	Austria (43) 3862 512500
QUAIFE ENGINEERING	01732 741144
QDF COMPONENTS	01332 760260
QUARTERMASTER	USA (1) 847 540 8999
QINETIQ	**Tel 08700 100942**
	www.QinetiQ.com
	Cody Technology Park, Ively Road, Farnborough, Hampshire, GU14 0LX
ZEUS ALUMINIUM	01384 482222

COATINGS

CAMCOAT PERFORMANCE COATINGS	**01925 445003**
CTG	**Tel: +44 (0)1295 220130 Fax: +44 (0)1295 220138**
	E-mail: motorsport@ctgltd.co.uk
	www.ctgltd.co.uk
	Thorpe Park, Thorpe Way, Banbury, Oxfordshire OX16 4SU United Kingdom
LURO COTE	USA (1) 909 885 3223
KENT MOTORSPORT CASTINGS	01795 662288
POETON	01452 300500
POLYMER DYNAMICS	USA (1) 713 694 3296
QINETIQ	**0 8700 100942**
SWAIN TECH	USA (1) 716 889 2786
WALLWARK HEAT TREATMENT	0161 7979111
ZIRCOTEC PERFORMANCE COATINGS	
	Tel: 0870 190 8480 Fax: 0870 190 8488
	E-mail: enquiries@zircotek.co.uk
	www. zircotek.com
	528.10 Unit 2 Harwell business Centre, Didcot, Oxfordshire OX11 0QJ United Kingdom

FINISHING

ALUMINIUM SPECIAL	01384 291900
APPERLEY HONING	01242 525868
ARMORALL PRODUCTS	01799 513130
CML GROUP	0151 647 5531
GRIFFITHS ENGINEERING	01582 600629
HEPWORTH INTERNATIONAL	01484 711720
JENVEY DYNAMICS	01746 768810
KENT AEROSPACE CASTINGS	01795 476333
QUAIFE ENGINEERING	01732 741144
QINETIQ	**0 8700 100942**
RICHARD BARRETT MOULDS	USA 353 282 9842
ZEUS ALUMINIUM PRODUCTS	01384 482222

FOUNDRIES

AEROMET	01795 415000
BA HARRISON	0116 2769351
GM DESIGN	0117 985 9964
FINECAST	01903 765821
H GRIFFITHS ENGINEERING	01582 600629
JENVEY DYNAMICS	01746 768810
KENT AEROSPACE CASTINGS	01795 476333
KENT MOTORSPORT CASTINGS	01795 662288
QUALCAST	01332 760260
UK RACING CASTINGS	01227 750877

HEAT TREATMENT

AR CORNELL	01245 268098
AUTOSPRINT	01675 464857
AVONBAR	01932 840058
BEAUFORT RESTORATION	01795 830288
JENVEY DYNAMICS	01746 768810
PANKL	**Austria (43) 3862 512500**
QUANTUM HEAT TREATMENT	01908 642242
TECVAC	01954 233700
ZEUS MOTORSPORT	01604 878101

MACHINING

ABBEY PANELS	02476 644999
ACTIVE ENGINEERING	USA (1) 714 637 1155
APPERLEY HONING	01242 525868
ATHENA MANUFACTURING LP	USA (1)512 928 2693
AVONBAR	01932 840058
AZTEK	01509 261299
BEAUFORT RESTORATION	01795 830288
CML GROUP	0151 647 5531
COLEMAN MACHINE	USA (1) 906 863 8945
DATUM ENGINEERING	02476 383032
FORMULA FABRICATIONS	01953 605490
DONCASTERS LTD	01332 864900
JENVEY DYNAMICS	01746 768810
KRONTEC GMBH	**Tel Germany (49) 9401 5253-0**
	Fax Germany (49) 9401 5253-10
	Pommernstrabe 33, 93073 Neutraubling, Germany
LANGSTONE ENGINEERING LTD	02392 452430
LINGENFELTER	USA (1) 219 724 2552
LOTUS ENGINEERING	01953 608000
MACDONALD RACE ENG	**0208 889 1633**
MASON ENGINEERING	USA (1) 805 527 6624
METAL SPINNERS	0191 267 1011
MILSPEC PRODUCTS	**USA (1) 407 814 8997**
QINETIQ	**0 8700 100942**
PANKL AUSTRIA	**(43) 386255122500**
PERFORMANCE MACHINE	USA (1) 303 828 4546
PREMIER AEROSPACE	01332 850515
PREMIER FUEL SYSTEMS	01332 850515
QUAIFE ENGINEERING	01732 741144
RICARDO INC	USA (1) 734 397 6666
RICHARD BARRETT MOULDS	USA 353 282 9842
TITAN MOTORSPORTS	01480 474402
TREVOR MORRIS ENGINES	015474 289
TRICK MACHINING	01493 751666
VIN MALKIE	01565 777395

METAL MATRIX COMPOSITES

BP METAL COMPOSITES	01252 37
CRANFIELD UNIVERSITY	**Tel 01234 754902**
	Fax 01234 751671
	Email motorsport@cranfield.ac.uk
	www.motorsport.cranfield.ac.uk
	Motorsport Group, Cranfield University, Cranfield, Bedfordshire, MK43 0AL
GM DESIGN	0117 985 9964
MMCC	USA (1) 617 893 4449
PANKL	Austria (43) 3 8625 12500

METAL SUPPLIERS

ADVANCED METALS INTERNAT	01923 210250
AIRCO METALS LTD	0118 973 0509
ALUMINIUM SPECIAL	01384 291900
APPERLEY HONING	01242 525868
BRADY FABRICATIONS	01869 252750
BRITISH ALCAN ALUMINIUM	01753 887373
AVESTOPOLART LTD	0114 2443311
BYWORTH MATERIAL SERVICES	01453 821609
COLUMBIA METALS	01604 810191
CROMPTON TECH GROUP	01295 220130
MASON ENG	USA (1) 805 527 6624
RICHARD BARRETT MOULDS	USA 353 282 9842
RGB STAINLESS	0121 558 3111
SMITHS HIGH PERFORMANCE	01767 604708
SPA AEROFOILS LTD	01827 260026
SUPER ALLOYS INTERNATIONAL LIMITED	**Tel: +44 (0) 1908 260707 Fax: +44 (0) 1908 260404**
	Email: sales@superalloys.co.uk
	Number 1 Garamonde Drive, Wymbush Milton Keynes MK8 9DF UK.

TITANIUM SPECIALISTS

AIRCO METALS LTD	0118 973 0509
A.N. MOTORSPORT DESIGN	01628 776320
APPERLEY HONING	01242 525868
ATHENA MANUFACTURING LP	USA (1)512 928 2693
CML GROUP	0151 647 5531
COAST FABRICATION	USA (1) 714 842 2603
DATUM ENGINEERING	02476 383032
DONCASTERS LTD	01332 864900
PANKL	**Austria (43) 3 8625 12500**
QINETIQ	**0 8700 100942**
SPA AEROFOILS LTD	01827 260026
TITANIUM INTERNATIONAL	**Tel: 0121 789 5764**
	Fax: 0121 784 8054
	Email: nhoskison@tiltd.co.uk
	Keys House, Granby Avenue, Garretts Green, Birmingham B33 0SP

TUBE FORMING

CONTRACT MFG & ASM	USA (1) 920 720 4225
MALVERN AIRCRAFT	01684 892600
SPA AEROFOILS LTD	01827 260026

8.5 Race Preparation

CHASSIS

ACTIVE ENGINEERING	USA (1) 714 637 1155
AMS	01831 501363
AMT MOTORSPORT	01444 483477
ANEX SYSTEMS	01869 345038
AUTOMECH	0161 775 1851
AVONBAR	01932 840058
BARWELL MOTORSPORT	0208 397 4411
BR MOTORSPORT	01926 451545
BRR MOTORSPORT	01327 858055
CHRIS LEWIS MOTORSPORT	01677 422623
DEREK BENNET ENG	**01565 777395**
PRO MOTORSPORT	01555 893315
DOME CARS LTD	Japan (81) 75 744 3131
DON FOSTER	France (33) 470 580308
FOXCRAFT ENGINEERING	01264 810110
FRP RACING	01494 771609
GRAHAM WISEMAN	01278 685349
HAUS OF PERFORMANCE	USA (1) 714 545 2755
HAWKINS RACING	0208 579 1438
INTERPRO ENGINEERING	01454 412777IVAN
JACK CRONE RACING	USA (1) 909 371 6090
JOHN VILLAGE AUTOMOTIVE	01246 450580
K2 RACE ENGINEERING	01825 766728
MACDONALD RACE ENG	**020 8889 1633**
MARDI GRAS MOTORSPORT	01327 857246
MARK BAILEY RACING	01380 850130
MARK DUNHAM RACE ENG	01353 648922
MATRIX ENGINEERING	USA (1) 888 249 0013
MELTUNE PX MOTORSPORT	01923 242536
MIRKO RACING	**Tel USA (1) 408 776 0073**
	Fax USA(1) 408 779 9319
	16890 Church Street, Building no.14, Morgan Hill, CA 95037, USA
PLANET MOTORSPORT	01403 891553
PODIUM DESIGNS	07000 763486
QINETIQ	**0 8700 100942**
RACECRAFT INTERNATIONAL	01789 297000
RACE TEC DESIGN & ENGINEERING	01386 871292
RILEY & SCOTT	USA (1) 317 248 9470
Ray Mallock LTD (RML)	**Tel 01933 402440**
	Fax 01933 676519
	www.rmlmallock.co.uk
	6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
ROY KENNEDY RACING	01327 858055
SCHNITZER	Germany (49) 8654 2034
SHENPAR PRODUCTS	01332 862901
STARTLINE UK LTD	01933 665752
STORM MOTORSPORT	01474 85 4367
TECH-CRAFT MOTORSPORT	01926 496075
TOLLBAR RACING	01433 631698
TT AUTOMOTIVE RACING	0147 485 3456
VIN MALKIE	01565 777395
ZAKSPEED	Germany (49) 2636 87923

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TESTING SERVICES

9.1 Chassis Testing

CALIBRATION SERVICES

RICARDO INC	USA 001 734 397 6666
THE STRAIN GAUGING CO	**01256 320666**
TORQUE FAST CALIBRATION	01782 744212
UNIVERSITY OF HERTFORDSHIRE	01707 284270

CRASH TESTING

CRANFIELD UNIVERSITY	**01234 754152**
CRANFIELD IMPACT CENTRE	**01234 751361**
KISTLER INSTRUMENTS LTD	01420 544477
MIRA LTD	0247 635 5000
QINETIQ	0 8700 100942
Ray Mallock LTD (RML)	**Tel 01933 402440**
	Fax 01933 676519
	www.rmlmallock.co.uk
	6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
THE STRAIN GAUGING CO	**01256 320666**

MEASUREMENT EQUIPMENT

AUTOSPRINT	01675 464857
BEAUFORT RESTORATION	01795 83288
BERU F1 SYSTEMS	01374 646200
CCA DATA SYSTEMS	01525 378938
CRANFIELD INSTITUTE	01908 694134
GENESIS ELECTRONIC SYSTEMS	01923 893 999
INSTRON SCHENK	01494 456789
INTERCOMP	USA +763 476 2531
KISTLER INSTRUMENTS LTD	01420 544477
LONGACRE	**USA (1) 425 485 0620**
LOTUS ENGINEERING	01953 608000
MICROLEASE	0208 427 8822
MIRA LTD	0247 635 5000
MOTORSPORTS INTERFACE	01788 890412
QINETIQ	0 8700 100942
ROEHRIG ENGINEERING	**Tel USA (1) 336 431 1827**
ROTO TEST AB	**Sweden (46) 85 325 5890**
THE STRAIN GAUGING CO	**01256 320666**

ROLLING ROADS

ALDON AUTOMOTIVE	01384 78508
AUTOMECH	0161 775 1851
AUTOPOINT	01842 766226
AUTOSPRINT	01675 464857
BD ENGINEERING	01795 843980
PIT STOP	01993 850654
B&J MOTOR ENGINEERS	0161 748 8663
BOSCH	01895 834466
BBR GTI LTD	01280 702389
BRUNO HANSON	Denmark (45) 65 99 1616
CARBURETTOR CENTRE	0208 340 5057
CHAMPION MOTORS	01621 857444
CRANFIELD INSTITUTE	01908 694134
DERBY AUTO ACCESSORIES	01332 671493
DTM CONSULTANTS (UK)	01865 407726
ELABORAZIONE COLASUNO	0207 738 8331
FGR	01885 400639
FROUDE CONSINE	01905 856800
INTERPRO ENGINEERING	01454 412777
JANSPEED MOTORSPORT	01722 321833
MACHTECH	01923 269788
MATRIX ENGINEERING	USA (1) 888 249 0013
MIRA LTD	0247 635 5000
MOTORSCOPE	01609 780155
OHIO STATE UNIVERSITY	USA (1) 614 292 5491
OSELLI ENGINEERING	01865 248100
RE PERFORMANCE CENTRE	0161 761 1177
RICHARD LONGMAN RACING	01202 486569
ROADSPEED PERFORMANCE	01453 750864
SARDOU	France (33) 16 00 10 367
SCHENCK	01869 321111
SOUTHAMPTON UNIVERSITY	01703 585044
TIM STILES RACING	01278 453036
TIPTON GARAGE	01404 812091

STRESS ANALYSIS

COSINE TECHNOLOGY	01706 378851
LOLA	**Tel 01480 451301**
	Fax 01480 456722

WELD TESTING

C & B CONSULTANTS AERODYNAMICS LTD	
	Tel 01202 661707 Fax 01202 685588
	Email candbaero.uk@candbconsultants.com
	www.candbconsultants.com
	Unit2B, 8 Cowley Road, Nuffield Ind Est, Poole, Dorset, BH17 0UJ
C & B INTERNATIONAL INCORPORATED	
	Tel 317 291 0978 Fax 317 536 0656
	email candbaero_indy@email.msn.com
	6210 La Pas Trail, Indianapolis, IN 46268, USA
KISTLER INSTRUMENTS LTD	01420 544477
WIND TUNNELS ACTIVA TECH	0208 974 1615
AIOLOS ENG	Canada (1) 416 674 3017
CRANFIELD INSTITUTE	01908 694134
CRANFIELD UNIVERSITY	01234 754152
DOME CARS LTD	Japan (81) 75 744 3131
IMPERIAL COLLEGE LONDON	0207 589 5111
LANGLEY FULL-SCALE	USA (1) 757 766 2266
MARCH	01280 704160
MICRO CRAFT	**USA (1) 909 947 1843**
MIRA LTD	0247 635 5000
OHIO STATE UNIVERSITY	USA (1) 614 292 5491
RMCS (CRANFIELD)	01793 785359
QINETIQ	0 8700 100942
SARDOU SA	France (33) 16 00 10 367
UNIVERSITY OF MARYLAND	USA(1) 301 405 6861
WESTLAND HELICOPTERS	01935 702190

WIND TUNNEL MODELS

ADVANCED COMPOSITES	01773 763441
AERODINE COMPOSITES	**USA (1) 317 271 1207**
CAPITAL PATTERNS	0208 777 9276
COMPOSITE DESIGN	USA (1) 727 539 0605
DOME CARS LTD	Japan (81) 75 744 3131
MARTIN FELDWICK	01603 712611
MICRO CRAFT	**USA (1) 909 947 1843**
MIRA	0247 635 5000
SARDOU SA	France (33) 16 00 10 367
THE STRAIN GAUGING CO	**01256 320666**

9.2 Engine Testing

COMBUSTION ANALYSIS

AM TEST SYSTEMS	01253 780780
AUTOSPRINT	0121 236 5133
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9.3 Transmission Testing

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9.4 Suspension Testing

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9.6 Metal Testing

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Yaw changes things

It's always easier, and certainly tempting, to think in straight lines, but in aerodynamics life is rarely that simple

A cornering racecar can exhibit very different aerodynamic effects to running straight ahead

LAT

Creating any model is simpler if we make more assumptions and simulate the fewest variables. But more assumptions furnish less realistic results. An assumption frequently used in aerodynamic modelling is that the car runs straight. But if we're interested in aerodynamics relating to cornering performance then the 'straight ahead' model is less than realistic.

One way that computational fluid dynamics (CFD) can address this complication is to rotate the computational domain surrounding the model by pivoting it about a vertical axis, an appropriate distance along the car's centreline. In this way, the virtual airflow and the moving road beneath approach the car at an angle that simulates a fixed yaw condition. Naturally this is another simplification, the choice of yaw angle and axis location being two of infinite possibilities. Furthermore, the angle at which the airflow encounters the front and the rear of the car will also differ in reality, to an extent that depends on the radius of the corner and the geometry of the car. The direction the front wheels point as the car progresses around a corner will change. But these realities aside, a study by Advantage CFD of how a four-degree yaw angle affected the pressures and forces on a Reynard 01I ChampCar yielded some fascinating insights.

The table above right shows the changes to the aerodynamic forces running at four-degrees yaw, compared to the baseline 'dead ahead' case (actual forces cannot be revealed). The airflow was effectively approaching the car from the driver's right side.

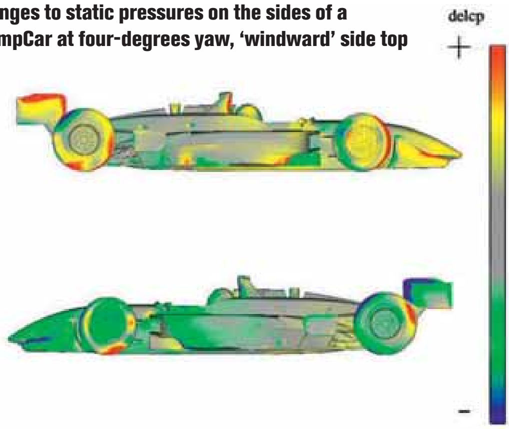
Produced in association with Advantage CFD
advantage CFD
Tel: +44 (0)1280 846806
Email: cfd@advantage-cfd.co.uk
Web site: www.advantage-cfd.co.uk

	Downforce %	Drag %
Total	**-4.91**	**-3.14**
Wheels, front	-27.53	+3.96
Wheels, rear	-79.2	+2.83
Wing, front	-1.25	-1.24
Wing, rear	-5.05	-6.25
Underbody	-1.6	+29.3

Overall, the car saw a significant reduction of 4.9 per cent downforce and 3.1 per cent drag, but some of the detail changes need to be put in perspective. The highlighted values show large percentage changes, but the baseline values in these cases were small contributors to downforce and drag, and so are of minor significance. The other values relating to components show smaller percentage changes, but these were changes to major contributors to overall downforce or drag and so were of considerable significance.

As ever, the picture is far from simple, so let's use some CFD visualisation to illustrate how pressures have altered around the car. Figure 1 shows the changes to static pressure (delCp) on the two sides of the car. The positive yellow (and red) colours indicate where static pressure increased when yawing the car, relative to the baseline case. The negative green (and blue) colours show where the static pressure reduced in yaw. The windward side clearly saw increases in pressure because a component of the airflow was now incident upon this side. The airflow was thus slowed down (partially stagnated), so the static pressure increased. The leeward side saw reductions in pressure because the air's lateral component that flowed, for example, around the side curvature of the nose and sidepod accelerated, and so static pressure reduced. There are also small areas of flow separation arising from this lateral velocity component, the most obvious being the lee side of the front and rear wing end plates (blue colours). ➔

Figure 1: changes to static pressures on the sides of a Reynard ChampCar at four-degrees yaw, 'windward' side top



Illustrations courtesy: Advantage CFD

Figure 2: changes to static pressures on the top surfaces at four-degrees yaw

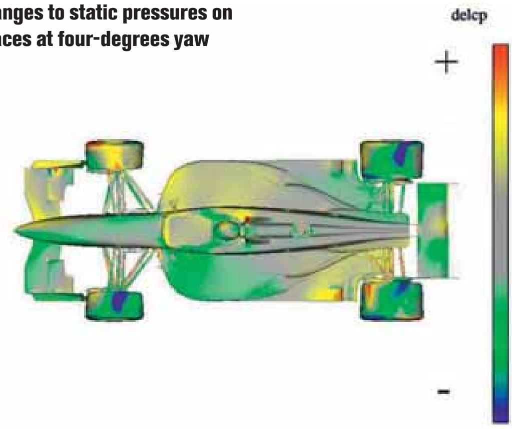
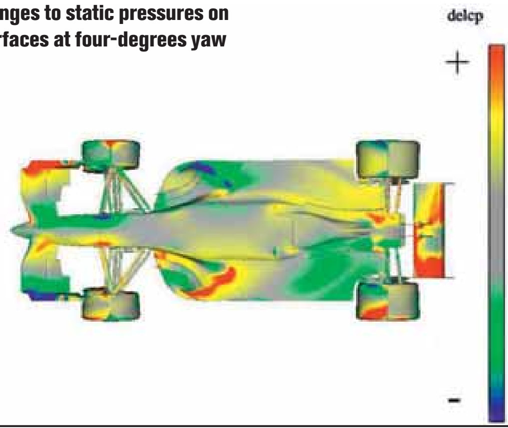


Figure 3: changes to static pressures on the lower surfaces at four-degrees yaw



In the delCp plot from above (figure 2), the increases in static pressure on the front wing right side and front of the right sidepod coincided with the windward side view. The decreases in static pressure on the left side of the front wing and the front of the left sidepod were the result of these parts being, in terms of the lateral component of the airflow, in the wake of the nose and cockpit respectively. The patterns over the tyres show marked changes to static pressure distributions, these resulting from changes to separation patterns that caused increased tyre lift. [Note this CFD model included a support strut (the 'sting') located 'through' the driver so that direct comparisons with the wind tunnel model could be made.] This in part explains the area of the rear wing, just left of centre, which was at lower static pressure when yaw was applied – caused by the sting's wake.

In the delCp plot seen from below (figure 3), the patterns of change to static pressures in the underbody region pretty much matched those seen from above, but the marked changes seen under the forward parts of the sidepod underbody, just aft of the curved vortex generators, seem to be the result of a lateral shift of the front wing tip vortices. Figure 4 reveals how the blue low total pressure region formed by the front wing vortex on the windward side (top in the image) interacted with the sidepod vortex generators, whereas that on the leeward side passed outboard of them. This resulted in the asymmetric changes to the static pressures across the car.

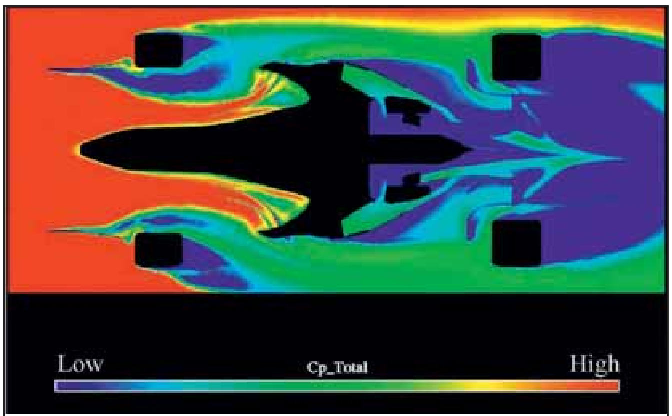


Figure 4: total pressures along a horizontal slice level with the bottom of the front wing endplates, as viewed from above

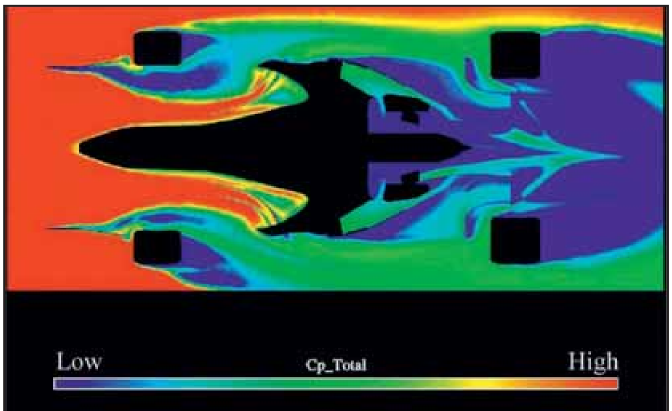
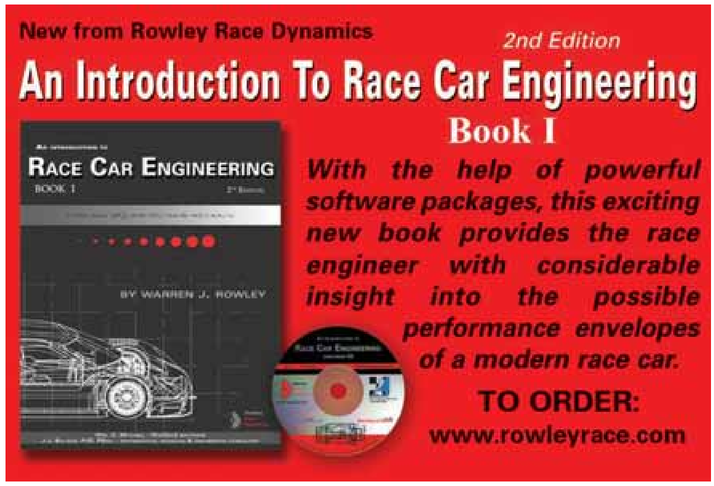


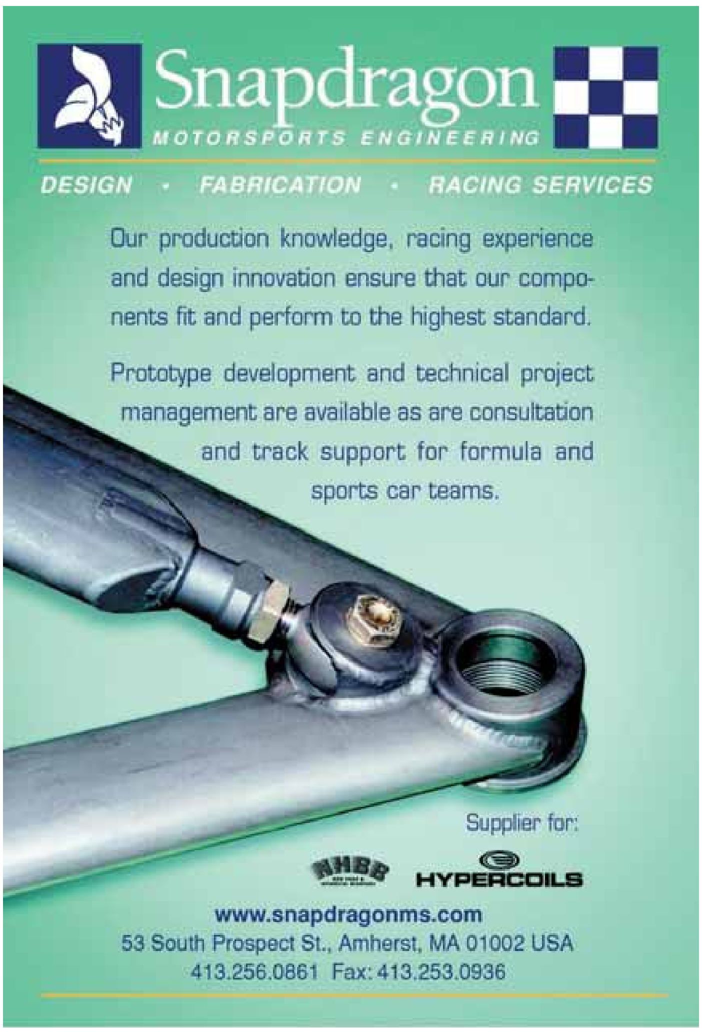
Figure 5: total pressures along a horizontal slice level with the tops of the front tyres, as viewed from above

Other changes to the wings were rather different. The windward side of the front wing, viewed from below, saw decreased static pressure outboard and increased static pressure near the nose. The outboard decrease was because of changes to the tip vortices under the end plates – the windward side vortex was intensified (as figure 4 again shows), leading to greater static pressure reduction. Adjacent to the nose, however, the angle of the incident flow again saw it partially stagnate here, which increased the static pressure on the windward nose underside and on the adjacent front wing surface. The leeward side front wing saw completely opposite pressure changes when at yaw. The leeward side vortex was weakened, leading to increased static pressure outboard, and the lateral acceleration under the nose saw decreased static pressure inboard.

The static pressure can be seen to have decreased on top and increased underneath the rear wing, both changes losing downforce. The windward side end plate appears to be responsible for some of the losses, masking that side of the wing from clean flow. The wake of the windward side front tyre also impinged on that side of the rear wing, whereas the wake from the leeward side front tyre did not, as figure 5 reveals. The engine cover wake, which in figure 5 has clearly enlarged at yaw, also impinged just off centre of the rear wing. Both these wakes reduce energy, and possibly alter the angle of the flow reaching the wing, which can both lead to reduced downforce.

So, although the force changes at four-degrees yaw were relatively minor, it's not hard to imagine, when such a racecar gets really out of shape, that there would be far greater aerodynamic disruption. RE





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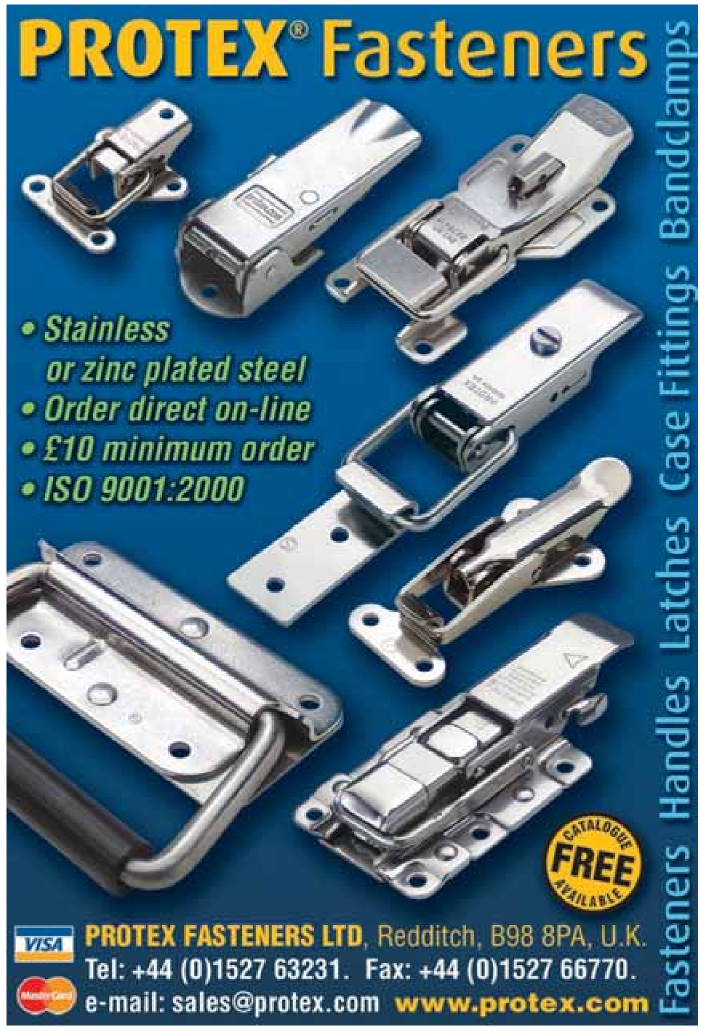
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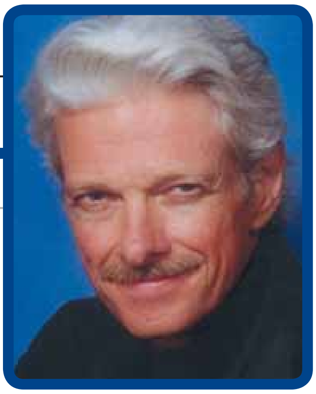

Dynamics of three wheelers

Three-wheeled chassis exhibit behaviour that is unique to this configuration

LAT

Q **If you were building a three-wheeled vehicle, would you put some roll in the two-wheeled end or not?**

A I am assuming that the questioner is asking whether there should be some roll compliance at the wide end, or whether the suspension should be essentially rigid in roll.

This is a reasonable question because, at least at low speed, a three-wheeler doesn't need suspension to keep all its wheels on the ground. Because any three points invariably lie in a common plane, a tricycle can trundle over very uneven ground at low speed with very little load change at the wheels, and without picking up a wheel, even if the entire chassis is rigid. This fact led many of the earliest designers of motor vehicles to adopt tricycle layouts. Among these vehicles was the very first self-propelled, off-rail vehicle – the Cugnot steam tractor of the 1760s (or 1771, if we go by the still-existing second model). Carl Benz's first petrol buggy, in 1885, was also three wheeled.

The trike layout was not universal, however, even in the early days. Benz's petrol-powered buggy was preceded by two models of internal-combustion, petrol-fuelled (or more accurately, benzine-fuelled) cars built by Siegfried Marcus in 1865 and 1874. I don't know what the first of these looked like, but the second model (of which three were built) had four wheels. In 1879, George Selden applied for a US patent on the automobile. The model he submitted to the patent office had four wheels.

"ANY THREE POINTS INVARIABLY LIE IN A COMMON PLANE"

It also had unitised body/frame construction and front wheel drive!

By the time automobiles became common, a wagon-style four-wheel layout had become the norm. This is not surprising, because this layout provides the best resistance to roll and pitch available within an →

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**

LAT

2000 Pikes Peak Hillclimb. Swedes Anders Nilsson and Tom Grindberg demonstrate the art of motorcycle sidecar racing. Even with the optimum centre of gravity – as far away from the two-wheeled side as possible – and a wheel spread as wide as regulations permit, rollovers are a very definite possibility

envelope defined by a maximum length and width. Despite this, the tricycle layout has refused to die out completely.

The primary reason people have kept building trikes is economic. In most of the world, trikes are licensed and taxed as motorcycles rather than cars. Where cars are heavily taxed, this gives the trike a substantial price advantage. A secondary reason is that a trike can be made very light. Due to the aforementioned fact that a trike's tyre contact patches always lie in a common plane, the frame does not see the torsional loadings that a four wheelers does. Consequently, it can be built considerably lighter.

The tricycle layout does bring problems, however. The main problem is poorer resistance to rollover. A trike can tip over by rolling about a line connecting the contact patches of the outer tyre at the wide end and the single tyre at the narrow end. For a given wheelbase and track, the vehicle's centre of mass will unavoidably be closer to this line in plan view than it would be to a line connecting the front and rear outer tyre contact patches on a four wheeler. Strictly speaking, the tipping motion we refer to here is not pure roll, but a combination of roll and pitch. But regardless of what we call the motion, the vehicle is limited by the easiest way it can tip.

"THE MAIN PROBLEM IS POORER RESISTANCE TO ROLLOVER"

The key to minimising this problem is to put the c of g toward the wide end as far as we can. If the single wheel is at the front, we need a rear-engine layout, similar to the VW-engined tricycles that are still fairly common today. If the single wheel is in the rear, we need a front engine, as in a Morgan trike. It is important to assure that the operator does not place any heavy cargo toward the narrow end.

It is best to drive the two wheels at the wide end, rather than the single wheel at the narrow end. Not only does this provide much better traction, but it further concentrates the masses at the wide end.

One problem we encounter when the c of g is toward one end of the vehicle is that in hard longitudinal acceleration, the single wheel may lift, or become so lightly loaded as to impair directional stability. In a front-engine trike, the rear wheel will tend to lift in braking. In a rear-engine trike, the vehicle will tend to wheelstand under power. We can minimise this problem, and improve rollover stability, by making the wheelbase long, and by getting the c of g as low as we can.

When choosing between the rear-engined and front-engined approaches, there is a safety advantage to the front-engine, front-drive layout. It has its best rollover resistance when decelerating, whereas the rear-engine, rear-drive layout is most likely to flip when the driver tries to lose speed upon entering a turn too fast. The front-engine, front-drive layout also provides much better crosswind stability.

Returning to the original question, what sort of characteristics should the suspension have at the wide end? First of all, it should not have large jacking forces. Either it should be an independent layout with a low roll centre, or it should be a beam axle layout.

Particularly with an independent suspension, the wheel rate in roll needs to be substantial, but it should not approach infinity. If there is too much wheel rate in roll, the vehicle will see large roll accelerations, and large wheel load changes, when traversing one-wheel bumps at speed.

Barring a great increase in the popularity of trikes, we are unlikely to see a class for them in racing, except vintage racing where one does see Morgans and their contemporaries. We do, however, have racing for sidecar rigs. These are normally constrained by the rules to have two wheels in line, with the rear one driven, and a third wheel to one side. This is not the way to design a three wheeler if we have a free hand, but it retains the connection to a roadgoing motorcycle with sidecar, and it provides thrilling, if somewhat dangerous, racing.

To optimise a sidecar layout, the wheels should again be spread as far in all directions as the rules allow and the heavy side should, if possible, be toward the predominant turn direction. The c of g should be away from the two-wheeled side, and fairly close to the single wheel in the fore-and-aft direction. Even when all of this is carefully attended to, there will be no substitute for a good 'monkey' or passenger, and the best possible helmet and leathers...


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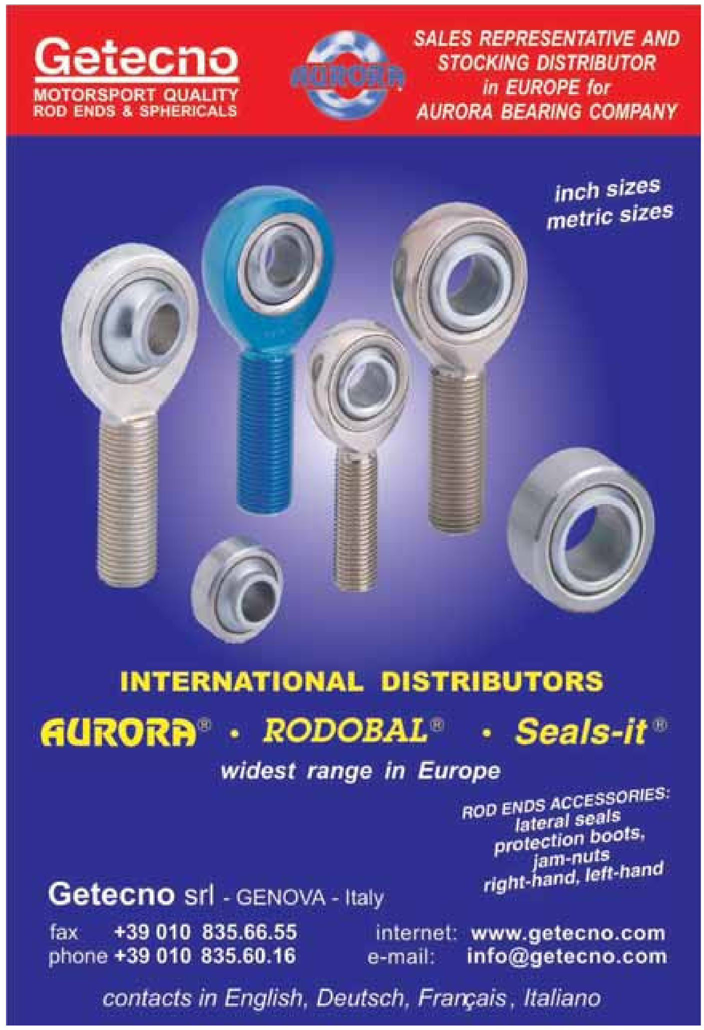
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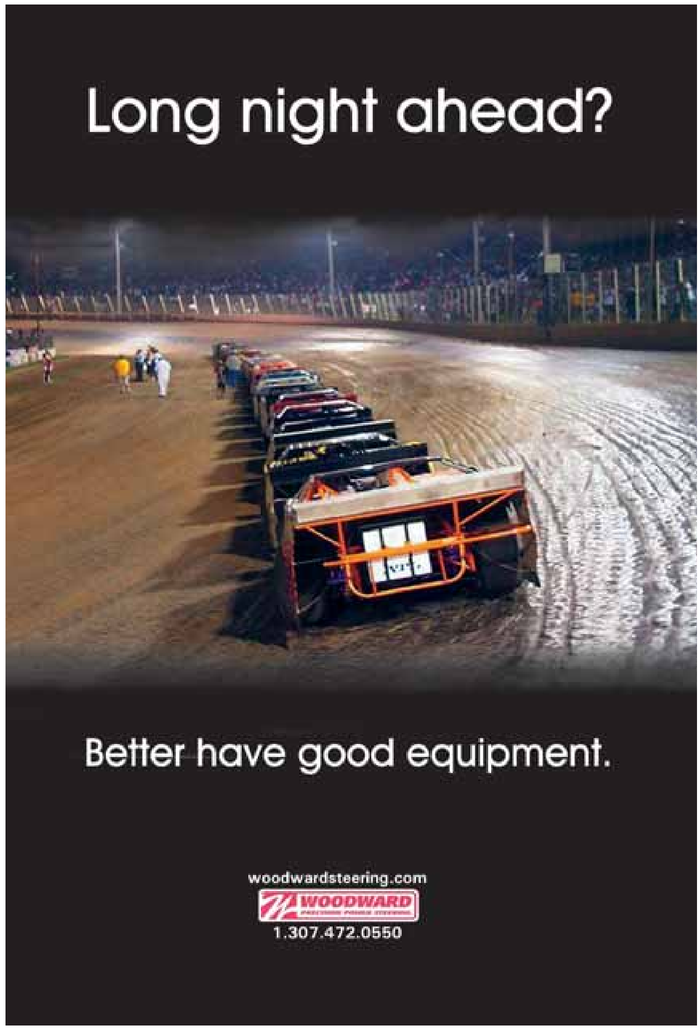
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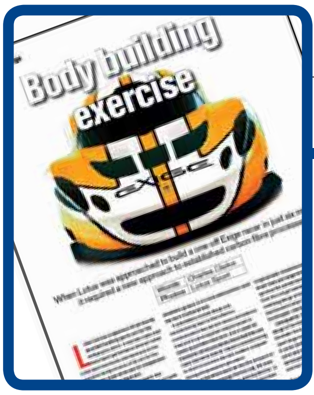

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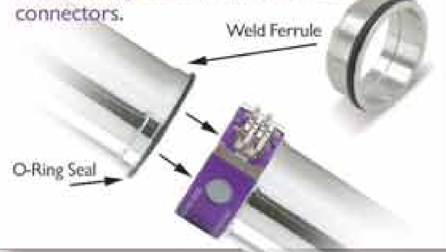

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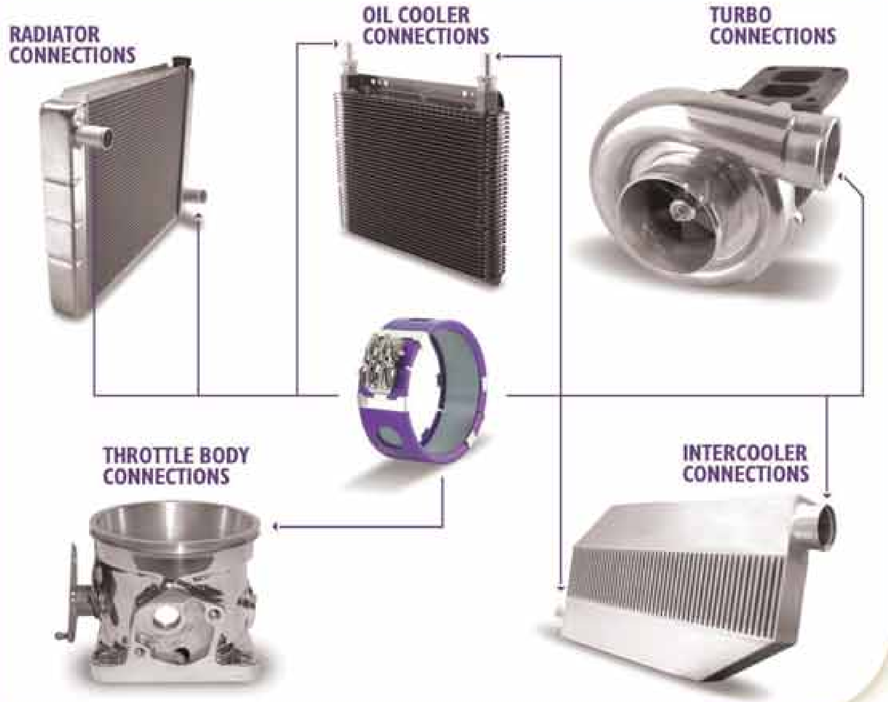

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