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The technical tricks behind the fight for grand prix glory

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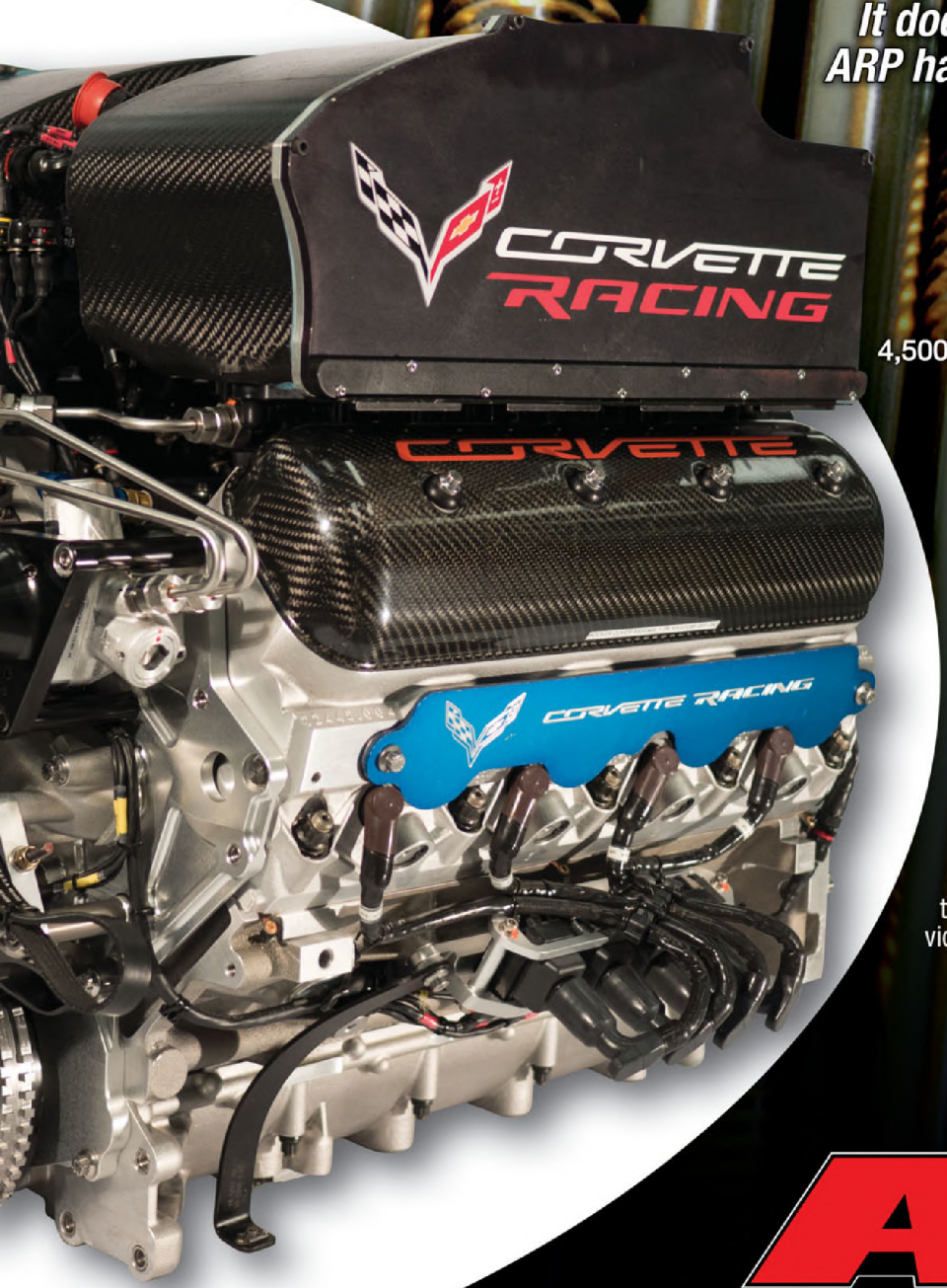

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Commonsense prevails (sort of)

NEWS that the F1 Commission has rejected plans for an alternative "client" engine does not come as a surprise. Despite FIA president Jean Todt and F1 commercial rights holder Bernie Ecclestone coming together to push the idea forward, there was little hope that they were going to overcome the combined might of the teams. However, what has been proposed by them may be an acceptable alternative whereby the four engine manufacturers will jointly put forward a proposal of their own that addresses the issues the alternative engine was meant to. For the FIA, it is a victory of sorts, although less so for Ecclestone who was really trying to curtail the power of the engine manufacturers.

What is left on the table now is for Ferrari, Honda, Mercedes and Renault to come up with a solution that guarantees the supply of power units to teams at a lower cost, make them less complicated and do something about the noise. Another provision is that they must agree to a minimum number of teams they will supply. However, they are not being allowed to think they have got away with it because they are on a fairly tight deadline, the FIA giving them until 15 January, 2016 to come up with a firm plan. If they fail to do so, then the alternative "client" engine is back on the table.

The idea of an alternative engine was always a stretch. When you consider such things, you automatically think of Cosworth, but it put an immediate stop to that by saying in a pithy statement that it was declining the opportunity to lose money. However, Mike Lancaster, boss of British company AER, said his company was ready to deliver a suitable powerplant, while there were also expressions of interest from Ilmor Engineering and Meccachrome.

Had the FIA and Ecclestone had their way, it would have led to a slightly ridiculous position of there being a two-tier Formula 1 as it was being implied that the alternative engine would be just that and not a so-called power unit. The message that would have sent out would have been confusing at the very least. Was Formula 1 really at the cutting edge of hybrid technology or was it looking back over its shoulder to the glory days of the V8? What message would it have sent to other manufacturers who might have been tempted into Formula 1?

In the end common sense is sort of prevailing, although it is beholden on the engine manufacturers to present something that is sensible and affordable. The one worry, though, is Ferrari because it was they who were opposed to the alternative engine proposal and ready to use its veto to enforce its wishes, an act that made former FIA president Max Mosley extremely angry. He told Sky News that he thought it showed a certain amount of small-mindedness and if he were in the position of Ferrari he would be inclined to say 'I need Formula 1 to succeed and therefore I will do everything I can to see that it will succeed and if I don't win it is my engineers' fault as they have the resources and they should get on with it'.

As usual, bang on the money.

William Kimberley
EDITOR

Citroën Motorsport

ABOVE Dominant force: Citroën has been consistently ahead of the opposition ever since entering the WTCC in 2014

Citroën chooses rallying over Touring Car racing

Andrew Charman

PARIS, France: Citroën is to close its World Touring Car Championship (WTCC) programme at the end of the 2016 season in order to focus on the World Rally Championship (WRC) – a move predicted by *Race Tech* in issue 178. The French manufacturer will put its 2016 WRC programme on hold in order to build new cars to the FIA's 2017 regulations, which promise more powerful rally cars with dramatic aerodynamics.

The situation is reminiscent of the changes to the WTCC that occurred ahead of the 2014 season. Citroën was one of the first manufacturers to commit to the new TC-1 regulations, its C-Elysee cars, based on a road car sold mainly in the Far East, since dominating the series.

In its first season the C-Elysee triumphed in 17 of the 23 WTCC races, earning Citroën the manufacturers championship and José Maria Lopez the drivers title. In 2015 both driver and manufacturer have repeated their title success, Citroëns topping the results in all but three of the 22 races held to date.

In fact, it is this domination that many observers believe is a factor in the French manufacturer deciding to end its works involvement after 2016, concerned at the declining media coverage, particularly in France, of its successes.

Wider, more powerful and more impressive, with imposing aerodynamic features, the 2017 generation World Rally Cars will succeed the cars that first appeared in 2011. This radical change in the regulations will enable Citroën Racing to compete on equal terms with its rivals, after devoting 2016 to development of the new model.

"We have never hidden our interest in the 2017 WRC regulations and the entire team is extremely motivated by this new challenge," said Yves Matton, Citroën Racing team principal. "We like the freedom granted to make the cars more spectacular, but also the possibility of reusing development work done on the Citroën C-Elysée WTCC's engine. With a view to managing our resources efficiently, we have decided to focus all our efforts on designing and developing our new World Rally Car. This is why Citroën will not be competing in the 2016 World Rally Championship as a works team. We will obviously be keeping a close eye on the WRC, both with the organisation of the FIA Junior WRC and with the WRC2 programme for Quentin Gilbert, this year's JWRC Champion."

Francois Ribeiro, head of WTCC promoter Eurosport events, said that he respects Citroën's decision. "(We) know manufacturer involvement in motorsport has always been cyclical," he added.

However, he insisted that negotiations are still underway for Citroën to be represented in the championship in 2017 in a semi-works capacity. He added that the series remains healthy with much interest from manufacturers.

"With Volvo making a long-term commitment to the championship, five manufacturers will be represented in 2016 with discussions continuing with other car makes who are considering a WTCC entry," Ribeiro said, adding, "We will shortly announce two new championship sponsors and a revamped calendar for 2016."

He has also said that he wishes to find a way of decreasing costs for privateer entries in the WTCC's next homologation cycle, that runs from the 2017 season.

Rumours persist that the Chevrolets racing in the series, built by RML and effectively forming the privateer ranks, could decrease in numbers next season as entrants struggle in particular to maintain the pace of engine development led by manufacturer entrants Citroën and Honda. Ribeiro said that independents remain vital to the WTCC and the series would be badly damaged by allowing costs to inflate out of the reach of the privateer entrants. RT

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ABOVE The super-successful Fiesta R5 is on the receiving end of some substantial updates for 2016

Further boost for successful Ford Fiesta R5

COCKERMOUTH, UK: M-Sport's globally successful Ford Fiesta R5 will receive an extensive upgrade from 1 January 2016. The development will bring substantial performance enhancements to what is already a championship-winning vehicle.

Since its debut in the middle of 2013, the Fiesta R5 has become M-Sport's most successful global rally car. With more than 130 cars competing around the globe, the latest Fiesta can boast hundreds of class victories alongside outright wins and championship laurels.

The Fiesta was the first R5 on the market and – despite not receiving a single upgrade in the past two and a half years – remains one of the most competitive having been crowned this year's FIA European Rally Championship winning car in the hands of Kajetan Kajetanowicz.

Now, as M-Sport continues to make strides in development and has evaluated all of the other R5s on the market, the time is right to launch a comprehensive upgrade.

A dedicated team of M-Sport designers and engineers have been assigned to the project and six months of development has resulted in what the team believe to be their most substantial upgrade to date.

With eight allocated homologation jokers still available to use, the first five are solely aimed at increasing engine performance – updating the cylinder head, pistons, inlet and exhaust cam, exhaust manifold and a new clutch/flywheel.

M-Sport engineers have achieved an incredible gain of 32 bhp at 4500 rpm and 56 Nm of torque at 4000 rpm, which represents the single best development step in any engine designed and built by the British firm.

The remaining three jokers will be used for chassis related upgrades which are due to be released in March 2016.

A number of other items are also scheduled for upgrade. M-Sport is currently investigating improvements to the rear aerodynamic device, front bumper, suspension arms, Reiger dampers as well as auxiliary lighting. These upgrades remain in the development phase with a scheduled release towards the end of the first quarter of 2016.

"I am extremely proud of all of the work that has gone into this project," said M-Sport managing director, Malcolm Wilson. "The original Ford Fiesta R5 remains a reliable and competitive package, but these upgrades will see us take that performance to another level. We're constantly developing all of our products, but I have to say that this is the single biggest upgrade we have ever produced; and when you consider how competitive the Fiesta R5 currently is, that really is some achievement!" RT

Ricardo marks rally renaissance with delivery of complete AWD system

LEAMINGTON SPA, UK: The result of an intensive development programme between Ricardo and a leading international carmaker, the recently announced ultra- lightweight and highly compact AWD transmission and driveline is the first of many products that will once again see the company supporting the world's top rally teams.

The new transmission is a sequential five-speed unit with ratio's optimised for gravel and asphalt, offering a class-leading balance of robustness and package, while achieving the FIA requirements of the R5 championships for which it is intended. In close collaboration with the client's rally team, the complete driveline system has been designed and developed by Ricardo at its Leamington UK facility, including an extensive programme of physical testing on the company's in-house test facilities.

The transmission and driveline that has now been delivered is the first of a series that will be supplied to this particular client to support its event activities in the 2016 season – and it will be followed also by Ricardo-designed and developed driveline products for other automakers competing in other forms of rallying. RT

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JAS debuts its Mk2 TCR Civic

Andrew Charman

MILAN, Italy: Contracted Honda supplier to the TCR International touring car series, JAS Motosport, unveiled its 'step 2' Civic at the championship's penultimate meeting in Thailand. According to JAS, the new car meets all the minor changes resulting from the updated 2016 TCR technical regulations, but the major change is to the engine. Having from the start of TCR's initial season used a normally-aspirated engine with a turbocharger added, JAS has now adopted the production turbocharged unit from Honda's new Civic Type-R.

According to JAS co-owner Maurizio Ambrogetti the company has ambitious aims for its continued TCR involvement. More than 14 cars have been completed so far, and "our goal is to build and sell 25 cars before the beginning of the 2016 season. We wish to have at least two cars running in each TCR series."

The new Civic TCR car will be offered at a price of €104,000 plus taxes, ready to race. RT

ABOVE Second step: JAS intends to increase its Honda builds in 2016

LEFT Italian company Romeo Ferraris has released first pictures of the TCR specification Alfa Romeo Giulietta it is developing for the 2016 season. The team failed in its initial bid to have the car ready to race at the TCR finale in Macau on 22 November, so the Alfa will now undergo testing in Italy in December. Romeo Ferraris hopes to build 10 cars by April 2016, selling them at €98,000 plus data acquisition and taxes

No fastest lap battle in 2016 BTCC

Andrew Charman

LONDON, UK: The British Touring Car Championship has issued its sporting regulations for the 2016 season, with the only significant change being the setting of the grid for the second of each meeting's three races. In the 2015 season this was decided on the basis of fastest laps from race one, which resulted in drivers who had a poor qualifying session, notably Team BMR's Jason Plato, deliberately starting race one from the pit lane on soft-compound tyres so they could circulate away from the race pack and set a faster lap for an improved race two grid position.

In announcing the change of regulation, BTCC series organisers commented that the combination of success ballast and soft tyres, which must be run in one of the three races at each meeting, was adding sufficient variety to race results without needing the fastest lap option.

The BTCC has also issued its list of TOCA BTCC licences (TBLs) for 2016. Introduced in 2014, the TBLs are required for entry into the championship and can be removed by TOCA if a team does not fulfil its appearance requirements during a season – this penalty was handed out to the Support our Paras and Welch Motorsport teams during the 2015 season after both squads failed to field entered second cars in more than one meeting.

TOCA issues a maximum of 30 TBLs and keeps a further two for its own use. Teams had until 30 October to pay their deposit for the 2016 series, with TOCA having previously said applications for any additional TBLs that might become available would only be considered if accompanied by complete details relating to the additional car, driver and funding.

The resultant list of 2016 TBLs has revealed few surprises. Speedworks Motorsport will run a second car having been issued with an additional licence, while the TOCA-held licences have been loaned to Honda Yuasa Racing, which will run a third Civic Type-R, and Support Our Paras Racing for its single Infiniti. Having secured its entry to the 2015 series as part of an Infiniti manufacturer programme, Support our Paras did not possess a TBL to renew for the 2016 season. RT

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MOTION AND MOBILITY

NASCAR tech to keep IndyCars on ground?

Andrew Charman

INDIANAPOLIS, IN: NASCAR-style flaps that will deploy in a spin and keep a car from flipping into the air are likely to be included in a series of technical changes coming to the Verizon IndyCar series in 2016.

The series has been carefully analysing the effect that a car spinning backwards has on the bespoke aerodynamic kits introduced to IndyCar by Honda and Chevrolet in 2015. The urgent study was initiated after three dramatic accidents at Indianapolis in May when Chevrolet-kitted cars took off after spinning.

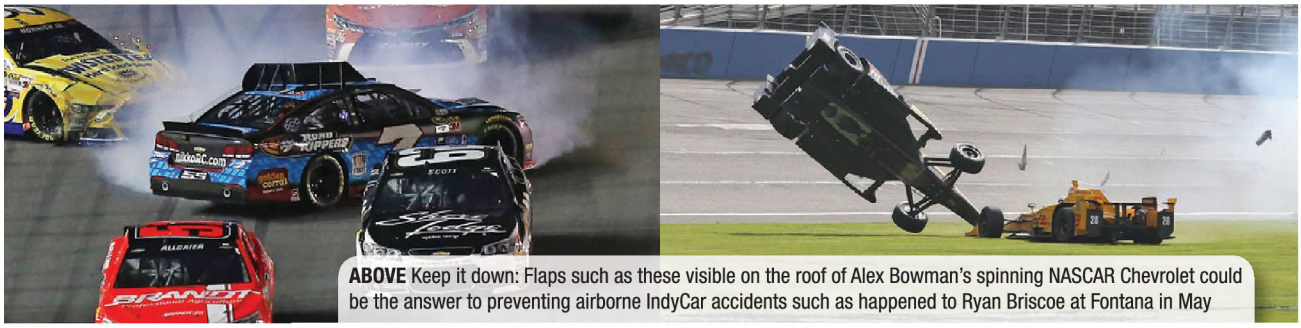
The flaps would be mounted on the lower beam of the rear wing on superspeedway-specification Indycars. Air getting under the leading edge of the flap when a car spun would cause it to deploy and the resultant drag would keep the car on the ground, in similar fashion to the roof and hood flaps that have been part of NASCAR's safety package for some years.

Speaking to motorsports.com in early November following a meeting with team managers, IndyCar's vice president of technology, Englishman Will Phillips, said that research, including wind tunnel tests, was still underway into the flaps to ensure there is no "unintended consequence" of adopting them.

IndyCar is also actively studying the potential for fitting extra cockpit protection following the fatal accident at Pocono in August to British driver Justin Wilson, who was hit on the head by a piece of debris from another car. However, no decision to implement any changes has yet been made.

Turbo boost levels on the 2016 IndyCars are set to increase from 50 to 70 horsepower, while calls by some drivers to add power steering will not be answered next season, though the concept remains under consideration.

• IndyCar will stage an 'aero kit safety test' at the Indianapolis Motor Speedway on 6 April to determine the suitability of aero kit components for the Indianapolis 500 meeting in May, and hopefully avoid the crashes that marred the 2015 event. RT



ABOVE Keep it down: Flaps such as these visible on the roof of Alex Bowman's spinning NASCAR Chevrolet could be the answer to preventing airborne IndyCar accidents such as happened to Ryan Briscoe at Fontana in May

Chevrolet unimpressed with Honda aero break

INDIANAPOLIS, IN: The Verizon IndyCar Series has permitted Honda to make changes to its aerodynamic kits introduced at the start of the 2015 season, to the disappointment of rival Chevrolet. Honda will be allowed to modify elements of the road/street and short oval versions of the kit, but not the superspeedway variant.

IndyCar tested cars with both the Honda and Chevrolet kits in Windshear's rolling-road wind tunnel at Charlotte, and then decided to apply its Aero Kit Rule 9.3, which permits a manufacturer to make changes to its package if there is considered a competitive disadvantage detrimental to the series.

Honda had been lobbying for the aero break after Chevrolet dominated the 2015 season, the first to feature the bespoke kits. Chevrolet-kitted cars headed every grid and won 10 of the series' 16 races, also taking four fifths of all laps led during the season.

Honda will now be permitted to design new components for approval by the series governing body, and once it is determined that the Japanese brand's kit is more competitive with Chevrolet's both manufacturers will be able to submit proposed changes to their kits for the 2016 season, under the series' Rule 9.2.

Reacting to the decision, Chevrolet immediately issued a statement in which its motorsports head Jim Campbell pointed out that all manufacturers had originally received the same set of aero regulations and subsequent updates.

"I am proud of how our Chevrolet engineering team and partners worked continuously for nearly four years to prepare our kit for the optimal combination of downforce, drag and engine performance to give our teams the best opportunity to win poles, races and championships," he said. "The existing rules already allow each manufacturer the opportunity to improve on the performance of their aero kit and engine for 2016. So, we are disappointed in the decision to invoke Rule 9.3." RT

ABOVE Drag factor: Honda has been given the go-ahead to make changes to its 2015 aero kit, here seen on the car of Ryan Hunter-Reay

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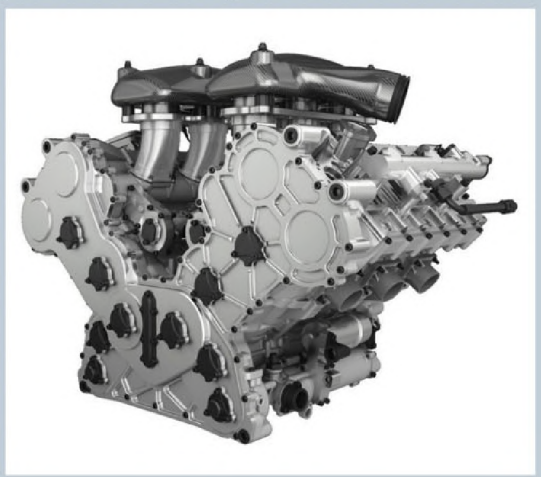

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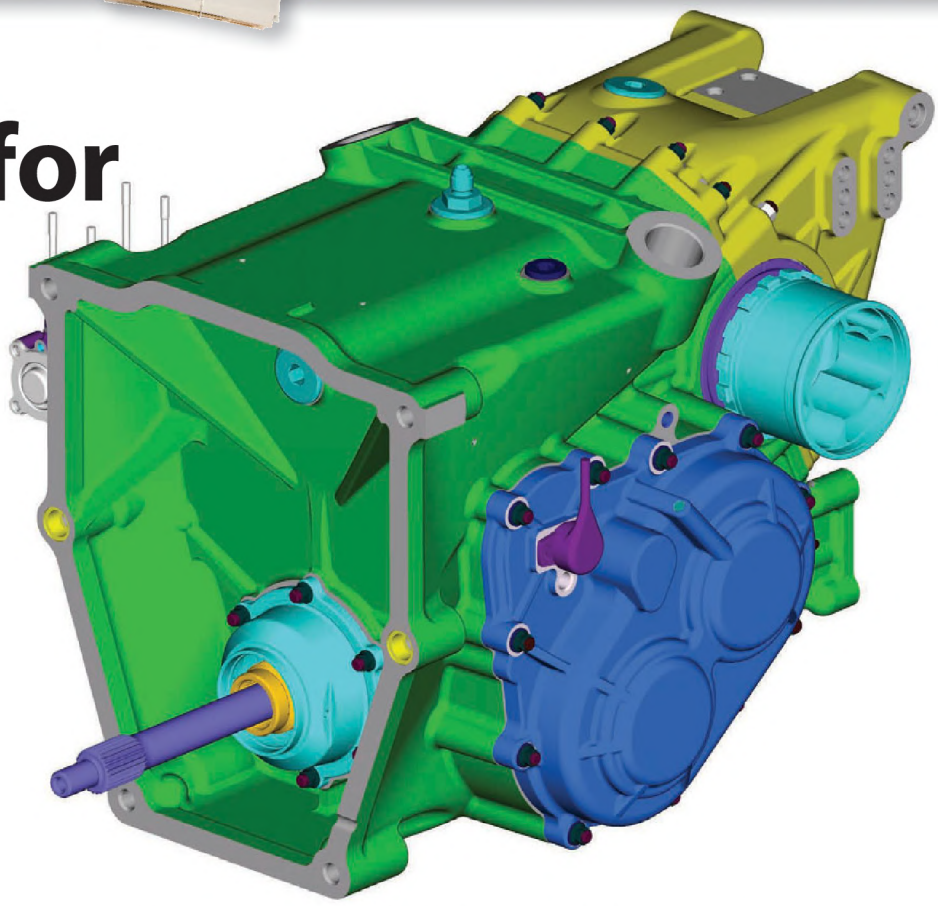


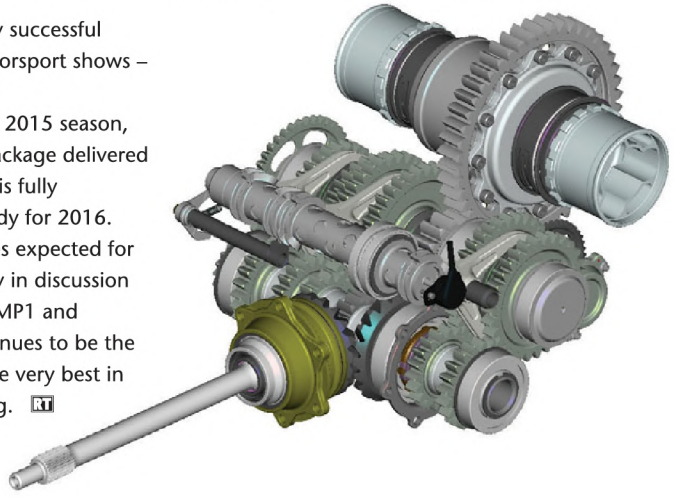
ABOVE & BELOW Following a successful 2015 season, the Ricardo driveline package delivered to Greaves Motorsport is fully optimised and race-ready for 2016

PETERBOROUGH, UK: Fresh from celebrating its European Le Mans Series teams' title, Greaves Motorsport has permitted Ricardo to reveal its role in a transmission and driveline partnership, providing robust, ultra-reliable technology and support to the European Championship winning team.

The partnership between Ricardo and Greaves Motorsport goes back over eight years, with Ricardo being responsible for the design, ongoing development and support throughout the season, for the complete driveline – connecting the clutch to the wheel hubs, and including the transmission, visco-mechanical differential, clutch shaft and drive shafts – of Greaves Motorsport's LMP2 Gibson 015S 2015 championship winning chassis.

"We're really pleased to have helped Greaves Motorsport in their very successful 2015 season," said Ricardo Performance Products managing director Mark Barge. "As with so many of our motorsports customers, the relationship with Greaves Motorsport extends to far more than equipment supply. Ricardo believes in a partnership approach which also extends to our engineers supporting customer teams in both pre-season testing and race weekends as required. It's a model that we have developed and refined over many years, and it's one that – as our highly successful work with Greaves Motorsport shows – is highly effective."

Following a successful 2015 season, the Ricardo driveline package delivered to Greaves Motorsport is fully optimised and race-ready for 2016. With regulation changes expected for 2017, Ricardo is already in discussion with several teams in LMP1 and LMP2 to ensure it continues to be the partner of choice for the very best in endurance circuit racing. RT



High-performance merger powers ahead

BOWLING GREEN, KY: Holley Performance Products has merged with the MSD Group to combine Holley's fuel expertise with MSD's one in ignition, and with Racepak being part of MSD it includes vehicle monitoring and gauges that can be integrated into the Holley system to offer a more complete package for racers.

"We are going to combine our thoughts and technologies for mutual help," said Bill Tichenor, Holley's marketing director. "Fuel injection is super-hot for us. Not only are we supplying the Holley EFI ECU for the spec Ilmor 396 ARCA engine along with the throttle body and Hooker headers, but the National Hot Rod Association (NHRA) has recently announced that it has selected Holley EFI ECUs to power all the Pro Stock teams starting in 2016."

Pro Stock's transition to electronic fuel injection is part of several changes the NHRA is making in an effort to make the class more relevant from a technology standpoint, increase spectator appeal, and enhance the overall pit experience for fans of the 200 mph factory hot rod class. "While the volumes won't be large it's important as it will show how well our fuel injection works to the lower level teams," said Tichenor. RT

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Tech Talk and new tech at Autosport Show

ABOVE The Williams F1 team will be a prominent feature at Autosport International

BIRMINGHAM, UK: New for 2016 in the Trade & Technical is Tech Talk, which, in partnership with *Race Tech* and the Motorsport Industry Association, will host a number of technical talks and Q&A sessions plus seminars and presentations on key areas of motorsport engineering and new technology.

"In addition to witnessing the latest technological developments from the industry, the Trade and Technical area supported by *Race Tech* will host the all-new Tech Talk," said show director Ian France. "Visitors will be able to listen to fascinating talks from representatives from the world's foremost high-performance engineering and motorsport companies."

A major highlight of the show is a tie-up with Williams Martini Racing that brings all of the glamour of a Formula 1 race weekend to the Autosport stage. For the first time ever, the eight-metre-tall Williams Martini Racing motorhome will be constructed away from a race circuit to form part of an all-new Autosport stage, which will be packed full of insightful interviews and features with famous faces from motorsport.

Williams will also be bringing an incredible selection of its most famous Formula 1 cars to the NEC, from the very first Williams-Ford FW06 to this season's Williams-Mercedes FW37. Among them will be the team's greatest ever car, the Williams-Renault FW18, which won 12 of 16 races in the 1996 season. The car will be reunited with driver, Damon Hill OBE, who has recently confirmed his attendance at Autosport International.

Visitors will also get an insight into the world of Williams Advanced Engineering, the division that transfers technology from Formula One to market sectors as diverse as defence and renewable energy.

One of the new cars being launched at the show is the Zenos E10 R. With significantly more power and torque – the turbocharged 2.3-litre Ford EcoBoost engine, which uses a bespoke ECU developed with partner Specialist Components to deliver 40 per cent more power (350 bhp) and 19 per cent more torque (475 Nm/349 lb/ft), it features lighter components and uniquely tuned suspension to deliver maximum performance and driving thrills both on track and on road.

"As the fastest and most focused car we have yet created, the Zenos E10 R is a hugely exciting stage in the development of our company's story," said Mark Edwards, founder and managing director of Zenos Cars. "Thanks to its advanced architecture and natural balance, it was always clear that the E10 could handle even more power than the 'S' offers. Yet it is vital that any new Zenos model features the Zenos hallmark of affordability, and the E10 R is perhaps the most accessible way to join the 500 bhp/tonne car club."

On the product front, Bosch will be unveiling its brand-new MW 7.4 premium engine control unit. The new ECU is based on insights gained from the MS 5 and MS 6 product series and has been designed for high-end touring, monoposto, rally, and long-distance applications. What makes the MS 7.4 ECU so advanced is its ability to integrate engine control, injection power stage units, and data recording in a single device. The central control unit manages fuel injection for engines up to eight cylinders with triple high-pressure injection. In addition it works on engines with up to 12 cylinders with low-pressure injection. With an integrated data logger with dual 4GB capacity, the device eliminates the need for an additional data logger. Within a customer code area (CCA), customers can also run functions they have developed and need for racing.

DMS Technologies will be showcasing its range of lead-acid and lithium-ion batteries for race cars and motorcycle-engined cars. For decades, DMS has supplied the reliable Varley Red Top lead-acid batteries to club and professional racers and this year it will be showing off its newly developed range of lithium batteries. Lithium batteries have become increasingly popular during the past three years as they weigh significantly less than their lead-acid equivalents – a Red Top 30 weighs 10.6 kg while the Li16 weighs in at 3.2 kg.

Old Hall Performance is launching its recently homologated and FIA-approved seat insert – ENER-CORE EC 50 – the first of its kind to meet both driver impact and fire resistance tests. Manufactured using a highly advanced, fire-resistant and self-extinguishing EA urethane foam, the insert has already proven itself at the highest level of motorsport having been used by LMP1 teams at Le Mans this year.

Aero Tech Ltd (ATL) will be celebrating the fact that this year it supplied every winning team at the Le Mans 24 Hours.

Every year Aurora, which offers a complete line of standard rod end and spherical bearings, in addition to designing and manufacturing bespoke products to meet a variety of applications, has an interesting car on its stand that always attracts large crowds, this year it being the LMP3 Riley. RT

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Porsche introduces Cayman GT4 for club racer

BELOW Porsche has developed the Cayman GT4 specifically for the club racer and trackday driver

STUTTGART, Germany: Porsche has added the Cayman GT4 Clubsport for recreational and club racing to its fleet. The 385 hp mid-engine racer for motorsport newcomers, which is not road homologated, is based on the successful street-legal Cayman GT4 sports car. Powered by a 3.8-litre flat-six engine, the racing version exclusively features a modified 6-speed Porsche double clutch transmission with shift paddles on the steering wheel and a mechanical rear-axle locking differential specifically for racing.

The lightweight strut front axle is taken from the 911 GT3 Cup car while at the rear is an enhanced lightweight strut suspension with transverse arms that is also adopted from the 911 GT3 Cup car. The impressively dimensioned racing brake system features 380mm steel brake discs all round. Fitted at the front are one-piece, six-piston aluminium fixed callipers, with a four-piston equivalent at the rear. The anti-lock brake system can be adjusted in twelve stages. The Electronic Stability Programme has been expanded for slicks. The power steering is operated electro-mechanically. Tipping the scales at just 1,300kg, the Cayman GT4 Clubsport is delivered ex-works with a welded-in safety cage, a racing bucket seat as well as a six-point harness. RT

IN BRIEF

GINETTA has released details of the G57, a cost-effective prototype that is eligible for sports car competition across the globe. Comprising a Chevrolet LS3 engine developing 580 bhp, the car features an unrestricted aerodynamic package, delivering some of the quickest lap times for cars of this genre. The Ginetta Prototype has already been accepted for competition in VdeV and various open sports car championships.

PLANS by NASCAR to introduce a 'Charter Programme' to its series in time for the 2016 season are believed to be running into delays. The scheme aims to provide teams with long-term equity, effectively franchising them so that they have tangible assets to sell on to a new investor in the event of losing their financial backing.

Such a situation has occurred this year – Sprint Cup team Michael Waltrip Racing will cease operations at the end of the season after its leading investor, Rob Kauffman, bought into rival team Chip Ganassi Racing.

In September NASCAR announced that it had presented teams with "framework concepts for future qualification to compete in NASCAR's top national series with an eye toward implementing a new model for the 2016 season."

Series organisers have since been negotiating with the Race Team Alliance organisation of team owners, but sources close to the negotiations are indicating that an agreement is still some distance away.

NASCAR officials confiscated the carbon fibre front splitters from the Joe Gibbs Racing cars of Denny Hamlin, Kyle Busch and Carl Edwards before the Sprint Cup Series race at Texas on 8 November, saying that they were too thick for the pre-race inspection gauges. Some observers reported that a resin had been added to change the splitter's shape and allow it to run closer to the track surface. The splitters were later inspected at NASCAR's R&D Centre in Concord but no penalties to the teams resulted.

AERO TEC Laboratories Ltd (ATL), the Milton Keynes based industry leader in safety fuel cells, has recently confirmed a substantial investment in new plastic moulding machinery that allows greater freedom to create FIA certified plastic moulded tanks to custom shapes. The investment will be of particular interest to manufacturers or racing series that do not currently specify an FIA FT3 fuel cell, but would like to increase their level of safety.

IN FURTHER news, ATL is continuing to expand both the workforce and output as demand for its high technology and high-performance products increases. Now a closely knit group of 90 people, a new production bay has been built to house the next batch of cell technicians. The technicians will first complete a one month ATL developed apprenticeship, designed and operated by some of the most experienced ATL team members, before moving on to cell production in earnest.

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MOVE OVER, FORMULA E!

ABOVE Once and future Audi? Maybe Formula H should be low drag, low downforce

What source of energy will motorsport harness a decade from now? **Chris Ellis** says you might not believe it…

I WAS interviewed for the technical director's post at McLaren, way back in 1995. Even then, we spent 15 minutes discussing kinetic energy recovery, and how flywheels might be the best way of achieving it, more than a decade before Williams and Porsche proved it. But we didn't discuss future fuels because it was inconceivable then that we would eventually need to replace petrol. Now, though, we need to start thinking seriously about what the optimum source of energy will be for motorsport a decade from now.

To be clear, it's not because petrol is running out yet, but because it will soon be obvious that hydrogen is the best way of storing energy in heavy duty vehicles and high-performance road cars, and motorsport should promote it to maintain its technical leadership. If you like, Formula H is the obvious successor to Formula E.

California's Electric Car Cult wants us to believe all vehicles will need, eventually, to be powered by batteries. But this appears impossible. In 2013 the University of California published a study which compared the various ways Class 8 (i.e. big) trucks might be powered in future. Battery-only delivery trucks are easy, but long-distance 'big rigs' and coaches are another matter. Typically covering 150,000 miles a year and averaging less than 8 mpg, they consume almost 20% of the road vehicle fuel used in the U.S., and almost all of it is diesel, so they produce a much higher share of emissions.

Here's the technical problem. Prototype battery-powered Class 8s typically need 400 kWh to achieve a range of 120 miles at minimal speeds. Conventional diesel-fuelled versions have a range of 1,000 miles, and cruise on the interstates at around 70 mph. But the prototypes can't run for much more than 90 minutes at freeway speeds before needing to recharge. How long will recharging take? Over three hours, even at the Tesla 'supercharger' rate of 135 kW…

To achieve a range of only 600 miles, probably just enough for a full day's driving, will require some 2,000 kWh. A quick 'sanity check' indicates a battery pack cost (note: not price) of some $350,000, given an optimistic (in any timeframe) cell cost of $150/kWh. At an optimistic cell specific energy of 300 Wh/kg, the pack will probably weigh over eight tons, seriously reducing the cargo capacity and hence profitability of the truck. Simply put, unless there is an amazing breakthrough in battery technology, in terms of both density and cost, big long-distance battery-only trucks are impractical, to put it mildly.

High-performance road cars are just as limited. Mercedes openly admits that the £350,000 SLS Electric can't manage two full laps of the Nordschleife despite the top speed being limited to 155 mph, and despite a 60 kWh battery pack weighing over half a ton. Less than 35 miles flat-out on an autobahn, and that's it? For only 15 minutes? Even a Tesla S fitted with a 90 kWh battery pack is not going to last 25 minutes, and will probably drop into 'safety' mode well before that. Remember, the reason Formula E limits the maximum speed of the cars to 140 mph is to allow 20 minutes of racing before the driver has to swap cars. That won't need to happen in Formula H.

MOTORSPORT SHOULD LEAD

The way to remove the need for carbon-based fuels for trucks is also the most effective way to power high-performance road cars in the future. Consequently, if the 'top-end' of motorsport wants to continue its traditional leadership role, as it is doing with hybrids now, then it needs to understand the logic behind this view, and decide when to move into the lead.

So what is the most promising solution for big trucks, coaches and fast road cars? In a word, hydrogen. Ten years ago, 100 lucky notables got their hands on BMW 7 Series fitted with 6.0-litre V12s capable of running on petrol or liquid hydrogen. The range on hydrogen was up to 125 miles, with 300 more on petrol, i.e. conceptually similar to a plug-in hybrid.

More recently, both Honda and Toyota have started to offer a limited number of hydrogen-only vehicles, using fuel cells as power units rather than engines. Similarly, hydrogen fuel cells are the most probable solution for big trucks.

Formula E was intended to promote electric road cars. I believe it is time to put Formula H into play. An initial step might be to use this magazine to share ideas. I have a few on the design of the first generation of FH cars, but I have been asked to reserve them for later, to avoid seeming obsessive! RT

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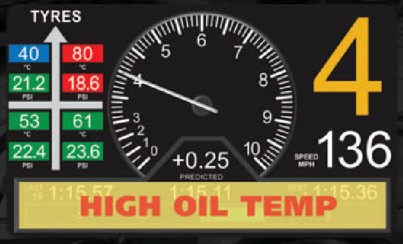

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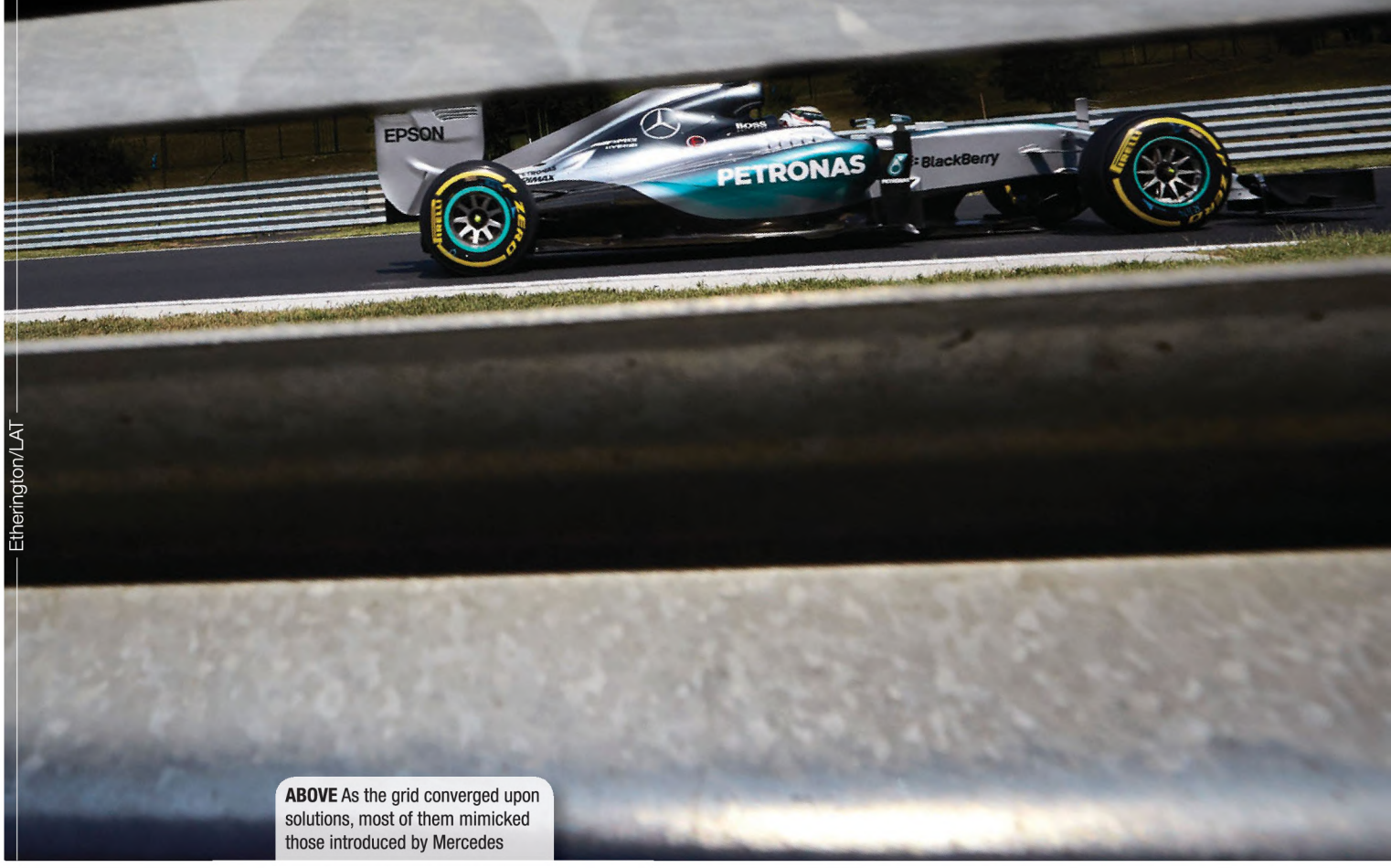
Follow that car!

Craig Scarborough analyses the key trends that marked the second season of Formula 1's new turbo era

THE 2015 season was one which underlined the ferocious pace of Formula 1's arms race. Just one year after the rule-makers hit the 'reset' button, introducing complex new hybrid Power Units and further constrained aerodynamics, most teams had converged on the same ideas. And the majority of them, both chassis and powertrain, had a distinct look of Mercedes about them!

The key trends were finding more power and extending the energy recovered from the fuel flow-restricted 1.6-litre V6 engines. The maturing of the Power Unit also allowed teams to go for higher top speeds with a lower drag set up, which was a crucial factor in shaping changes to the aerodynamics and suspension.



Etherington/LAT

ABOVE As the grid converged upon solutions, most of them mimicked those introduced by Mercedes

POWER GAMES

F1 isn't quite an engine-dominated formula, but certainly the hybrid engines have put some scatter into the performance of each team. Unarguably the Mercedes was the class of the field and Mercedes-powered cars typically occupied the top half of the grid.

Although this was the second year for F1's latest Power Units, the development freeze enforced by the regulations ensured that the lessons learnt from 2014 are only now being applied. What should have been a compressed 2014-2015 winter development period was disrupted by a miss-wording in the 2015 technical regulations, which did not update the homologation date. This opened a window for engine manufacturers to disregard the February 28 date and instead continue to develop throughout the 2015 season, albeit capped by the token system. Thus each manufacturer started the season with updated PUs, but not having used all of their 32-token allowance.

THE BEST GETS BETTER

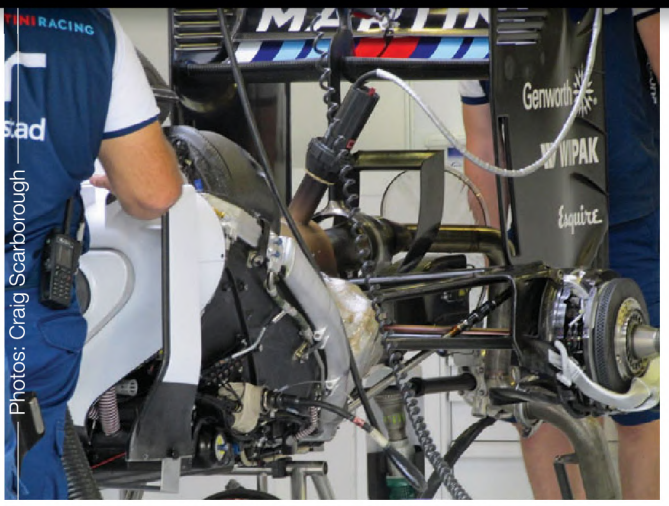
The Mercedes Power Unit had set the standard in the 1.6-litre formula's first season, the Brixworth High Performance Powertrain operation getting its sums and simulations right. Thus the focus on maximum ICE power and MGU-H energy recovery saw the PU outperform its rivals both around a single lap and in the races. Reliability did hamper the team in 2014, so the emphasis over the winter, with a clear performance advantage, was to ensure that reliability problems were covered off. This was an even greater concern for 2015, with the rules limiting each driver to just four Power Units for the season, down from five.

Notwithstanding the token system, the allowance to alter the PU for reliability reasons enabled Mercedes to change most parts of the PU in its quest for dependability. Despite an effectively all-new PU, the package remains visually similar to its predecessor with the large compressor housing mounted ahead of the engine and the turbine behind the V6. The turbine is now fed by a 3-into-1 exhaust rather than the old log-style setup, this change costing a little extra weight from the extra Inconel tubing. Additionally the rules allowed moveable inlet trumpets, thus the inlet system was revised with a far larger carbon fibre plenum.

Even in testing the Power Unit ran like a train: powerful, driveable and totally reliable. Each Mercedes runner completed the 12 days of pre-season testing with a single PU each, accumulating massive mileages. As the season unfolded, the Mercedes PU dominated the top half of the grid. Unsurprisingly, the Mercedes AMG team's implementation was ahead of its customers, departing from the others with its cooling and airbox setup. The factory team exclusively used a water intercooler, sacrificing a few kilos of weight for better thermal management and aerodynamic packaging.

Through the year reliability was almost impeccable, only rare failures occurring to its customers. The permitted reliability and fuel updates aside, it wasn't until Monza that the factory squad expended any of its available tokens on the unit.

The Monza spec was largely an ICE upgrade, a joint project with fuel partner Petronas that brought a new combustion process that



ABOVE Not even Red Bull's threats to quit the sport could secure the supply of the best Power Unit in F1: the Mercedes. Its PU106B is seen here installed in the customer Williams

improved efficiency, providing a little more power, superior fuel economy and better cooling. A water leak on one of the Monza engines in practice was a setback, especially when the old high mileage PU that was put back into the car failed spectacularly in the race. Despite water ingress, the updated PU returned to service and proved to be reliable for the balance of the season.

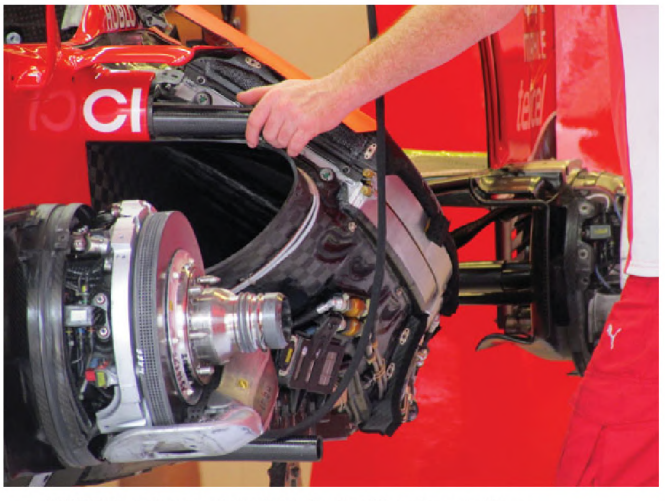
With this step, Mercedes now effectively has its 2016 ICE designed and tested. That leaves winter development to be spent on its turbo and ERS – a worrying thought for rivals playing catch-up.

FERRARI'S RESURGENCE

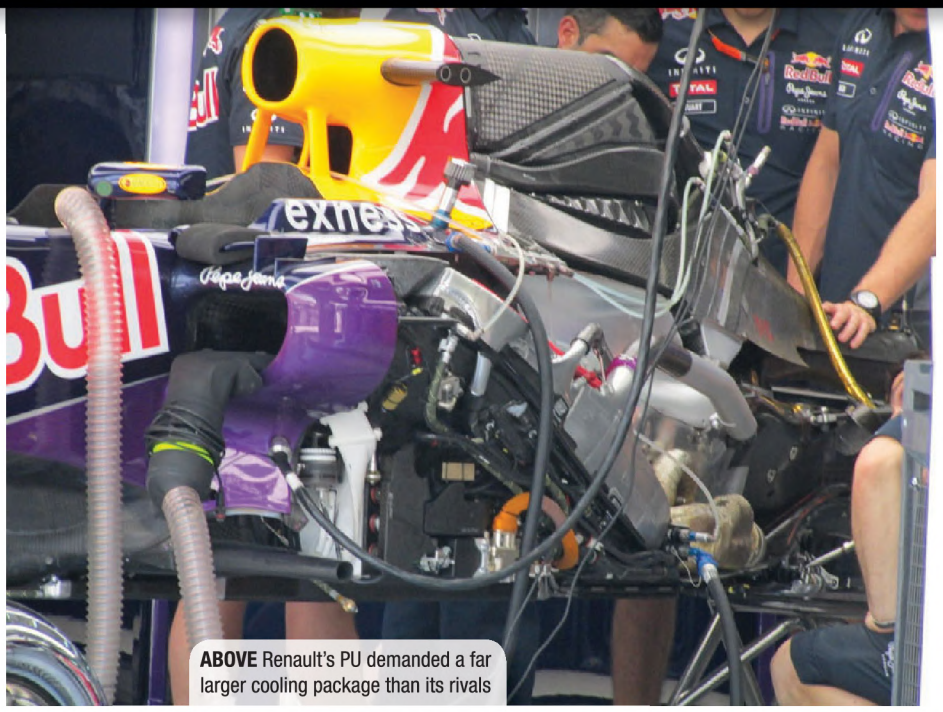
Of those rivals, Ferrari without doubt made the largest step in closing the power deficit. Where paddock wisdom suggested it lagged Mercedes by as much as 50 horsepower in 2014, this season the gap was said to have fluctuated between 5-10 hp.

In 2014 its PU had lacked outright power in a bid to improve its packaging within the chassis. It was handicapped with a small turbo, plus tortuous inlet paths and exhaust routing. The ERS also struggled to recover enough power in race conditions to provide the 160 hp ERS boost every lap. This was an issue caused by the small turbocharger and a wastegate strategy aimed at maximising ICE power rather than energy recovery.

Winter development focused on the turbo and the ERS-H ▶



ABOVE Ferrari was able to downsize its sidepods more than anybody for 2015, its water intercoolers a factor in reducing volume



ABOVE Renault's PU demanded a far larger cooling package than its rivals

attached to it. The compressor was upsized, the exhaust shortened to take a more direct route, and the huge wastegate reduced in size and used far less. The improvement was clear: the peak power and ERS was far closer to the Mercedes. This was despite Ferrari not adopting the variable inlets, the token spend not being used when the existing inlet system and intercooler placement would compromise its setup.

Through the year Ferrari used its remaining tokens wisely. Combustion and turbo modifications, along with token-free fuel updates, brought the Scuderia to within a tiny margin of Mercedes by the season's end. This leaves the PU with a winter development programme targeted at closing the remaining gap still further.

One point on the to-do list is the slimming of its profile for even better chassis packaging. Ferrari uniquely places the MGU-K inline behind the V6 and the Mezzo water intercooler within the vee. While this was initially an effective placement in 2014, a further year of experience with the new Power Units means that the turbo setup can now be revised to maximise engine performance and reduce aero blockage at the rear of the car.

RENAULT EMBARRASSMENT

In contrast to Ferrari's resurgence, Renault commenced testing in a situation almost as bad as it had endured last year. A winter's development had used up fewer tokens than its rivals, and it showed: the new Power Unit lacked power, driveability and, most importantly, reliability.

The fact that the Renault PU demanded a far larger cooling package, especially in terms of turbo intercooling, further handicapped overall performance. The poor reliability in testing slipped over into the first races, with a piston problem causing IC engine failures. A fall-out with the primary customer team, Red Bull, soon ensued and apparent progress with the Power Unit was almost negligible through the year. Not until the 18th race did Renault expend any of its remaining tokens with a combustion upgrade. Although the permitted reliability upgrades solved the worst of the blow-ups, it was only fuel updates that added HP to the V6.

Renault's path from here is clouded by the relationship with its current prime customer, Red Bull, and what may become its eponymous team with the acquisition of Lotus. The fractious relationship with Red Bull was already a problem in 2014. The Milton Keynes-based team set up its own engine department, with a full AVL Schrick chassis dyno, and engaged Mario Illien as a consultant with regard to the Power Unit's problems. These steps were taken despite Renault Sport's own programme being run from Viry Chatillon.

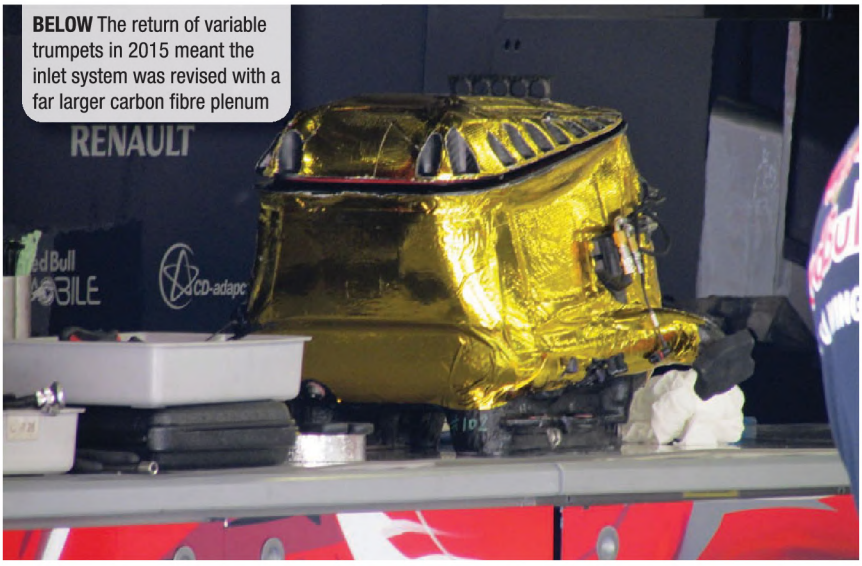
It is believed the Illien work focused on the inlet tract and the combustion area, his experience with the Chevy IndyCar engine having addressed similar combustion issues. The results were presented to Renault, along with a revised inlet plenum and cylinder head setup. Renault is believed to have politely turned down the upgrades and preferred its own developed parts to form the late-season update.

The politics were complicated by Red Bull's mid-season bombshell that it was to split with Renault and seek engines elsewhere. With Renault unsurprisingly keen to follow its own path with Lotus, Red Bull's embarrassment grew as the doors were subsequently slammed shut by every other potential supplier. Ultimately only the option of reverting to a customer Renault engine remained.

Whoever ends up using the 2016 version of the PU will know they will have an excellent ERS, but will be hoping developments to the combustion side of the PU will bring more horsepower and, with it, meet the contradictory requirement of a smaller cooling package.

HONDA HORROR

For all the failures of the Renault 2015 programme, Honda's re-entry to the sport proved to be an unmitigated disaster. Notwithstanding the advantage of a partnership with McLaren, an extra year of development in which to learn lessons from its ▶



BELOW The return of variable trumpets in 2015 meant the inlet system was revised with a far larger carbon fibre plenum

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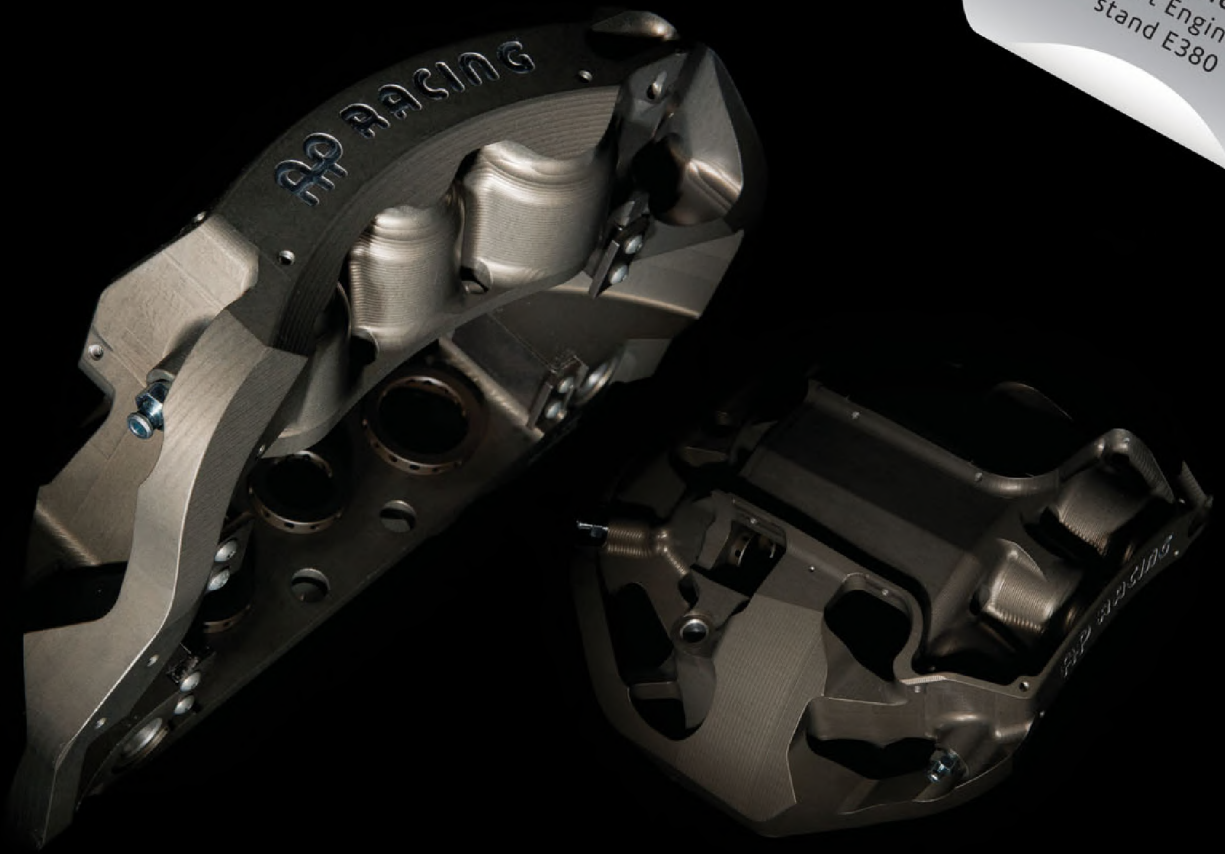

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Honda

ABOVE & LEFT Hammer House of Honda: thermal and mechanical issues afflicted every part of Honda's PU

rivals, and no token restrictions, the resulting PU failed in every area.

Visually, the package looked good. It featured ultra-tight packaging to meet McLaren's 'Size Zero' chassis concept, and took cues from Mercedes with a split turbo setup and log exhausts. But, as with Ferrari last year, the ratio of IC engine power, ERS and chassis packaging was wrong. Horrific unreliability further compounded these issues.

Quite how Honda arrived so under-prepared remains a mystery; the actual issues in the Power Unit are easier explained. In its bid to downsize the package, the losses in the IC engine and ERS far outweighed the potential gain in the chassis. After initial lack of clarity, it transpires that the turbocharger is of a conventional centrifugal design. However, the compressor is tucked into the vee of the engine, thus requiring a smaller diameter in order to fit in the tight confines between the cylinder banks and under the inlet plenum.

The undersized turbo had to spin towards the effective cap of 125,000 RPM to produce its power; this in turn led the high-revving MGU to have thermal issues, exacerbated by it also being inside the vee of the engine. Furthermore, with the small turbo already stretched to provide ICE power, it was hard for the MGU-H to recover enough energy in a wastegate-like mode to extend the ERS's 160 HP boost.

Thermal and mechanical issues afflicted every part of the PU, the McLaren drivers having to endure massive grid penalties from multiple PU component failures. It was soon clear that whether Honda had aimed for reliability or for power, both aspirations had failed, so the Anglo-Japanese project slowly worked to constantly update the PU within the token and reliability limits. Although externally indistinguishable, the PU has seen combustion, MGU and turbo upgrades. Even the exhaust system was changed late in the season for a conventional tubular 3-into-1 format.

It might seem hard to believe, but the intensive work did see the PU catch the leaders on peak IC engine horsepower. But without an ERS that can deliver throughout the lap, the car lacked straightline speed, the battery emptying part of the way along the straight and cutting off the ERS boost.

Honda now needs to look to 2016. It can be argued that the IC engine's poor performance, if not reliability, is resolved. The turbo sizing and MGU-H issues need to be sorted within the limited token spend allowed, so there is light at the end of the tunnel.

CHASSIS & AERO

An engine formula? That might be a common perception, but comparing customer Mercedes runners to factory cars from other teams reveals that chassis performance is still a primary factor in competitiveness.

The lead taken by Mercedes has been even more marked on the chassis side of the car than it has the engine. Despite a wind tunnel/CFD cap, the chassis is unconstrained by the same rigid development restrictions as the PU. Theoretically, a team could still bring a completely new chassis and aero to every race if it had the resources to do so.

The 2014 Power Unit regulations had been accompanied by new aero rules, with a narrower front wing, nose revisions, and no rear beam wing. How the new Power Units would cope with the fuel flow restriction on the straights was a big factor in deciding aero setup: many thought power would be capped, so higher drag would not be a penalty, as speed would be lower anyway. A few, however, realised that low drag could be exploited for the straights and that the PU wouldn't be a handicap to high top speeds. A year of experience proved the latter to be the case.

For 2015 most teams ran less overall drag. The nature of most tracks – with the exception of Canada, Spa and Monza – did see cars near the upper end of their downforce range, but it was the quest for lower-drag setups that shaped aero development.

2015 also brought yet more nose regulation changes, 2014 rules having resulted in long finger-shaped solutions rather than attractive wedge-shaped noses. Regulations were reworded to add an extra minimum cross-sectional area 100 mm behind that enforced for 2014. The trade-off in design was meeting a rigorous crash test and the effect on aerodynamics. A short nose has aero advantages in reducing blockage to the rear of the car, but also in not upsetting airflow over the centre of the front wing. Getting a short nose to work requires its structure to follow the FIA impact test deceleration targets incredibly accurately.

Most technical directors will suggest the nose is largely a visual thing and that relatively little performance can be gained out of it. But several teams sought to develop and crash test a new shorter nose through the year, indicating there is still a worthwhile, if finite, gain to be had from bringing its length back to the minimum possible within the rules.

With this shorter setup, the choice then became one of how you distributed the mandatory cross-sectional areas, either wide/flat or tall/thin. Furthermore, the 100 mm gap between these two cross-sections could either be streamlined or left as a step, creating a short fat thumb extending as the nose tip. Once the nose is short, the difference between these formats appeared to have very little performance impact.

Mercedes opted for a short, streamlined, ▶

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tall and thin nose, along with Lotus. The others in the 'short' camp followed the wide, flat nose with a stepped tip. These included Williams, Red Bull, Toro Rosso and Manor.

Ferrari and McLaren both initially opted for very long noses. McLaren switched mid-season to a wide, stepped nose, leaving Ferrari soldiering on with a long nose. The Scuderia appeared unperturbed to be in that unique position.

Force India provided a rare true innovation with its Silverstone update. Unable to invest the resources into crash testing a very short structure, but wanting the aero gain of the short shape, it instead invented its mid-length nose. Two 'nostrils' were made into the structure, cleverly shaped to meet the single open section rules. This appeared to be a cost-effective solution.

Now in their second year, the narrower front wings had to meet the lower drag and downforce targets for the preferred aero setups. Like any front wing, its function is merely to balance the downforce created at the rear of the car, but even with the 15 cm span reduction, the current F1 front wing is easily capable of producing enough downforce. So their design is largely focused on controlling airflow back along the car and in particular managing front tyre wake. Thus most of the front wing detail is about directing airflow around the front tyre, in order to improve flow at the rear, effectively moving the centre of pressure rearward to allow less rear wing for a given downforce level.

ABOVE & BELOW Where Mercedes led, with its outswept front wing, the likes of Ferrari (below) followed. The grey colour seen on the W06 is silicone spray to prevent debris sticking to the wing

Where 2014 yielded aggressive front wing endplates to turn the airflow out around the tyre, this year saw a revision to the same function, but sacrificing effective front wingspan in the process. As the wingspan is not required wholly for downforce, the leading edge of the wing is narrowed and then the wing expands in plan view. The resulting outswept wing tip performs the airflow redirection, allowing the endplate to be far simpler. This creates a lower drag implementation of the same effect as an aggressively twisted endplate.

Mercedes led the field in this respect, the narrower leading edge wing then augmented with a stepped profile to the outer span of the wing. Airflow passing under the stepped section is pulled into a strong vortex, which further acts to direct airflow around the front tyre.

Ferrari soon followed this direction, albeit less aggressive in the stepped shaping. Subsequently, by Austin, nearly every team with budget to spend had this format of front wing.

Despite ongoing battles with the FIA, the teams find ways to exploit front wing deflection for aero benefit. Nevertheless, front wing deflection testing was limited to a vertical load on the endplate to see if the wing bends span-wise in beam or torsion. This left the flaps free for exploitation, a point highlighted by Red Bull's flexible/sprung adjuster mechanism caught by the FIA at the last race of 2014.

A flap deflection test was introduced for the Spanish GP, aimed at preventing the front flaps backing off at speed. By the season's end, though, it was clear from the onboard cameras that flaps were easily deflecting ▶

ABOVE As the rest of the field converged on nose concepts, Force India came up with its innovative 'nostril' solution

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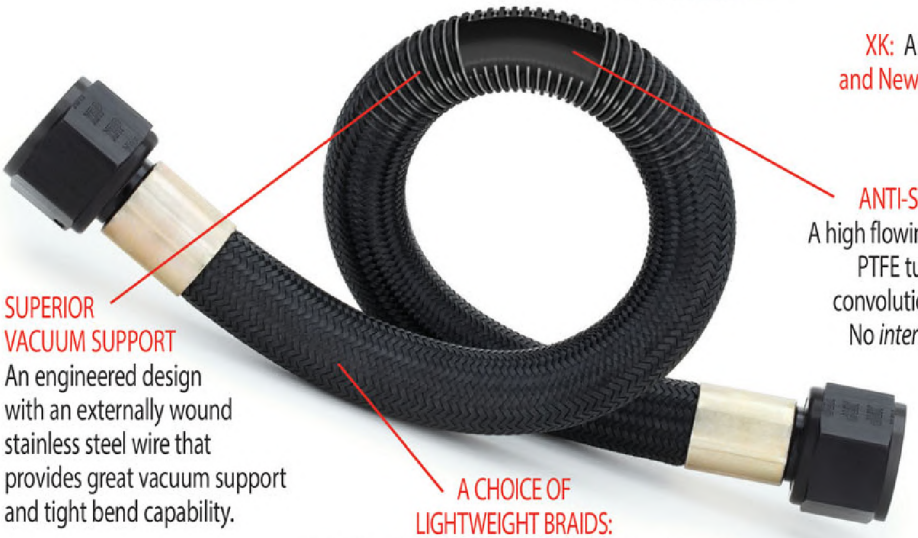

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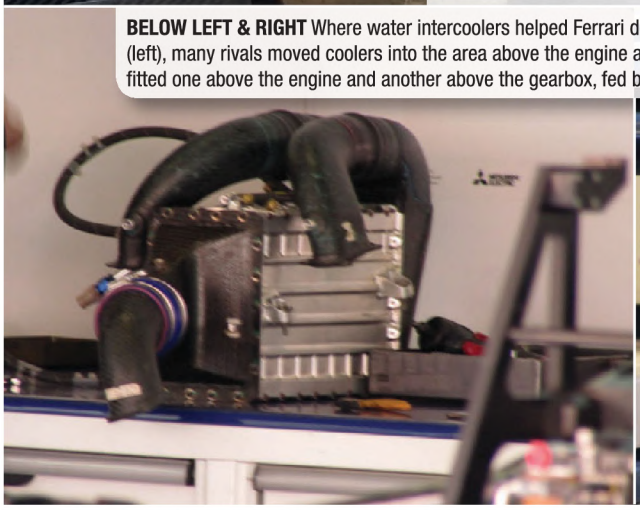
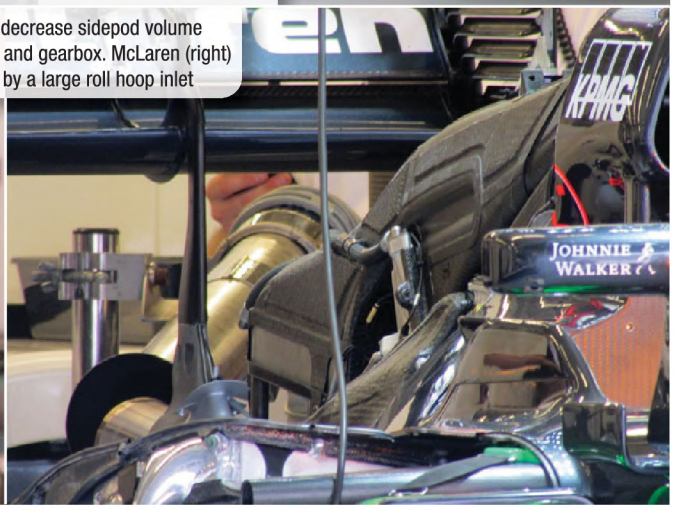
THE XTREME IN RACECAR PLUMBING

ABOVE Merc's efforts to harness the Y250 vortex with a bat wing and turning vanes were copied down the grid





BELOW LEFT & RIGHT Where water intercoolers helped Ferrari decrease sidepod volume (left), many rivals moved coolers into the area above the engine and gearbox. McLaren (right) fitted one above the engine and another above the gearbox, fed by a large roll hoop inlet

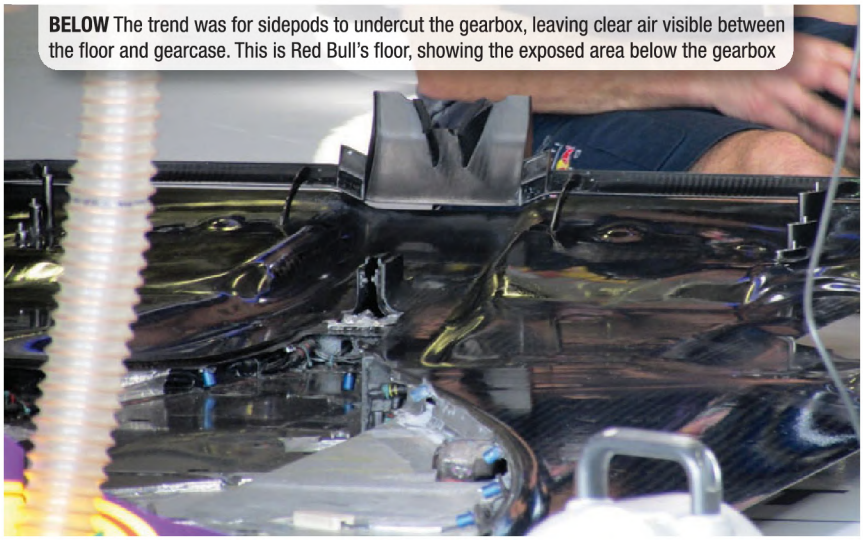
as speeds increased, to the order of tens of millimetres. At the time of writing, this was not acted upon by the FIA.

Another function for the front wing is to create a vortex effect at its inboard end: the inner flap shape, where the wing meets the neutral centre profile, is kicked up to create a flow structure along the so-called Y250 axis (250 mm from the car's centreline). This vortex, created at the inner wing tip, then sweeps out around the sidepod fronts before diminishing ahead of the rear tyres. The Y250 vortex keeps the front tyre wake from affecting the central bodywork of the car and being sucked in to between the rear tyres. As a result we saw most teams work this inner area of flaps into aggressive rounded shapes, to better induce the vortex.

The other device that works on the Y250 vortex is the turning vanes under the nose of the car. Up until this year their shape was commonly a couple of hanging vanes each side of the car. To better reduce drag from the working of the Y250 flow, they are being worked ever harder. Mercedes already had a complex setup in 2014, with four element vanes joined by a wide footplate along their bottoms, allied to a small bat-shape wing mounted behind them. The upturned wing worked with the vanes to set up more vortices along the Y250 axis.

Through the year most teams adopted three- or four-vane setups with wide footplates adjoining them. For Austin Ferrari even copied the Mercedes vane and bat wing shape, having followed a simpler vane setup up until then.

For all teams the cooling set-up of the cars has been progressing since the introduction of the complex new power units. Many had worked hard to downsize the sidepod volume, both through detail design and with the engine manufacturers decreasing the heat rejection of the PU. Water intercoolers remained a good way of managing turbo charge temperatures and decreasing sidepod volume, but only the Ferrari-engined teams and the Mercedes AMG squad exploited this setup in 2015. ▶



BELOW The trend was for sidepods to undercut the gearbox, leaving clear air visible between the floor and gearcase. This is Red Bull's floor, showing the exposed area below the gearbox

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For most other teams moving some coolers into the area above the engine and gearbox was the next best solution. Trading rear wing airflow for diffuser airflow, the diffuser being the less draggy means to achieve downforce meant it was a compromise worth accepting.

McLaren fitted two large coolers in this area, one above the engine and one above the gearbox fed by a large roll hoop inlet. Toro Rosso continued to fit a large oil cooler in between the roll hoop and inlet plenum, this year's cooler being even larger and formed in an inverted "V" shape.

Ferrari found greater gains by micro-managing the airflow through the radiators in the sidepods, fitting louvres to divert the airflow 90 degrees as it passed from radiator duct to the radiator and back out again. Arguably Ferrari had downsized its sidepods the most for 2015, even further reducing the shape by Monaco once the early hot flyaway races were completed.

Tightly-waisted sidepods have been a design goal for many years for F1's aerodynamicists. This season the second-generation gearboxes, aided by the mandatory high crankshaft axis on the V6, had the sidepods undercut the gearbox, with clear air being visible between the floor and gearcase. This aided airflow towards the diffuser

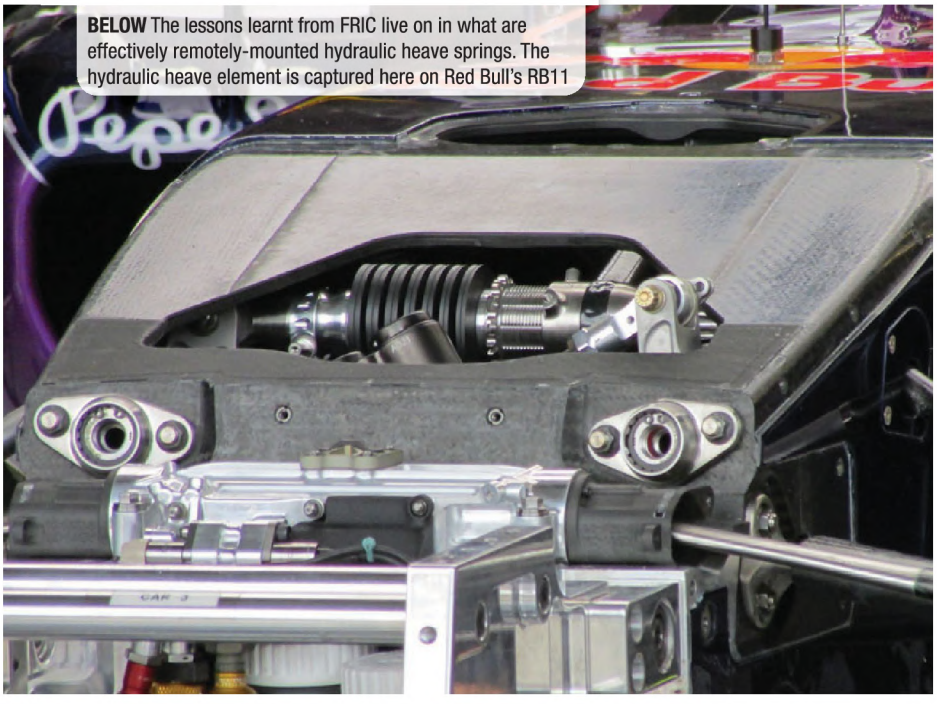
Opening up the floor was another key area of development, albeit in the area ahead of the rear tyres. It has long been understood how airflow spills off the tyres and passes laterally into the diffuser, choking its performance. This effect, known as 'tyre squirt', has been offset by slots made in the floor in the area around the tyre.

ABOVE McLaren's tour de force of floor slots, designed to counteract tyre squirt

Most teams have a single or twin slot to feed air from above the floor to below, blowing along the inner face of the tyres in order to counteract any tyre squirt. McLaren first upped the ante, with a four-slot design, only for Ferrari to fit eight slots along the floor's edge and a further two at the rear corner of the floor. Working on the basis that more of anything is better, this concept drew admiring glances from rivals. Just a few races later McLaren took the concept further with 11 edge slots and two corner slots, some 13 in all!

Rear tyre squirt issues have become ever more important as teams add rake to the car's setup, pushing the nose lower and the rear higher. This makes the front wing work better in ground effect and the entire floor act as the diffuser, effectively increasing diffuser height normally limited to just 125 mm above the floor.

Controlling the airflow with a diffuser now running at some 10-15 cm of rear ride height and preventing the front splitter grinding along the track is a task for suspension. The passive front to rear interconnected suspension systems (FRIC) had been enjoyed up until being banned at the German GP last year. But the lessons learnt from FRIC have now led to what are effectively remotely-mounted hydraulic heave springs, no longer connected front to rear, but still useful for controlling ride height at each end of the car independent of roll stiffness.



BELOW The lessons learnt from FRIC live on in what are effectively remotely-mounted hydraulic heave springs. The hydraulic heave element is captured here on Red Bull's RB11

It can be clearly seen from onboard shots that the Mercedes AMG car rolls with quite a soft spring rate, but in heave is near-solid, no appreciable dive being evident from the coil and hydraulically-sprung front end. Most teams either had or have implemented just such passive unconnected systems, along with heave, roll and individual wheel control by a combination of hydraulics, dampers, springs and inerters. Suspension is becoming hugely complex and supports the case for a return to a simple programmable active system using homologated components.

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TEAM BY TEAM

MERCEDES

Dominant in 2014, with good team stability and resources, Mercedes AMG always looked likely to live up to its billing as title favourites. Such was the pace advantage last year, no risks needed to be taken. The team already led in most areas of car design anyway.

The W06 as it was launched was all-new, but tied very closely to the concepts of its predecessor. It was soon clear that no mistakes had been made. The car was quick and development progressed cautiously throughout the year. It could be said that visually development was low key, but still the car had a clear gap to its rivals.

Despite its pace, Mercedes packages the car into an unusually short wheelbase, often considered bad for aero. Conventional wisdom is that the Power Unit is handicapped having its ancillaries ahead of the engine, forcing a long fuel tank, moving the engine's bulk back along the wheelbase. Yet the car works in all areas: traction and braking; fast corners and slow turns; there is little to be seen as a weakness in vehicle performance.

Going into the season, you could perhaps point to the car's low-drag setup making it hard to run maximum downforce for street circuits; or to the fact that braking performance was on the limit. But both of these weaknesses were addressed during the year.

Once again the team finds itself ending the season in a position of dominance. With preparations already well advanced for 2016, the signs are ominous for its rivals.

FERRARI

The most improved team in 2015, the winter marked a resurrection for a squad recovering from a 2014 campaign that had disintegrated as it went on. Both chassis and Power Unit failings were honestly accepted and resolved, paving the way for a season where progress on track was made at every opportunity.

The Power Unit is not quite the match of Mercedes, while the chassis still lags behind both the champions and Red Bull, but the margins are now much smaller. With its more effective car and happier management, Ferrari struck whenever Mercedes was handicapped by conditions or race strategy errors.

The next gains needed to catch Mercedes will be smaller than before, but no less difficult to achieve. All indications are that Ferrari should continue this improvement curve and get closer to Mercedes in 2016.

WILLIAMS

Having got its simulations right for 2014, Williams found its advantage eroded in 2015 as other teams caught on to its low-drag advantage. The margin was no greater to Mercedes than the year before, it's just that Ferrari was able to step into that gap by improving over the winter aerodynamically and, perhaps more significantly, with a vastly improved power unit.

The car still lacks some low speed performance. Steps were taken to improve its rear end instability from 2014, which the drivers declared as an improvement. Tyre management was tricky and wet weather pace was lacking until addressed later in the season. Thus stronger race results were lost from a lack of sheer pace and, occasionally, questionable strategy calls. Williams needs to make a step over the winter to avoid falling behind.

RED BULL

Red Bull entered the season a very different team: Adrian Newey was now focused on wider Red Bull Technologies projects, Sebastian Vettel had departed for Ferrari, and even the race team was restructured and re-staffed. This instability, allied to Renault's failure to get on top of its engine programme, meant that the first part of the season was a huge disappointment by Red Bull's usual standards.

Underpowered, but also unexpectedly lacking chassis performance, the RB11 was often outpaced by the similarly-engined Toro Rossos in the first part of the season. It wasn't until the Silverstone race that the car's development caught up with its sister squad.

Admittedly, the engine was still under-achieving, but the team's future was risked by its management's increasingly petulant dealings with Renault. That approach cost it opportunities when it was seeking an alternative supply for 2016.

BELOW Ferrari's close-season overhaul meant it replaced Red Bull as Merc's main rival, able to steal opportunistic victories

ABOVE In a season where the shortcomings of the Renault engine were laid bare – in more ways than one, at Monza – Toro Rosso often outshone its Red Bull parent team

BELOW Williams punched well above its weight for a second successive season

Williams F1/LAT

FORCE INDIA

The team's struggles towards the second half of the 2014 season were identified as relating largely to the shortcomings of its wind tunnel. Therefore the bold move was taken to stop development in its Brackley tunnel and move aero testing to Toyota's Cologne facility. This held up true development of the 2015 car, while the programme to create a B-spec design was readied for Silverstone.

Design echoed many Red Bull ideas, partly from key recruits into the aero department from the Milton Keynes-based team. From this point on, the car's performance was turned around; further developments kept coming and, crucially, kept delivering their expected gains.

With things on the engineering side looking positive for the future, Force India's next step will be to commit to a 60% scale model to fully exploit the Toyota tunnel.

LOTUS

Continuing to function on shaky ground financially, the team's technical development has taken a hit.

Winter development turned the awkward-handling twin-tusk 2014 car into a far better balanced chassis, now fitted with a Mercedes PU. But development stalled almost as soon as the season started, a reworked engine cover and revised front wing being the key updates through the campaign.

A year of great potential was wasted. Only stability in the team's ownership and funding will start the recovery

TORO ROSSO

Not normally given sufficient credit for its independent design spirit, Toro Rosso seized its first real opportunity to eclipse the factory Red Bull team. The STR10 shared the same power unit and gear cluster as the RB11, but despite lesser resources, fairly outpaced the parent team as well some other rivals.

Led by James Key, the team kept making the right developments, although perhaps budget and the inexperience of its drivers prevented what could have been an even stronger end to the season. As with Red Bull, a huge amount of uncertainty surrounded the 2016 programme as we closed for press. The choice of engine deal – which looked likely to involve the use of a year-old Ferrari unit – is critical to its bid to maintain momentum.

SAUBER

Bereft of funds, Sauber still managed to start the season incredibly well. Its giant-killing feats were aided by the far-improved Ferrari engine, fitted to a reworked version of the inherently good 2014 chassis. But with key technical staff having left the team and no development budget, the car was not improved until late in the season. By then the advantage to the rest of the midfield had been lost.

McLAREN

There was talk ahead of 2015 that McLaren and Honda could have a huge advantage, with their extra year of development. The chassis and PU looked the part, but looks were deceiving.

Even from initial testing the chassis and PU didn't pair well, with a near total lack of running. Pre-season testing continued the same theme and as the year unfolded, the package simply didn't deliver.

Honda's woes are well-documented and well deserved; however McLaren's chassis problems have been masked by the PU's shortcomings. Despite the potential in the 'size zero' aero concept, the gains are not obvious. With ex-Red Bull aero man Pete Prodromou onboard, the chassis was updated at nearly every race, yet even if fitted with a Mercedes PU it's unlikely the car would be the class of the field. There's a lot of work to do at Sakura and Woking over the winter to bring a step change to the chassis and PU.

MANOR

It's a miracle that Manor made it through the season at all. At one point much of the hardware needed for 2015 was up for auction and only a last-minute reprieve got the parts back to the team to prepare for its first race.

As it transpired, it didn't actually race at Melbourne because the cars sat in the garage without software to run the power unit. With a year-old Ferrari engine mated to a 2014 chassis, updates to the launch spec of the car were simply to make the nosecone legal for the revised rules.

It remained this way until Silverstone when a major aero update was fitted. There was a plan for a pukka 2015 car to be built by mid-season, in order to fit the latest Ferrari engine. But with Mercedes Power Units signed up for 2016, another new chassis would be needed and it was pragmatic to put off the expenditure until the winter.

Be careful what you wish for

PART 1

IndyCar released the aerodynamics genie from its bottle this season. Aerodynamicist **Mark Handford** delivers his verdict, assessing IndyCar past, present and future

Bret Kelley/IndyCar

ABOVE The Indy 500 remains the jewel in IndyCar's crown. Without it, the series would be long gone

BACK in 1978, Indy cars came to the UK. They raced at Silverstone and Brands Hatch. They smashed the lap record at Silverstone and set staggering lap times around Brands' low-grip club circuit, which was forever after the "Indy" circuit. At 900 horsepower, the methanol-burning, turbocharged monsters had way more power than tyre. And, together with rudimentary aerodynamics, staggering power-to-weight ratios and elegant simplicity, they set about doing what motorsport did best: they entertained.

They did this with a spectacle of noise, speed, skill and mechanical uncertainty. The drivers were accessible, articulate and yet uncomplicated. The cars were, perhaps, exotic (and perhaps not) but they were certainly brutally powerful; fundamentally straightforward, yet beguiling. They made the UK national news, were all over the TV and were a great advert for American motorsport. To me, a local 18-year-old, it was all summed up in one word: fantastic!

And then they left…

At that point in time Formula 1 wasn't the behemoth that it now is and there was no doubt that IndyCar was "there". It was "there" right on the top step of open-wheeled motorsport and standing squarely alongside F1. After all, F1 was, well… just one of several other FIA/European racing formulae, with F2 and F3 representing sibling series and creating a well-defined feeder system.

Post-1978, F1 went (largely) from strength to strength with just a few hiccups. It remained true in its pursuit of the right blend of technical wizardry, driver excellence, celebrity culture, trackside spectacle and media-savvy television and marketing. All of this was possible because of the power of TV (and Bernie Ecclestone).

But, for IndyCar, clearly something went wrong. Well, actually, an awful lot went wrong: it short-changed its parents; ran away from home; got giddy on success; endured a messy divorce; lost a lot of friends; went bust; remarried; blundered around and almost 'checked-out' entirely.

The financial crash of 2008 was particularly unkind to a fading IndyCar Series. The fact there *is* an IndyCar in 2015 is testament to the brand and probably the globally-recognised, blue riband event: the Indy 500. Without those two things, IndyCar would surely have met its maker.

Somewhere in the middle of all that, for over 10 years I was able to take a break from F1 and be in the thick of it with Newman/Haas Racing, helping to develop the team's Lolas and then designing, from scratch, the Swift Indy cars. Those were exciting times and working with the IndyCar technical director, Kirk Russell, I also did my best to help steer the aerodynamic regulations in a way that responded to the need to trim top speeds and contain performance.

Easy, you might say, but sadly not so. The Firestone/Goodyear tyre war and the Mercedes, Ford, Honda and Toyota engine war were things we couldn't control. We couldn't control them because they were also our paymasters. But the car constructors were being paid to supply cars, so the obvious target was to hobble the cars when needed (mainly for the banked superspeedway events).

So we tackled the aerodynamics, detuning the cars in an incremental manner (over several seasons) using, as our tools: underbody changes; tunnel-fillers; and agreeing to ever-smaller 'regulation-boxes' (for the wing sizes). All of which were needed to offset the engine and tyre gains, along with aerodynamic developments realised via 500+ hours/year of tunnel testing and the ability to fund the design and manufacture of a new chassis each year. As part of those steps I became associated with the eponymous 'Handford Device'.

In itself, the Handford Device was just part of a sequence of events which began almost a year before Mauricio Gugelmin's record 241 mph pole for the 1997 race at Fontana Speedway. Reynard (well, PacWest) achieved that 241 mph feat by building a special narrow-track car. You could say that we were gutted by that speed. I was at Swift at the time and we had worked with CART to create a triangular-shaped tunnel-blocker that bolted up into the

ABOVE Nigel Mansell leads Jacques Villeneuve on the banking in 1994 in the midst of IndyCar's own 'space race'. An era of open competition spawned a series that stood toe-to-toe with F1

About the writer

DR MARK HANDFORD has amassed a wealth of experience as an aerodynamicist in a 30-year career spanning all of motorsport's top categories: Formula 1, NASCAR, IndyCar and sportscar racing.

Rolls-Royce sponsored him through his first degree at Southampton University. He then spent four years studying at Imperial College, London, and was awarded a PhD for turbulence modelling.

He cut his teeth in F1 in 1985 with the Beatrice Haas project running Ford V6 turbo power. In 1987 he joined Tyrrell F1 and in 1990 became Chief Aerodynamicist at Benetton F1. In 1992 he was re-hired by Carl Haas at the same time as Nigel Mansell defected, as World Formula 1 Champion, to IndyCar with Newman/Haas Racing (NHR).

Over the next eight years he developed the aerodynamics of the NHR Lola chassis and moved to California in 1996 to design the all-new Swift Indycar which won its maiden race in the hands of Michael Andretti. He returned to the UK in 2000 and became Chief Aerodynamicist of Jaguar F1 under team principal Bobby Rahal.

For the last 12 years he has been with Multimatic where projects have included collaboration on NASCAR, LMP1, F1, IndyCar and, more recently, the 2016 Ford GT Le Mans project.

exit of the underbody to act as a throttle.

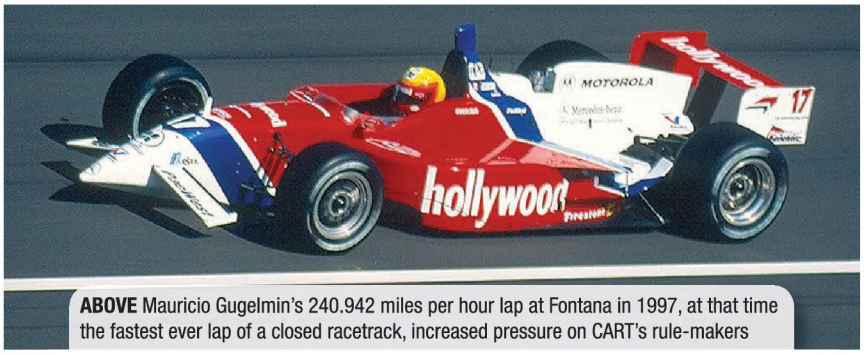
The intent had been to restrict the ability to dump underbody flow, raising the underbody pressure (reducing suction and thus downforce). We expected the cars to be run with more rear wing to create the necessary grip and since that was draggier than underbody downforce, we felt confident that speeds would be clipped.

Clearly we had underestimated the scale of the change needed (and, as it turned out, an inventive interpretation of the rules by Reynard that allowed them to reduce the size of the blocker). This was all happening behind the scenes with almost no media awareness. It was a side story that had merit but one that was barely picked up – it didn't need to be, because there was so much else for the media to focus on.

In response to Gugelmin's speed, and at Kirk's request, I worked along with my assistant Jon Tomlinson (now Head of Aerodynamics at Lotus F1) to identify a means to trim the downforce. Our target was to ensure that, through the banked turns, the cars would be grip-limited – but only just. We aimed for a 100 hp surplus in engine power throughout the period the car remained grip-limited so that there was 'something' left underneath the driver's right foot (but not a landmine). And, we aimed to add drag. In fact we aimed to add a lot of drag, almost 100 hp worth of it. In short, we set about creating a boat anchor!

Strangely enough it was less easy than you might think because as soon as you remove downforce, you also remove a lot of drag. ▶

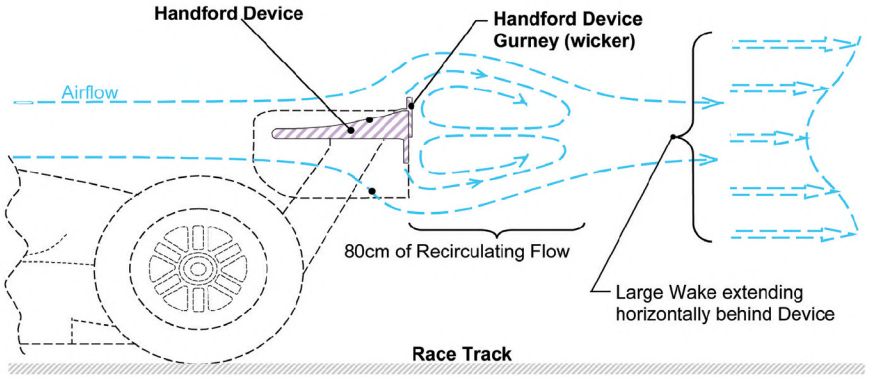
ABOVE It's 1978. Al Unser Sr, Rick Mears and Danny Ongais thunder through Paddock Bend. Brands Hatch was never the same again…



ABOVE Mauricio Gugelmin's 240.942 miles per hour lap at Fontana in 1997, at that time the fastest ever lap of a closed racetrack, increased pressure on CART's rule-makers

So we were in uncharted territory trying to do the exact opposite of what we'd spent years pursuing. But our aim was simple: the cars would need a driver to get around the corners, not a pilot, and they wouldn't reach such extreme speeds on the straights either.

To achieve the overall vehicle aerodynamic targets the Handford Device itself (wholly inadvertently) created zero lift and zero downforce but lots of drag. And the consequence of that was that there was neither upwash nor downwash. The wake of the Handford Device (basically a flat plate with a fairing on the front) remained at precisely the height above track of the device itself, which was to trigger a profoundly awkward side-effect. Nevertheless, at the time, it wasn't even called the Handford Device. Due to its similarity with a wedge of cheese, we actually had a test-bench full of parts that got dubbed 'Gorgonzola', 'Cheddar' and even 'Wensleydale'. We were the big-cheese makers!



ABOVE The Handford Device was introduced by CART for Superspeedway events. Its curved upper surface gave the appearance of a wing; the flat rear surface allowed space for sponsors. The large lower lip caused the lower surface flow to curve downwards, where it would curve upwards on a normal wing. The result was much higher pressure than underneath a normal wing, almost eliminating any downforce from the device whilst creating a large amount of drag. A secondary result was that it created neither upwash nor downwash so the wake remained at a constant height about the racetrack's surface – reducing the drag of a following car

As regards the Handford Device, the rest is history because Kirk decided our rather unimaginatively-named 'parachute wing' wasn't the best of tags to aid sales and marketing. Instead, he announced it to the world using my name – albeit with the best of intentions. The persistence of the powerful wake (just above track level) resulted in slingshot racing that wasn't our intent at all. Things got even more out of hand when we got involved in derivatives applicable to short ovals.

However, the thing is, life was exciting because there was change. Like Darwin's theory of evolution, the winners were those that adapted and changed the fastest. You could perhaps argue that there was much change that wasn't capitalised on, and perhaps that was wasteful, but in the late 1990s there was plenty of money to fund such a pace of change. There were literally scores of engineers working for Lola, Reynard, Swift and AAR (All American Racers) developing and evolving just the chassis and aerodynamics. Elsewhere, there were similar efforts being made on the engines at Cosworth, Ilmor, HPD and TRD.

It made for a development feast not dissimilar to F1. There was plenty of meat on the bone for the media to chew upon and much cat-and-mouse at the racetrack to hide new pieces. All the time, the more tech-savvy journalists could chase down a technical story. The fact that they could nearly all find a novel angle was indicative of the sheer diversity of development. ▶

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FEAST TURNS TO FAMINE

Then the CART/IRL divorce began to bite. Not enough value was being generated to move the TV coverage forward. The engine manufacturers were either driven away by cost escalation or lured away by the more global reach of F1. Goodyear retired hurt and rapidly the feast turned to famine. I departed back to F1 and then to Multimatic's broad base of motorsports activities, which for some time now has kept me busy helping with Ford's 2016 Le Mans GT racecar (and the need to make hundreds of road cars each year to satisfy the homologation requirements).

So, how does all this affect the 2015 IndyCar aero kits? They say that those who don't study history are condemned to repeat it…

Indy cars did return to Brands, 25 years on, in the summer of 2003, but made nothing like the same impact. By then IndyCar was in the final throes of a schizophrenic act of suicide with the series having split into two. And anyway, the world had moved on. If you reflect on what had happened in the intervening years between those UK races, there had been a direction of travel from which the series is really still recovering. It was that trajectory that steered the ship into 2015… when the best thing on offer was a pair of highly-constrained aero kits to spice-up the action.

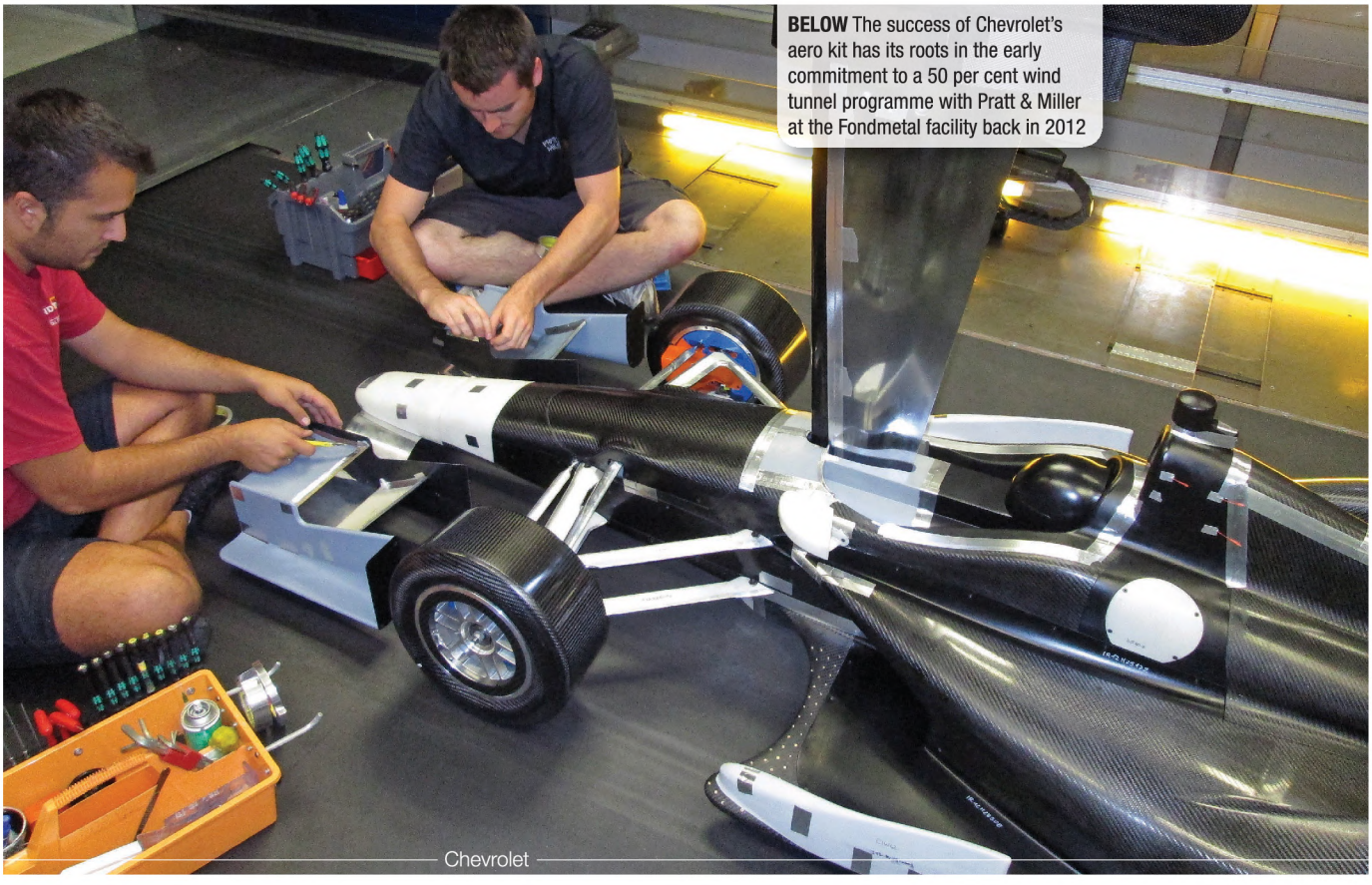
The rise, then fall, of the series provides context to what is a hugely difficult problem: how do you build IndyCar back from a single-make, spec-racer series to what it once was, given a limited budget?

Given the state of IndyCar's finances, and the sheer diversity of motorsport today, perhaps it's folly to even think that this can happen. But, as long as the series continues to survive, then surely it's possible to improve the technical challenge so that it moves beyond a one-make racing series and both allows and rewards innovation? Only then can we hope to strengthen its broader appeal, capture a bigger audience and perhaps some better TV coverage. But I would maintain that it's only through improved technical diversity (that's clearly communicated to the fans) that the series can hope to broaden its appeal.

It's an enormously difficult job to entertain the modern public. They have a huge choice of TV channels, both subscription and free-to-view, along with live digital datastreams available on the Internet. Much to IndyCar's credit, it has made great strides in embracing on-demand video streaming. All these developments have completely revolutionised the viewing experience from 1978, 1998 or even 2003. You could even argue that the modern audience has attention deficit disorder (ADD). To keep the casual viewer engaged, the coverage now needs to thread multiple stories through any broadcast, never lingering too long without something new. All the while, the core story (the race) has to be covered in a way that holds true to the simplicity of the event: a competition pitching driver against driver.

Of course it's not just about the drivers. The cars and setup play a part. But nobody wants it to be easy to overtake. The drivers should have to fight hard to pass. In that respect the Handford Device was a failure. Whilst it was and remains largely irrelevant to road courses (and especially the stop-go driving of tight street races), what it did do was point toward two things that are peculiar to oval racing. *And it is oval racing that differentiates IndyCar so comprehensively from F1.*

Firstly, it's entirely reasonable to have to alter the aerodynamics of the car to ensure that on ovals the corners are indeed corners (grip-limited) and not just changes in direction. And because of the diversity of tracks it's reasonable to expect to have to do this on a circuit-by-circuit basis so that a hugely powerful car with lots of grip can be safely tuned (well, detuned) to make negotiating a quick lap a skilful rather ▶



BELOW The success of Chevrolet's aero kit has its roots in the early commitment to a 50 per cent wind tunnel programme with Pratt & Miller at the Fondmetal facility back in 2012

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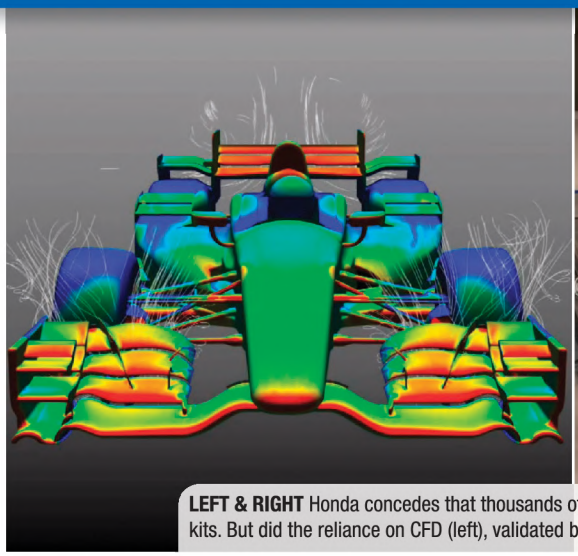

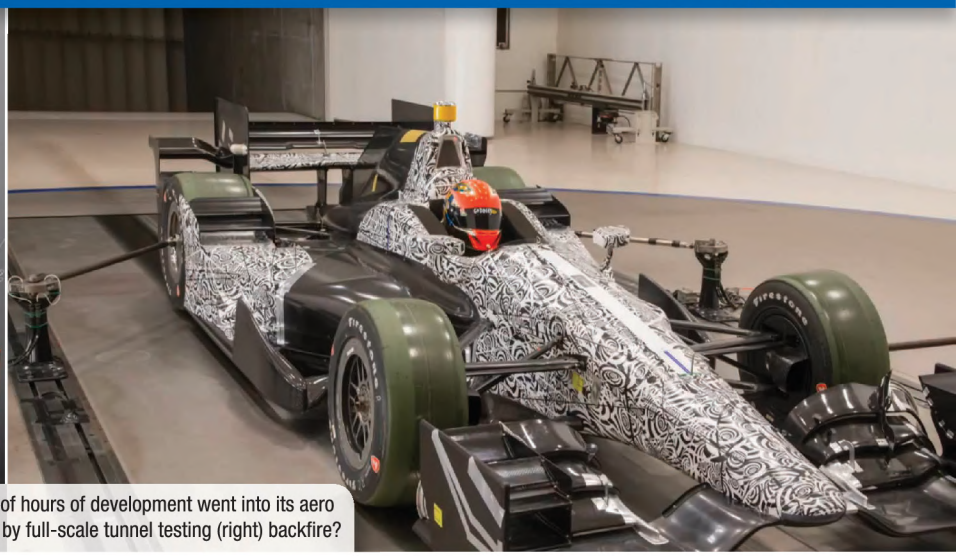

LEFT & RIGHT Honda concedes that thousands of hours of development went into its aero kits. But did the reliance on CFD (left), validated by full-scale tunnel testing (right) backfire?

than brainless endeavour.

Especially with respect to banked ovals, I would maintain that this point was sadly overlooked in amongst the bad publicity surrounding the Handford Device. The opportunity to develop open-wheeled aerodynamics to always ensure that banked ovals couldn't be taken flat-out was tragically lost. This was a contributing factor in the death of Dan Wheldon, whose name lives on as the 'DW' in Dallara's 2012 chassis, the DW12.

The second point the Handford Device leads us to is that – just as in other pursuit-sports like cycling, running and especially motorcycle racing – there should be at least *some* advantage to being behind the guy in front. Cars that make a lot of downforce, especially those that rely on small, highly-loaded, steeply-cambered wings, create aerodynamic wakes with considerable longevity. These wakes have such a debilitating effect on the aerodynamics of a following car that it is impossible to stay close when approaching a corner. So, we see great wheel-to-wheel racing in a low-downforce formula (particularly Formula Ford and MotoGP) and tedious processions in F1 and IndyCar racing.

This is because we've loaded the dice too much in favour of the guy in the lead. He has everything: track position, clear vision, clean air and with better grip allowing him to brake later and steer a predictable path to the apex of the corner. This needs to be mitigated to at least give the guy behind something of a tow… but nothing like what happened with the Handford Device.

There are always exceptions and NASCAR's Talladega and the old IndyCar races at the Michigan International Speedway serve as examples of such outliers where flat-out racing can be exciting. But in general surely corners should be corners with cars needing (if necessary) to be aerodynamically detuned to make this happen?

MISSED OPPORTUNITY

This ability to forcibly detune the car was not a core feature of IndyCar's aero kits which, to me, was a missed opportunity. Certainly there are circumstances where more downforce is better but so too are there occasions when less is more. Clearly this needs to be imposed via sympathetically-shaped aerodynamic restrictions that are common to all the cars (like the 1997 tunnel blockers) but the point is that this approach generates more 'knobs' that race organisers can twiddle to create better racing.

To my thinking IndyCar was onto a winner with the concept of the aero kits but the whole solution should have been turned on its head. The base car should have been embodied with much more underbody downforce and the aero kits would have been incremental 'detuning kits'. That way the car would have been able to carry the loads without the current problem of a base car being effectively overloaded by an OEM's (Honda or Chevy) uncontrolled 'bolt-on downforce'. The way things stand the series has forced the teams to purchase the equivalent of two-ton trucks and then allowed them to load three tons of cargo… When suspension components then started to fail it was difficult to see it being the fault of either the OEM or Dallara. And, you have to think (albeit with 20-20 hindsight) that this was a poorly thought-through concept.

Detuning is not new. Adjustable boost turbocharged motors are a big step in this direction. And IndyCar has had exactly that and used it to good effect for decades to tweak the power up and down to better suit the cars to the differing tracks throughout a season.

So, what did we get from the Honda and the Chevy aero kits?

Well, there is a strong motorsport presence in northern Italy with of course Dallara and Ferrari but also in the supporting service industry. The latter is typified by Fondmetal Technologies, with its collection of wind tunnels used by F1, DTM and LMP1 constructors. Whilst Honda was deliberating, Chevy gave the Pratt & Miller guys, led by Arron Melvin, the green light to get busy at the wind tunnels of Jean-Claude Migeot, my former boss, out there in Italy in early 2012. Soon after (I'm told) they switched to use the Penske Technology Group (PTG) tunnel in Mooresville. With around four aerodynamicists, four model design engineers and a cohort of model-makers and manufacturing support, they worked persistently to create a package in sympathy with the existing lines of Dallara's DW12… rather than using it as a platform to sprout wings from. Oh, and they used CFD too.

There is absolutely no substitute for 'calendar time' in developing a competitive car and I'm sure these aero kits were much the same. The Honda guys were put increasingly behind the 8-ball by dint of a failure to commit at the same time that Chevy did. It wasn't until almost 2014, nearly two years after Melvin got started, that Wirth Research – Honda's technical partner – was finally out of the starting-blocks.

Arguably Honda then made it even more difficult by sticking to the Wirth approach of relying on CFD until the latter stages of the development process when full-scale testing started at Windshear in Concord, North Carolina. By this stage wind tunnel testing was a simple commute for the Pratt & Miller personnel, but a red-eye transatlantic flight for their rivals at Wirth.

Once the Honda kits made it to pre-season testing it was mass disorganisation with grumblings of a lack of planning, parts arriving late and generally poor communication. In short: chaos. Then it became clear that the performance was poor. The car was only marginally faster, with some inconsistent behaviour that spooked the drivers.

At that point the Honda aero kits appeared to have encapsulated some beautifully- ▶

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sculpted individual components but in its entirety it looked very 'bitty' and created a labyrinthine system of parts that appeared likely to rob the underbody of good clean mass flow. Perhaps the logic was that the underbody of the DW12 is pretty basic and so it would have been tempting to treat it as a 'weapons platform', bolting on downforce rather than spending the time to first maximise the available performance from the rather limited underbody.

Certainly there are some talented CAD designers at Wirth and HPD but they were under huge time pressures. The kit as a whole appeared lacking the holistic approach evident in the Chevy kit where, in particular, the front wing treatment appeared more integrated with the donor car.

I can only speculate but I suspect that the CFD also didn't predict the sheer magnitude of drag that was evident once the full-size parts were made. It may even have over-estimated the creation of front wing downforce. Meanwhile the Pratt & Miller guys, with the luxury of time on their side, were able to chip steadily away, correlating their wind tunnel gains against the base DW12. In contrast to the Honda package, Chevrolet's front wing endfence featured a very different-looking swept-outward design that no doubt helped to maintain consistent front downforce across a range of steer angles and corner-entry roll, pitch and yaw.

Conversely, the cascade arrangement on the Hondas would also have shielded the front tyre and thus reduced front tyre lift and drag. But you couldn't help thinking that in practical terms it wasn't as elegant, was less stiff, probably heavier and almost certainly more vulnerable and less tolerant of varying steer, roll, pitch and yaw. Consistency of front grip at turn-in is vital for driver confidence and you couldn't help think that the Chevy kit was going to inspire more confidence.

Sure enough, in pre-season testing drivers using the Chevy kit were faster. So much so that they were complaining of excessive steering weight, and brake temperatures getting high… all signs of a big jump in performance!

The Honda road course car was improved by sawing off the endplates from the front wing. These had been breaking off and causing a flying debris hazard, but in reality they were also aerodynamically bad and the mass was causing some inconsistency with evidence of the wing tip bouncing up and down, excited by the sheer mass of the tip assembly. After that, the car calmed down and was at least a bit easier to set up.

The Honda teams also soon found that they needed to do their own aeromapping and the Windshear tunnel in Concord became unusually

IndyCar

ABOVE & BELOW Where the spectacular-looking cascade arrangement on the front wing of the Hondas shielded the front tyre (above), Chevrolet's swept-out endfences (below) looked a better bet to maintain consistent front downforce

ABOVE IndyCar had to mandate that a hole be cut in the new spec underwing in order to cap downforce

Chris Jones/IndyCar

ABOVE Love them or hate them, the aero kits have at least stirred interest and debate

busy. It's rumoured that the originally-conceived rear wing configuration was actually worse than the base spec from Dallara, and certainly the teams reorganised the flap priority for the latter part of the season. By dint of a lot of long hours, hard work and physical testing, the Honda cars did begin to improve.

The rules *do* allow for updates in 2016 but the catch is, the sidepods and engine cover were a one-shot deal with no provision in the regulations for change. You had to get them right from the very start. And Honda probably didn't. Wirth insisted that a traditional 'coke' at the back didn't work in its initial design studies. But, er, the Chevy has something of a coke bottle…

WHERE DID IT GO WRONG?

As for where it went wrong? Well, CFD might be good but it's not reality. The highly-strained flows prevalent in short-span, highly-loaded wings are difficult to capture accurately in CFD, if only because the empirical turbulence models used to solve the underlying physics are a poor approximation under such circumstances. CFD will usually get the trend correct but (at least in my experience) it struggles to match the speed, accuracy and interactiveness that can be got from using a wind tunnel. And anyway, why not use both?

Another problem for IndyCar was that nobody really coordinated with Dallara in terms of just how much more downforce the cars could take. So, whilst Dallara knew from the very announcement of the DW12 chassis that aero kits were part of the plan, it didn't really know how much redundancy to build into the suspension to cope with the huge increase in forces that the kits ended up creating.

Once the kits materialised, and Dallara was alerted to what was being achieved, it reacted. The teams duly got new wishbones and pushrods but, even so, there have been some isolated suspension and wheel rim failures.

The lack of overall coordination in the programme between the stakeholders was evident by the need to cut a big hole in the new spec underwing in early 2015 to cap downforce. It was further restricted via the removal of the strakes and sidewalls from the underwing exit for the road and street tracks. So whilst the Chevy and Honda people were busy adding downforce, the chassis manufacturer was busy removing it… and removing from the very place where you'd want it – the underbody!

Inevitably with such a basic underbody the aero kits are reliant on fiddly, fragile and aerodynamically dirty top-side pieces. So, sadly, the tale of 2015 was more about the crippling of some Honda teams rather than the overall technical merit of the aero kits.

To paraphrase Bryan Herta, he had to pay a huge amount of money to be less competitive than before the aero kits and he had no control over the outcome. In effect, in 2015 he became an unwilling (first class ticket-holding) passenger on a runaway train. Worse, he was almost totally unable to adapt and survive. Surely something that could have been anticipated and planned for?

To IndyCar's credit, it has reacted positively and implemented rule 9.3 which basically gives Honda a get-out-of-jail card (or perhaps a 'try again' pass). In the wake of back-to-back tests of the Chevy and Honda packages at the Windshear tunnel at the end of the season, the governing body deemed that while Honda's superspeedway kit was competitive, its poor performance on short ovals, street and road courses was detrimental to the championship.

Honda will therefore now be able to revisit the 2015 package and make changes without affecting its ability to implement further revisions in 2016. The rules permit both manufacturers to make updates to three of the nine 'legality boxes' for next season.

For all the criticism – and there has been plenty – one thing is beyond dispute: the aero kits have created intellectual 'chatter' and given IndyCar another thread to weave into the tapestry that will define the series in 2016. For that IndyCar deserves a big tick in the box. RT

THE WEC'S UNTOLD STORIES

Yes, Porsche grabbed the glory, but what was going on behind the scenes? **Gary Watkins** assesses the main talking points in this season's World Endurance Championship

How Porsche stole a march on Audi

PORSCHE might have battled hard with Audi for three of the six hours at the Silverstone World Endurance Championship opener in April, but the latest car to carry the R18 e-tron quattro moniker had a clear advantage around the fast sweeps of the British circuit. That suggested that Audi, with the even more efficient aero set-up introduced at round two at Spa, would be in the ascendancy on the resumption of the series post-Le Mans. Not a bit of it.

The latest high-downforce version of Porsche's 919 Hybrid didn't just remove Audi's advantage, it overturned it completely and then some. It was the returning grandee of international sportscar racing that had the advantage in LMP1 – and a clear one – when the championship got going again at the Nürburgring in August after its long summer break.

Audi driver Andre Lotterer summed it up best after coming home third at the 'Ring behind the two Porsches. "Our strength was that we had good aero, but now they have that too," he explained. "That's the big difference between now and the first two races. We are racing against an eight megajoule car and can't compensate for that."

Audi was running in the 4 MJ hybrid sub-class in 2015, two steps down on Porsche. Even taking into account the K Technology Factor, which compensates for the extra weight and cooling required by a turbodiesel powertrain, the R18 was behind in terms of grunt out of the corners compared with the 919. And that was supposing that the Audi was able to regenerate the full amount of energy through its front-axle kinetic energy-retrieval system [KERS]. The word in the paddock was that it couldn't.

Audi's advantage at Silverstone and to a lesser extent at Spa – a track where the amount of downforce required is closer to Le Mans levels – resulted from Porsche's decision to race in the first two WEC rounds with a compromise aero set-up that was a precursor to the package it ran at the Le Mans 24 Hours. It chose this route because the focus on its second campaign back at the pinnacle of endurance sportscar racing was on winning the 24 Hours.

"We sacrificed Silverstone because our aero strategy was focussed on Le Mans," says Porsche LMP1 technical boss Alex Hitzinger. That decision was based on a desire to learn about its all-new car with lower downforce levels and to prove the integrity of the bodywork.

Hitzinger suggests that the second-generation 919 Hybrid had the correct level of downforce for Spa in May. He insists that Porsche would almost certainly have won had it not been forced to change tyres – when Audi didn't – late in the race after Marc Lieb damaged his tyres going off in avoidance of an LMP2 car.

Porsche knew what was coming by the time it achieved its first goal of 2015 with

Dungan/Adrenal Media/FIA

ABOVE Audi (left) held a clear aero advantage over Porsche when the series got underway at Silverstone…

a 17th Le Mans victory for the marque at Le Mans. The high-downforce aero, known internally as 'kit five', was well into development at that stage, and Hitzinger was confident that it would give the 919 an advantage over the second, five-leg race of the WEC.

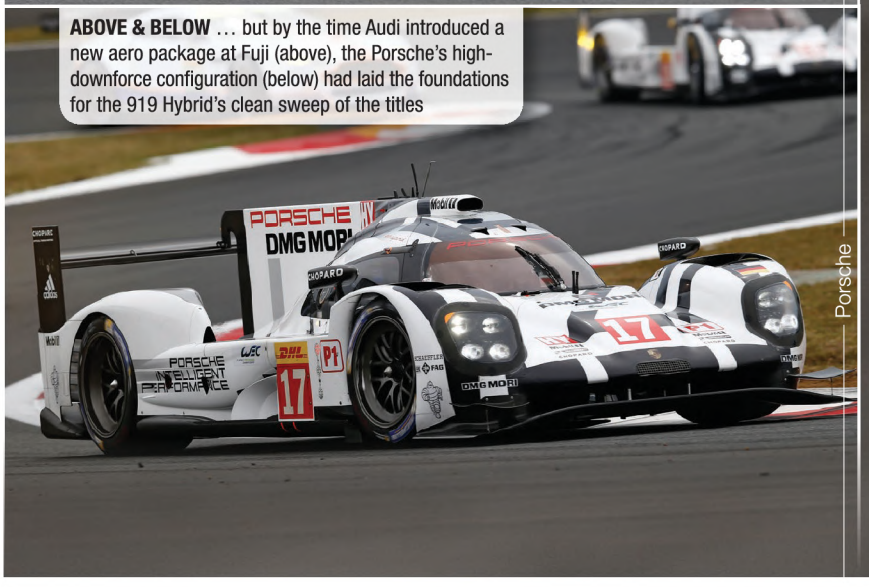
"After Le Mans, I knew what aero performance we would have for the second half of the season," he explains. "We had a little meeting on the Tuesday after the race with the whole team, and I said there is no reason why we could not win every race over the rest of the season. I said that we just had to keep pushing."

Hitzinger's confidence was well-founded. A run of four straight victories, all for the #17 Porsche shared by Mark Webber, Timo Bernhard and Brendon Hartley, yielded the manufacturers' crown in Shanghai with a race to spare. It also propelled this trio to the drivers' title, which they clinched in the series finale in Bahrain at the end of November.

Audi did react. It brought a new aero package to replace the so-called low-drag kit – the term low-downforce for the spec raced at Spa and Le Mans was both frowned upon and incorrect – for the Fuji race in October. More downforce did bring the R18 closer, but in another role reversal, it was the Porsche that looked better on its Michelin tyres than its rival from the Nürburgring on.

The weakness of the Porsche in 2014 and the opening two rounds of this year's WEC had been transformed into a strength. ▶

Ebrey/LAT


Porsche

ABOVE & BELOW … but by the time Audi introduced a new aero package at Fuji (above), the Porsche's high-downforce configuration (below) had laid the foundations for the 919 Hybrid's clean sweep of the titles

The refuelling conspiracy

"**FIVE** or six seconds lost at every stop is a lot: it adds up to two and a half minutes over the race." Those were the words of Audi Sport Team Joest boss Ralf Jüttner in reaction to the advantage Porsche stole in the pits at Le Mans this year with super-rapid refuelling.

Porsche's speedy pitstops weren't just the result of its decision to opt for 13-lap stints of the 8.47-mile Circuit de la Sarthe. It short-fuelled its cars because it didn't have the necessary safety margin to go for 14 laps. It only needed fuel for 13 laps in the tank of its fleet of 919s, plus that all-important margin for safety. But there was more to it than that.

> *"Gravity is the same for everyone, so you have to minimise flow restriction. There is no magic to it"*

Analysis of the race by Audi showed that its rival had made a major improvement in refuelling time from the first two WEC races. Proof was provided by quicker stops at the shorter Nürburgring and Austin tracks when there was no significant short-fuel from Porsche.

Porsche's fuel cell was twice stripped by WEC scrutineers as a result. Nothing was found to be untoward under regulations that specify gravity as the only force allowed to fill the car. Audi went back to the drawing board and found its own improvement ahead of Fuji.

Hitzinger won't say how Porsche achieved the quicker fuel flow into the car, pointing out that "Toyota didn't get it yet". He suggests, however, that it is nothing more than attention to detail.

"Gravity is the same for everyone, so you have to minimise flow restriction," he says. "It's as simple as that; there is no magic to it."

Conspiracy theorists suggest that Porsche had kept this tweak in its pocket through the first two races so that its rivals wouldn't be able to react. Hitzinger dismisses that idea. "It is something that you keep developing," he says. "We didn't run it, because we didn't have it."

Toyota's spectacular decline

TOYOTA has been outgunned throughout 2015. It was evident as early as Spa that it would not be able to mount a meaningful defence of its drivers' and manufacturers' titles. The uprated version of its TS040, still running in the 6 MJ class, was leapfrogged by both the heavily-revised Audi R18 e-tron quattro and the all-new, second-generation Porsche 919 Hybrid.

The latest Toyota has been significantly quicker than its predecessor – upwards of 1.5 seconds a lap in race pace – but that has not been enough in the face of the gains made by its opponents. The obvious factor was that Porsche and Audi had moved up a hybrid class and Toyota hadn't, but the Japanese manufacturer also believes it was losing out in engine performance from its 3.7-litre normally-aspirated V8.

That's why it is developing an all-new engine for 2016. Its initial plan had been to upgrade in two steps: to switch from super-capacitor energy storage to batteries for next year; and then to introduce the new ▶

ABOVE Conspiracy theorists suggested Porsche kept its refuelling breakthrough hidden ahead of Le Mans so that rivals couldn't react

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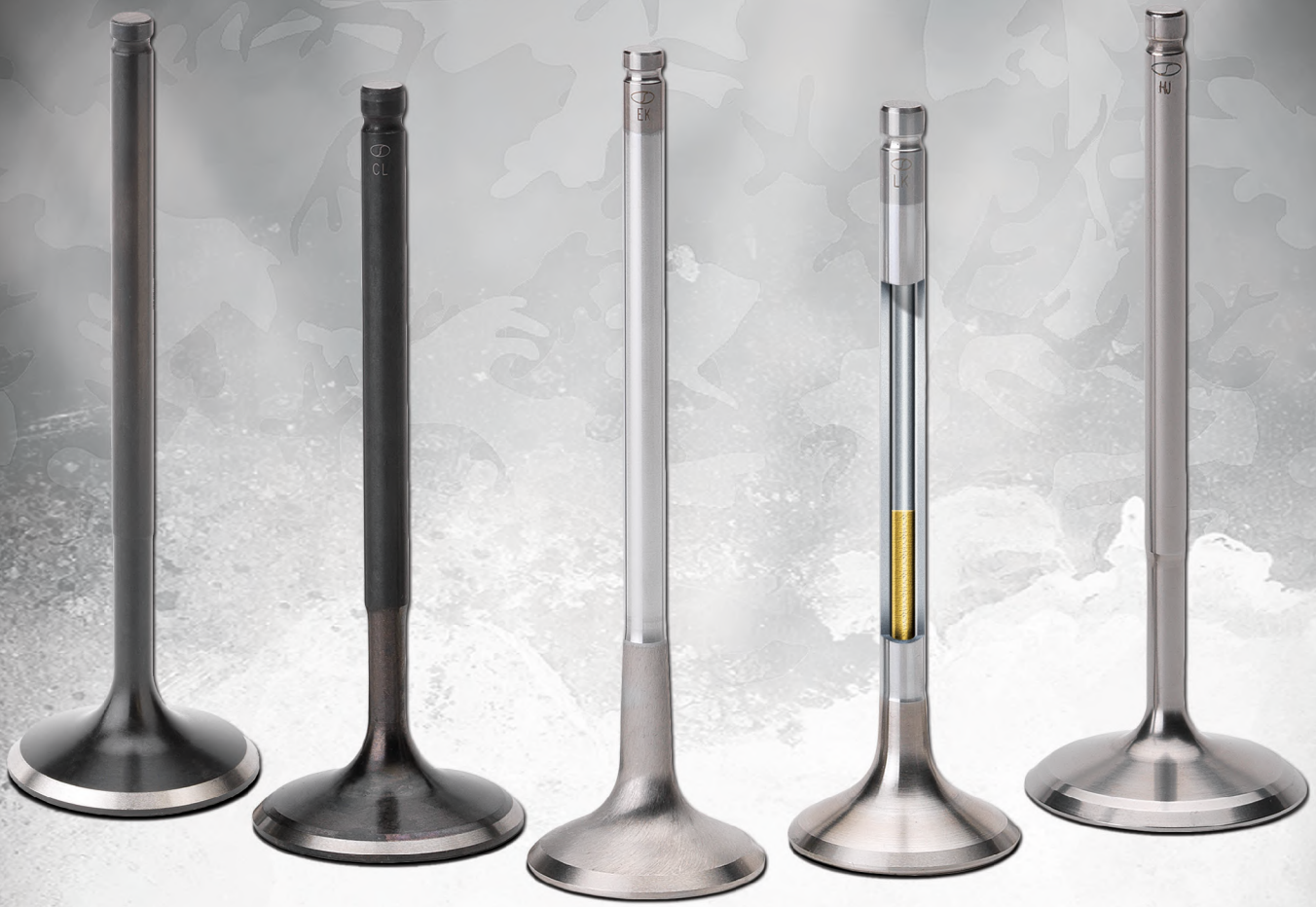

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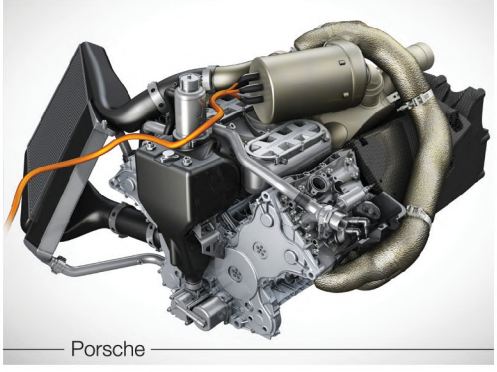
Toyota

BELOW Toyota found itself with a mountain to climb when it became evident that, although quicker than its predecessor, the TS040 was still outgunned by rivals

BELOW Could Porsche's small-capacity V4 turbo prove an inspiration for Toyota's new engine package?


Porsche

powerplant the year after.

"We didn't expect our advantage from last year to disappear so quickly; we knew it would, but not in such a short space of time," says Toyota Motorsport GmbH technical director Pascal Vasselon. "The original plan was just to upgrade the hybrid system, but we quickly realised that we couldn't wait to upgrade the engine as well."

Toyota has yet to reveal details of its new powerplant and is unlikely to do so until early next year, but it has dropped some heavy hints that it will be a turbocharged unit. The smart money is on it following the Porsche route by producing a small-capacity V4 turbo.

The new car and engine are on schedule, but the late decision to bring development of the powerplant forward – it was only announced at Le Mans in June – means that the schedule is, according to Vasselon "very tight and with no room for error".

Stint length controversy

AUDI made an attempt to re-open the debate on the length of stints on a tank of fuel before the end of this year's WEC. It again claimed at the Shanghai round that it was unfairly penalised because Porsche could go further on a tank of fuel.

Christopher Reinke, head of LMP at Audi, argues that the Fuji race, where Porsche stole a march on Audi because its leading car was able to complete a stop under a full course yellow, had brought the factor back into focus.

"If by regulation you can do a couple of extra laps, then you have more flexibility," he explains. "It has an influence in general because they pit later and can always see what we do, and on occasions it has a race-deciding influence like at Fuji.

"We should all do the same length of stints. That is the only way this championship is going to develop."

Audi voiced the same argument early last season, to which WEC organiser the Automobile Club de l'Ouest, which jointly writes the P1 rules with the FIA, responded by holding a press conference over the weekend of the Spa round to counter the German manufacturer's statements in the media.

Hitzinger has dismissed Audi's stance this time around. "If there is no performance incentive between running a 4 MJ and an 8 MJ car, why do it?" he says. "There needs to be a performance incentive for running a bigger hybrid – and that's how the rules were written and everyone bought into that.

"The rules were written so that an 8 MJ car could do 14 laps at Le Mans. So if anything the rules are against us and we should have a slightly bigger tank." ▶

Dungan/Adrenal Media/WEC

BELOW Audi re-opened the debate on the length of stints on a tank of fuel in the wake of its defeat by Porsche at Fuji

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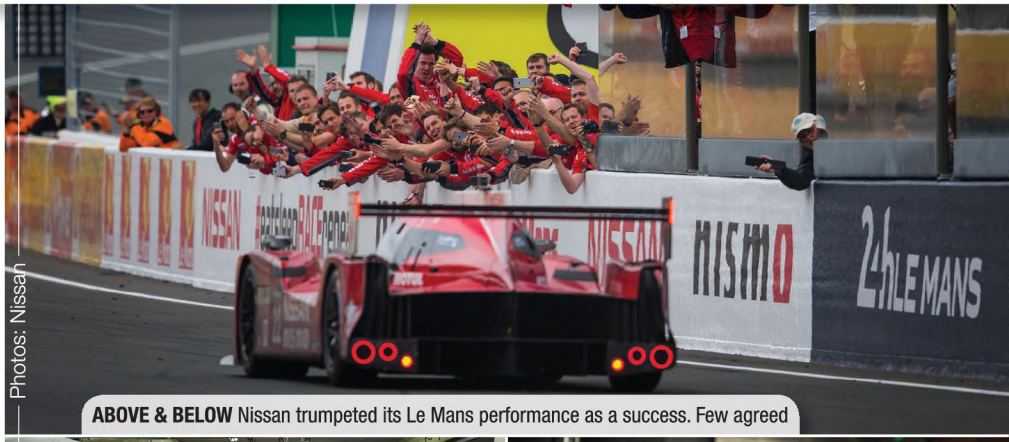
Nissan's no-show



Photos: Nissan

ABOVE & BELOW Nissan trumpeted its Le Mans performance as a success. Few agreed

NISSAN pulled out of the second leg of the WEC after a performance at Le Mans that was disastrous by any standards but its own. The decision to miss the final five races was actually made in two stages while development of the front-wheel drive GT-R LM NISMO continued.

The initial decision covered the races up to and including its home event at Fuji in October and followed the first test of the Ben Bowlby design after Le Mans at the Circuit of the Americas in Austin. The call to sit out the remainder of the series was made after a second test, also in Austin, straight after the WEC round in mid-September. The twin decisions were made after testing in the form in which the car had competed in the 24 Hours, namely without its hybrid system engaged.

What is not known is whether Nissan had an intention to race the car with its front-axle energy-retrieval system engaged had the US-based programme returned to competition in 2015. The answer to that question is probably not, given that it will not be running the fully-mechanical Torotrak arrangement, which was designed to harvest enough energy to put the car in the 8 MJ hybrid class, in 2016.

Nissan hasn't disclosed what will replace it or who is developing it, but a spokesperson said that it had been "under development for some time" and that it would be ready for bench testing before the end of the year.

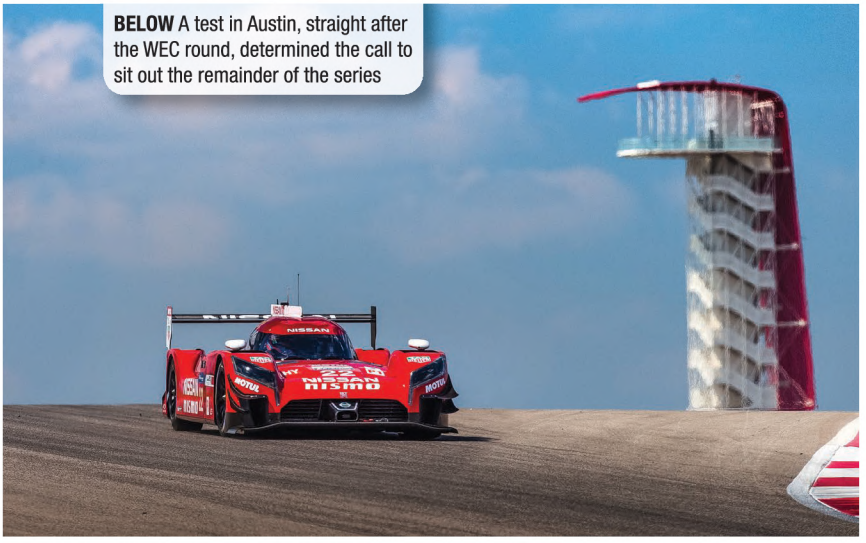
Speculation has suggested that it has taken development in-house and that the new hybrid system will be produced by NISMO, the manufacturer's motorsport department in Japan. This rumour remains entirely unsubstantiated, and it should be pointed out that NISMO has little or no experience of hybrids.

It is understood that the GT-R LM will have an electrical system like its rivals and battery power storage – also like its rivals – when it returns to competition. That suggests the philosophy of the car will be altered given that it is unlikely that it could retrieve the amount of energy required to put it into the 8 MJ class with such a system, even with front-wheel drive and its forward weight distribution. Or rather totally impossible, if you talk to LMP1 engineers elsewhere in the WEC paddock.

The original car called for front-axle regeneration and deployment through the skinny rear tyres. It appears that Nissan has opted for a secondary hybrid system. Presuming that it still aims to deploy through the rear wheels that must mean that it will also retrieve at that axle, which under the original concept called for skinny nine-inch-wide tyres.

Nissan also announced a new team principal for the LMP1 programme when it revealed that it wouldn't be returning to the WEC this season. Mike Carcamo joins from Nissan Mexico. He was a trackside support engineer in CART and IndyCar with Ilmor in the late 1990s and early 2000s before moving to Nissan and a series of road car appointments. He takes the team principal role from Bowlby, who will now focus on being technical director. "Ben had his hands full trying to do everything; managing the design and build but also the race and test operation," said Carcamo in an official statement. "That's a lot to ask anyone to do, especially with a concept that requires this level of development. My knowledge of Nissan engineering processes and project planning experience will help Ben and the team concentrate on making the car deliver on its promise."

Carcamo's arrival was followed by the departure of Darren Cox as Nissan's head of global motorsport. The Briton, who increased the Japanese manufacturer's presence in worldwide motorsport with the on-going GT Academy gamer-to-racer scheme and the DeltaWing experimental 'Garage 56' project at Le Mans in 2012, can be regarded as the architect of the marque's return to the top flight of sportscar racing. He appears to have made his own decision to leave and will be setting up his own marketing consultancy, but the effect of his marginalisation in the P1 programme since Le Mans on that decision is not known. ▶



BELOW A test in Austin, straight after the WEC round, determined the call to sit out the remainder of the series

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The mystery of the 1,000 BHP limit

HYBRID power has been capped at 300 kW – the equivalent of approximately 400 bhp – for next season, but only at the Le Mans 24 Hours. For now, anyway.

The rule has been introduced on safety grounds for a track that has FIA grade two status. It was originally announced, via a World Motor Sport Council bulletin, as a 1,000 bhp limit on the combined power of the internal combustion engine and energy-retrieval systems. That statement was incorrect, but it explained the philosophy behind the move.

The 300 kW limit pre-empts a projected change to the way circuits are licensed by the FIA. Under a system that has yet to be signed off, the grading of a circuit would be determined by power to weight ratios of the cars allowed to run on it. A 1,000 bhp LMP1 car would be significantly over that allowed for a grade two circuit.

There was no objection to the new regulation for Le Mans from the P1 manufacturers. The limit will have little effect on lap time; Porsche LMP1 technical director Alex Hitzinger says it will be measured in tenths only. That would not be the case on other circuits, which is why an extension of the rule to the Formula 1-spec, grade one circuits that make up the rest of the WEC schedule is still a matter of dispute.

Less of a short-sharp boost is required at Le Mans because the straights are so long. But on other tracks with shorter straights, it is imperative that the cars deploy their hybrid power more quickly. And Toyota argues that the rule would unfairly penalise its concept in comparison with those of its rivals.

Toyota retrieves and deploys from both axles via its twin kinetic energy retrieval systems and will continue to do so from next season with its new LMP1 challenger. Porsche and Audi only returned recovered energy to the track via the front wheels. That means the Japanese manufacturer has the potential for higher hybrid power levels because it has two motor generator units rather than one.

"This kind of limitation hurts a double KERS more than one KERS and an exhaust system [Porsche's set-up]," says Toyota GmbH technical director Pascal Vasselon. "It is not fair to introduce a rule that hurts one technology more than another."

Toyota claims that the extension of the rule to other circuits in 2017 has not been signed off. That contradicts what the other manufacturers are saying.

The rulemakers won't say what has been agreed and what hasn't, but ACO sporting manager Vincent Beaumesnil suggests that there is an intent for the 300 kW limit to cover all circuits from 2017. "It is best to have one rule for all circuits," he says, "because otherwise it is confusing."

If the 300 kW limit won't slow the cars dramatically at Le Mans next year, an across-the-board cut in fuel allocation will. Downscaling the amount of fuel allowed per lap in stages was always part of the philosophy of the energy-based rule book that came into force at the start of 2014 and it has been decided that the maximum reduction of 10 MJ, measured over a lap of Le Mans, will be imposed at all circuits in 2016.

The manufacturers agree that were this rule applied to this year's machinery, it would result in a four-second increase in lap times. That is in line with the ACO's desire to see average lap times at Le Mans above the 3m 20s mark – four seconds slower than pole this year, though the manufacturers agree that at least some of the lost time will be clawed back with development.

Other rule tweaks for next season include an increase in the size of the wheelarch vents, part of the rulemakers' strategy to prevent LMP1 cars from taking off in the event of a sideways moment. There are also new head restraint rules and changes to the way the field of vision from the rear-view mirrors is measured.

Nissan

ABOVE A reduction in fuel allowed per lap will increase lap times next season

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Do we fight invasion of the Cyber men?

The invention of intelligent tyres raises a dilemma for motorsport: embrace the technology, or ban it. **Anthony Peacock** investigates Pirelli's 'Cyber Tyre'

WHAT might just turn out to be the biggest-ever revolution – pardon the pun – in road safety and motorsport performance is likely to be on sale in less than three years, having already been tried out by no less a name than Ferrari. And the crazy thing is, most people aren't even aware that it exists.

We're talking about the 'Cyber Tyre'. It's a name that Pirelli has trademarked, although a number of tyre manufacturers are working on their own 'intelligent tyres' – both for motorsport and the everyday road.

Like most successful innovations, Cyber Tyre is based on a remarkably simple precept. The tyre is the only thing in contact between a car and the road (or track) surface. So why not turn that interface into a meaningful real-time sensor, as opposed to just a means of generating traction? Conventional systems such as ESP, traction control and ABS rely on second-hand information: data being fed to an ECU relating to a loss of grip after it happens. Consequently, there is always a delay in taking action. The aim of Cyber Tyre (and its assorted brothers) is to convey that information in real time and work with existing systems in order to anticipate rather than react to events.

READING THE ROAD

An autonomous electronic sensor is at the heart of the Cyber Tyre. It helps the tyre to read the road, sending this data wirelessly to the car's on-board computer and other electronic systems in real time. This data is then displayed to the driver via a graphical interface. The sensor is capable of interpreting the grip available, analysing all road conditions, and measuring traction.

Cyber Tyre senses the vertical, lateral and longitudinal forces on the tyre, calculating how much speed can be carried before ▶

Photos: Pirelli

ABOVE Could and should intelligent tyres play a role in motorsport?

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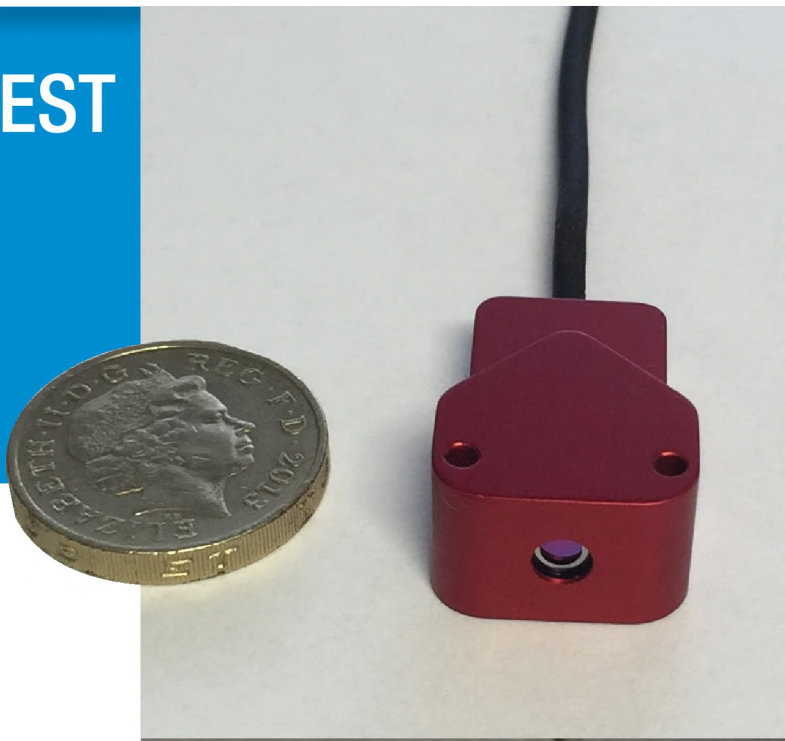

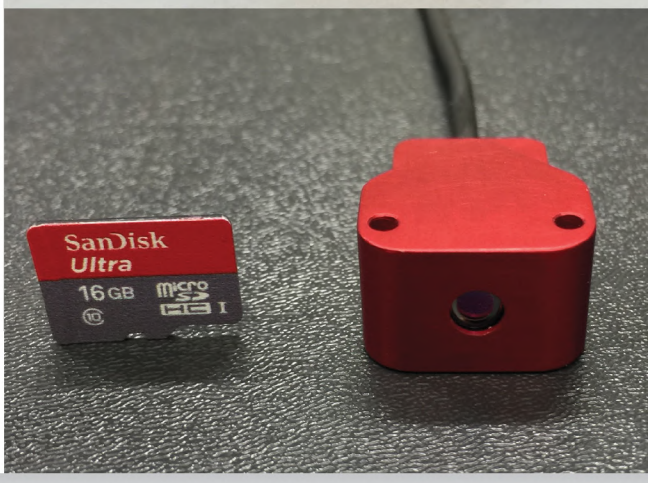

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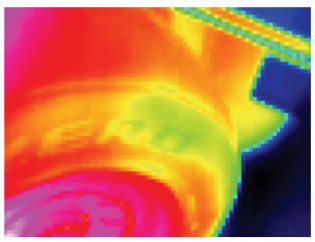

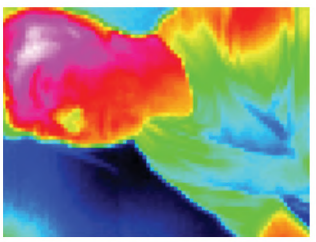

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ABOVE The electronic sensor at the heart of the Cyber Tyre

aquaplaning occurs, as well as how much grip is available before the car starts to skid. Other data fields include information about the type of asphalt on the road, the footprint and angle of the tyre, as well as tyre temperature, pressure, wear and number of revolutions. The sensor additionally acts as each tyre's 'passport', carrying unique information about its identity.

Of course, this makes the whole concept sound straightforward. Embedding a sensor within a tyre is not a significant challenge: it's something that Pirelli has already done with truck fleets – the polar opposite to high-performance or racing cars. The bigger challenge is to get that sensor talking to and working with all the existing systems on a car, and to make this happen, research projects are underway in the department of electrical engineering at prestigious universities such as Berkeley in the United States, among many others. Additional partners include Brembo and Magneti Marelli.

FERRARI TESTBED

The all-important sensor takes the form of a telematic box that incorporates a GSM/GPRS module for wireless connection with communication networks, a multi-constellation module for the satellite localisation of the vehicle, and a triple-axis accelerometer to detect acceleration and braking parameters associated with direction – among other functions.

Pirelli is the first manufacturer to use an intelligent tyre in a motorsport context: a prototype has already been tested on the Ferrari FXX-K: a 1036-horsepower 'production' hybrid trackday car based on the LaFerrari, conceived as a mobile test bed for customers to try out the latest automotive technology, unfettered by the rulebooks of any championship. Think of it as the ultimate 'Formula Libre'.

> *"The aim of Cyber Tyre is to anticipate events rather than react to them"*

The results have been remarkable, with a considerable improvement in lap times reported when passing to intelligent from dumb tyres, although nobody is willing to reveal any precise numbers.

The bigger question though is in which motorsport application this ground-breaking tyre technology could eventually be used. For the time being at least, Formula 1 is distancing itself from any form of additional driver aids. A more likely application is GT or endurance racing: even then, the advantages it brings may be seen to counter the stated aim of bringing speeds down (a largely futile exercise anyway, because even with speed-reducing measures in place such as narrower tyres, lap times at Le Mans were quicker than ever this year).

As FIA President Jean Todt said recently: "All driver aids we can ban, we should do it. Although the engineers are smart people, so they will try to find a way to interpret that."

It's ironic, because the invention of Cyber Tyre conforms precisely with the whole raison d'etre of motorsport according to the FIA: providing an opportunity to introduce and test new technology that will one day benefit road safety for the everyday motorist.

The godfather of the Cyber Tyre is, appropriately enough, an Italian: Maurizio Boiocchi, Pirelli's General Manager Technology. "Essentially there are two logical elements to Cyber Tyre, but they are both connected," he points out. "It can provide ultimate performance, as we've seen from the Ferrari FXX-K programme. Or it can benefit road safety."

Or maybe both… ▶

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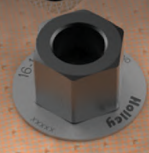

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Ultimately, the level of integration planned between Cyber Tyre and on-board ADAS (Advance Driver Assistance) systems goes so deep that it could lead to the car itself taking control of a marginal situation in order to regain grip.

Before it gets to that point, the information generated by Cyber Tyre could appear, for example, as part of a head-up display that indicates to the driver the maximum safe speed or g-force through a corner, with the superimposition of the ideal line to take.

Another way to display the information could be via a percentage, with a readout telling the driver that they are utilising 79%, for instance, of the grip currently available. At which point, according to some racing drivers, it becomes simply a question of joining the dots in any situation, with the car intervening if you overstep the mark. In a domestic context, different limits could even be set for different drivers via a form of parental control: new drivers, for example, could be limited to a usable range that falls well within the maximum grip available.

Does this sort of technology belong in motorsport? That's more of a philosophical debate. Most drivers are against the idea: "The more control that we have as drivers, the better," points out Formula 1 ace Lewis Hamilton, on the subject of driver aids. "I'm generally more old-school. I don't like tiptronic even though I race with tiptronic. I like having a gear stick. I like three pedals. I like the heel-and-toe effect. You just have a little bit more control."

> *"One of the most advanced frontiers of Pirelli's research"*

One man who has worked extensively with tyres in motorsport since 1982 is M-Sport tyre engineer George Black. He is responsible for all matters pertaining to tyres for M-Sport in the World Rally Championship: the form of motorsport that probably puts tyres through the most varied demands out there (including jumps; would it be hard to gather data while the tyre is in the air?)

"The problem could be just the sheer amount of data that could be collected, so the rules would have to be very different if such a product were used," Black points out. "At the moment, we're not even allowed TPS – tyre pressure sensors – on rally cars. We've looked at having other monitoring devices on the tyres such as infra red sensors on the tread, but that's not allowed on the car either."

Intriguingly, Black reveals that there is potential for a large amount of data capture on the Michelin tyres used for rallying already. "Our current tyre, as of Rally Germany this year, has a microchip in the sidewall, which will eventually replace the barcode and everything," he says. "Whether that microchip senses a load of other things, such a slip data… that could well be. The tyres we use are confidential, which means that they go back to the manufacturer as soon as they are used and there is a very big penalty if we lose a tyre. The reason for this is that they have a lot of futuristic technology inside that is used for the road industry. So it could be that they are already working in this direction, towards an intelligent tyre.

"A rally driver prefers to feel how the car ▶

Ferrari

ABOVE Testing on Ferrari's FXX-K hybrid trackday car produced remarkable results

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is reacting though – I don't think they'd actually want information to go from the tyre to the ECU, telling it to cut the throttle – but it could definitely be useful in certain situations. For example if you're on the Monte Carlo Rally and there's snow and ice, but because it's dark you can't even see the ice: this happens a lot. For the next generation of rally drivers, using an intelligent tyre might not be a problem, because it would be what they were brought up with."

So the capability for tyres to play an increasingly prominent role in aiding the driver is undoubtedly round the corner, if it's not here already. The first Cyber Tyres, developed in collaboration with manufacturers such as Audi, are expected to be on commercial sale as soon as 2018: initially for brand new models. By 2020, for example, it's estimated that 80% of a car's systems will be controlled by advanced electronics, as opposed to the current average of around 20%.

JUST TOO GOOD?

As time goes on, Cyber Tyre should be available for the aftermarket too. It will take us one step closer to the Holy Grail of the crash-proof car, a project whose scope goes far beyond just the efforts of tyre manufacturers.

As Pirelli's chairman Marco Tronchetti Provera – the architect of the company's Formula 1 engagement – points out: "The future of the automotive sector depends on research into cutting-edge solutions for sustainable mobility: which means knowing how to bring together safety, performance and respect for the environment. The development of Cyber Tyre is an important step in this direction and represents one of the most advanced frontiers of Pirelli's research, which has always cultivated in-depth and successful partnerships with the academic world. The alliance between the experience of industry and the ideas developed in universities is the only way forward to create quality innovation and far-reaching development."

No mention of motorsport there. The likelihood is, according to industry insiders, that this type of advanced technology will never be seen on top-level racing cars: like active suspension, for example, it's just a bit too effective. The tests with the Ferrari FXX-K have been enough to prove this – and that's with a product that is not even in its finished form. Imagine how it will be a few years down the line…

"As an engineer, your nature is to always look for the best of everything and the most complete performance," concludes Boiocchi. "So there could certainly be an application for Cyber Tyre in motorsport, as this is what it gives you. But there will always be a background of politics and regulations. At the moment, in Formula 1, we don't see the rules going in that direction. With other, more road-based, categories, who knows?"

One thing is "for sure", to borrow the most well worn driver quote in motorsport. Very soon, the tyre as we know it will never quite be the same again. RT

ABOVE The biggest challenge is to get the sensor to work with different cars' electrical systems

ABOVE Maurizio Boiocchi is godfather of the Cyber Tyre

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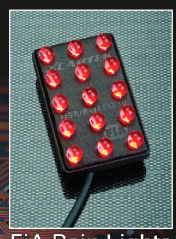
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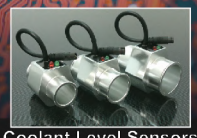
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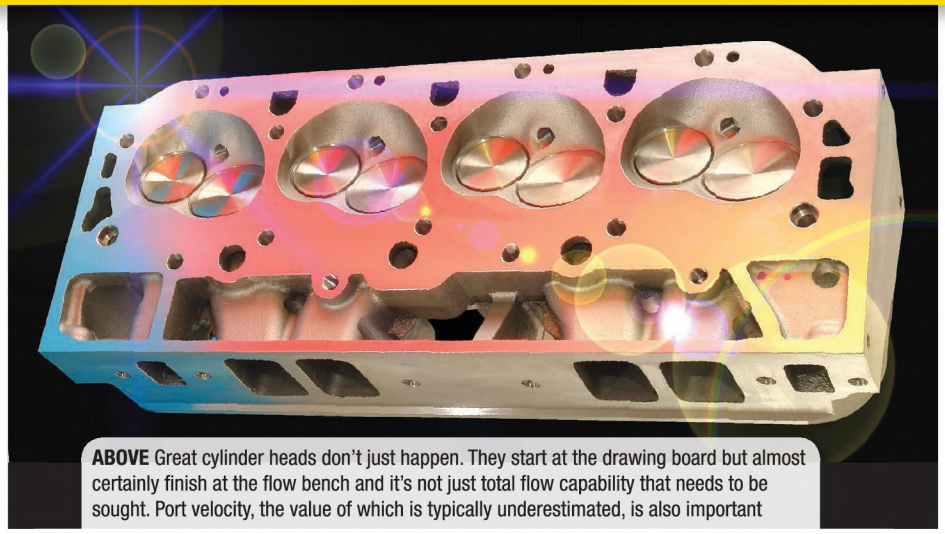

ABOVE Great cylinder heads don't just happen. They start at the drawing board but almost certainly finish at the flow bench and it's not just total flow capability that needs to be sought. Port velocity, the value of which is typically underestimated, is also important

ANY PORT IN A STORM? PART 1

David Vizard asks whether calculated port areas, sizes and forms are good enough, or is a flow bench essential?

IN the early 1960s plenty of engine design tech books stated quite categorically that peak engine power occurred at a mean port velocity of 300 ft/sec. This number, which seemed so convenient, was derived from dyno results in conjunction with calculations based on the rpm, piston and port areas involved. Personally-derived flow bench data was often far from being in complete agreement with that.

Back in those days the value of a flow bench was very often questioned or totally dismissed, even by greats such as the late Keith Duckworth. This opinion was often supported by the fact that one well known company, whose success was largely based on having and using a flow bench, produced some widely used designs that were among the poorest flowing heads of the day.

In practice such heads could be vastly improved upon just by applying some basic aerodynamic principles. Results were very positive and all (for the most part) without the aid of a flow bench. At the time this all tended to support the idea that a flow bench was not an effective or required development tool for the cylinder head specialist.

Back then the almost universal technique to assess the performance potential of a cylinder head was by using a finger to probe the port, usually around the short side turn, to make a judgement. That said, it should be kept in mind that not too many fingers are calibrated in CFM and even less in ft/sec!

Fast-forward to present times and it is reasonably fair to say the flow bench has proved its usefulness. Even so, most of those using a flow bench tend largely to focus on maximizing air flow and if velocity is ever considered it is moderate to low on the priority list. However there are a number of very successful cylinder head designers who will state quite categorically that port velocity is an important consideration. But, if asked how important that may be, you are unlikely to get a definitive answer. So, failing that, here are my findings on the matter based on my 50 years plus of flow bench experience.

HOW HEAVY?

Other than possibly those in the top league, one of the reasons cylinder head designers/developers fall a little short of a full understanding of what velocity characteristics are needed within the ports of a cylinder head (or manifold for that matter) is that, in spite of living in air, its properties are less appreciated than might be expected. Conversely, those who really understand the properties of air, dynamic or otherwise, most often don't explicitly design high-performance cylinder heads.

The reason for being so positive here is based on personal experience. At my seminars, largely attended by professional performance/race engine specialists, I poll the audience with a simple question: 'How heavy is a 100 ▶

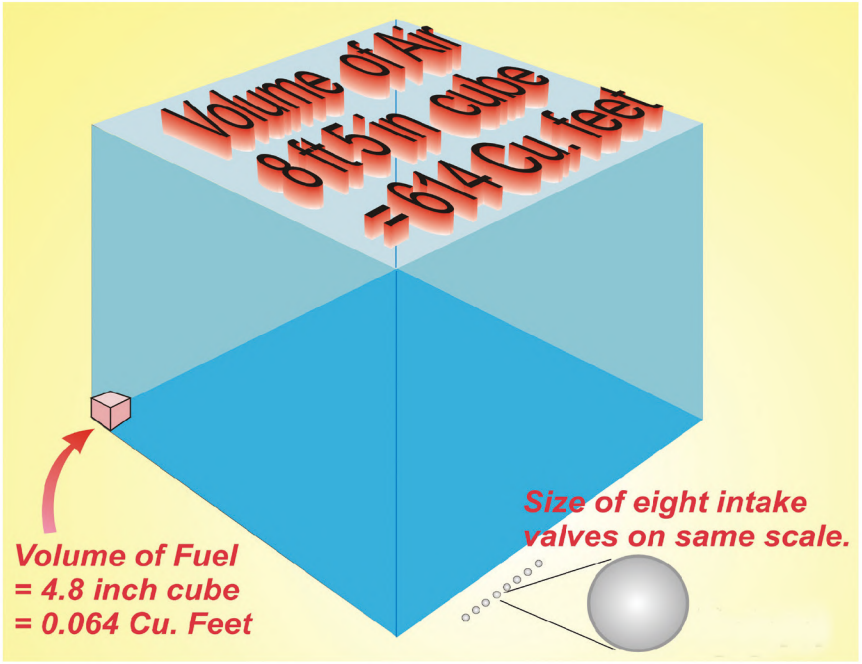

FIGURE 1 This illustration is intended to put the job of inducing air into the cylinders of an engine into perspective. What we have here is a cube representing the amount of air consumed per minute by a typical V8 engine making 400 hp. In the bottom left hand corner is the cube of fuel required to fuel the engine for one minute.

Barely visible along the right hand lower side eight intake valves on the same scale are shown with one enlarged so it can be seen that we are actually looking at valves. See how small the valves are in relation to the amount of air they must pass in one minute.

If that looks a daunting task then add this to the equation: only 2½ valves are open at any one moment! Now the proportions of the task are more evident, ask yourself if a flow bench might just be a good idea

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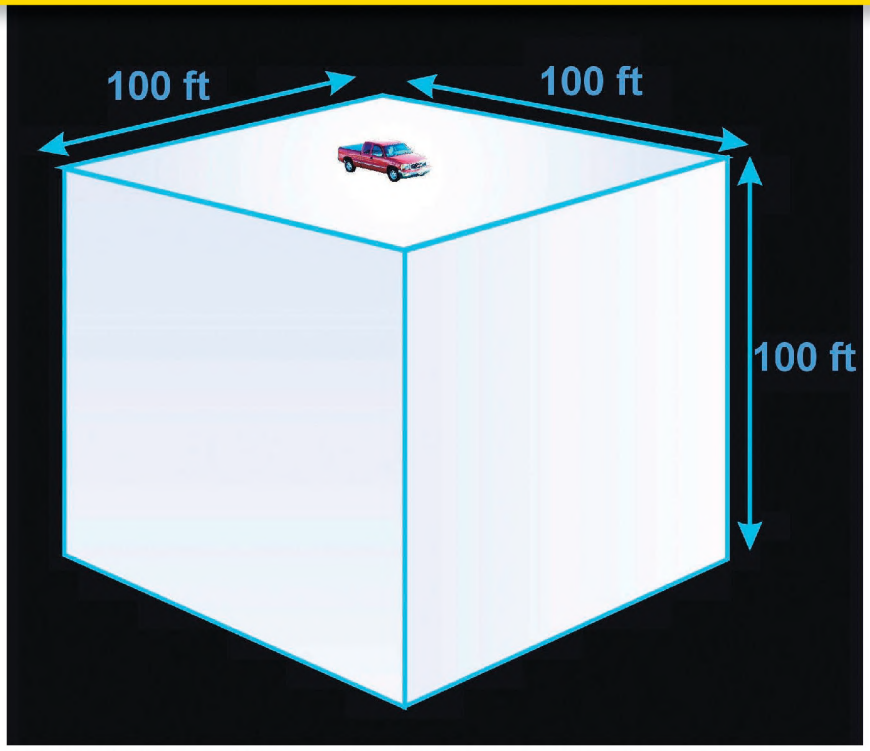

FIGURE 2 How heavy would you guess this 100 foot cube of air is? Assuming we could put it on a set of balance scales, how many of those cubes of air (or vice versa) would be needed to balance the 20 ft-long Chevy extended cab truck on top of the cube? This may come as a surprise but that cube of air is equal to the weight of almost 19 of those trucks (38 tonnes)!

foot cube of air (100 x 100 x 100)?' Most answers fall into the range of 75 to 400 lbs. The reality is 38 tons! This is an answer that less than 1% of attendees gave, while about 90% of the audience registered quite some surprise at the weight. The bottom line then is that air is heavier than is so often supposed. Let's now consider the consequences.

VELOCITY INFLUENCES

Chasing flow at the expense of port velocity can be much of a balancing act. This is especially so as the demand from ever bigger cylinders means shifting the priority more and more toward maximum flow, almost at the expense of velocity.

However this is very much a special case such as would be seen with a production Detroit V8 such as a big block Chevy, which can, while retaining production bore spacing, have a displacement in excess of 1400 cc per cylinder.

If production-style heads are used, as is so often the case, these massive cylinders are likely to be fed through an intake valve no more than 2.35 inches diameter. Such proportioning means that we have a seriously air-starved engine if the full rpm potential (say 5,500 ft/min piston speed) of the cylinder is to be employed.

If we remove ourselves from this extreme position of low flow capability for a large displacement, then the balance between port velocity and flow becomes significantly more influential on the power curve. With a big under-valved engine the cylinder never gets filled so there is, during the induction phase, almost always a considerably lower pressure in the cylinder that cannot be made up for by the intake port flow. When the valve size to cylinder displacement becomes more favourable then we find that the port pressures, after BDC and before valve closure, can rise significantly above atmospheric pressures.

That is something that, by one means or another, needs to be harnessed as a supercharging effect. Simply put, we need ▶

CHARACTERISTIC PORT AREA

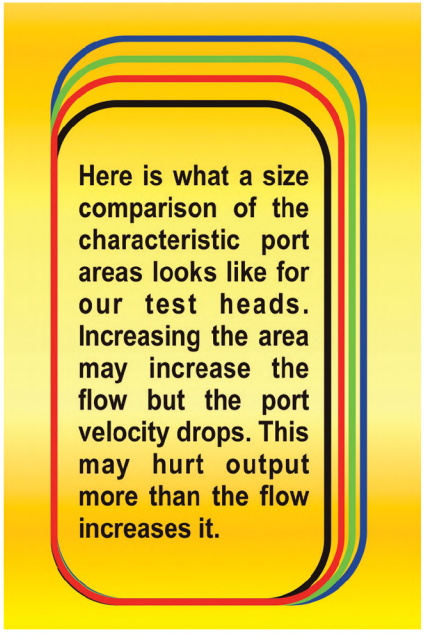

FIGURE 3 Here are the characteristic sizes of the intake ports of the four head specs tested. These sizes are determined using the intake port centreline length and the port volume. Black is 180 cc, red 200, green 215 and blue 230

INTAKE PORT FLOW

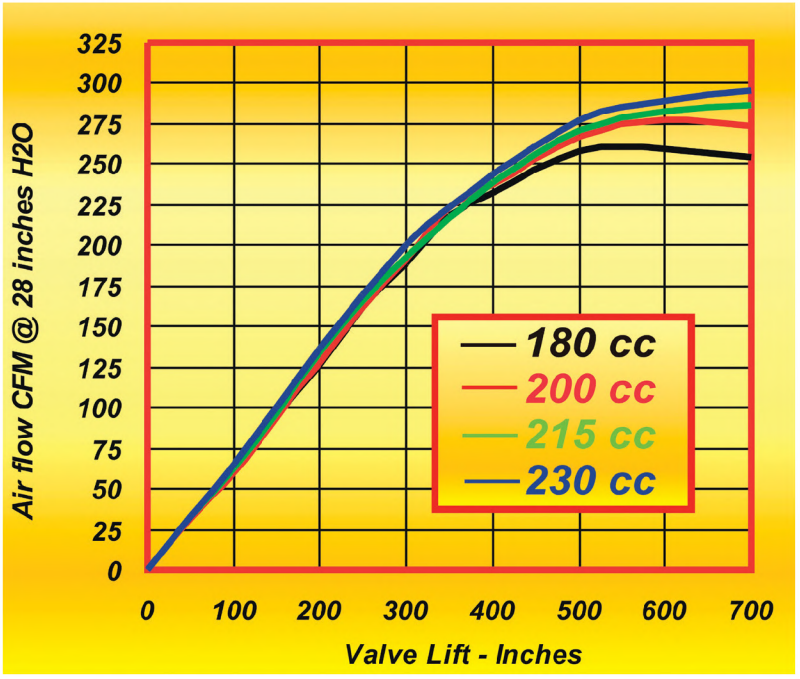

FIGURE 4 Here are the flow figures for the four heads in question. Note that for a similar port form and finish the bigger ports (as was to be expected) only started to flow more air at lift values over 0.400-inch lift. With the test engine valve lift was limited to a little over 0.500 inches

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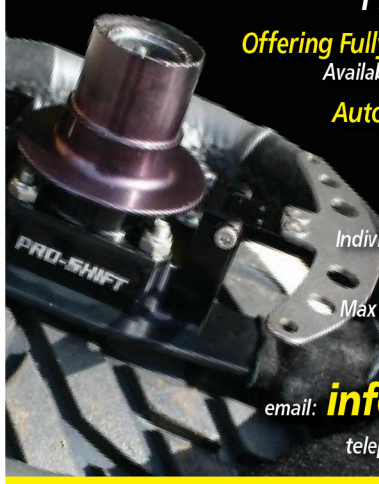

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the air, as far as possible, to have not only sufficient flow but also sufficient velocity that, from the point of induction to the point of exit at the valve, its flow, during the overlap period, is unidirectional. That means no reversion.

We have already established that air is so much heavier than often supposed. This means that, given sufficient velocity, the kinetic energy contained in the intake ports can be significant. In theory it should assist toward ramming the cylinder during the last few moments of the induction cycle. Assuming for the moment that any use of the induced charge's kinetic energy is practical, then it's a good bet that we should also ask ourselves just how critical the balance between striving for airflow vs velocity is.

Whereas airflow will almost certainly be the #1 priority, velocity can, as many dyno tests have indicated, come in at a respectably close second place. Also it's worth keeping in mind that kinetic energy is equal to ½ MV^2. This means if a port is just 10% bigger than optimal, the kinetic energy drops by 22%. Indeed practice shows that, if in doubt, it is better to err on the smaller side rather than the larger.

In case there is any possible doubt, this is as good a time as any to establish if, in fact, port velocity does actually have a significant effect on the torque/power curves. The results of some tests I ran at the bequest of the big performance head and block company Dart Machinery Inc., in Troy, Michigan serve to illustrate the issue being discussed here. To see the extent port velocity influences the power curve check out Figures 3, 4 and 5.

Figure 3 shows the representative sizes of the ports tested and Figure 4 the airflow each port size produced with a fixed valve size. These tests present strong evidence that intake port velocity (and for that matter exhaust velocity also) strongly influences the shape of the torque curve (and consequently the power curve). Bottom line: size does matter and even a marginal size excess can be detrimental.

The question now is how do we arrive at a suitable port size other than test what could literally be a truck load of expensive cylinder heads? To be sure we have a maze of obstacles to navigate around but that is where we are going next.

ABOUT THE AUTHOR David Vizard will, over the next few months, be writing a series of 'hands-on tech' articles for Race Tech. Subject matter will be across the board.

David, a championship-winning engine builder/engineer, currently has over 53 years of developmental airflow and dyno testing experience on which to draw for editorial material. He has consulted for various F1 entities as well as Aston Martin, Ford, Chrysler and GM to name but a few. He has also authored almost 4,000 magazine articles, 36 books and over 40 patents.

INTAKE PORT VOLUME OUTPUT COMPARISON

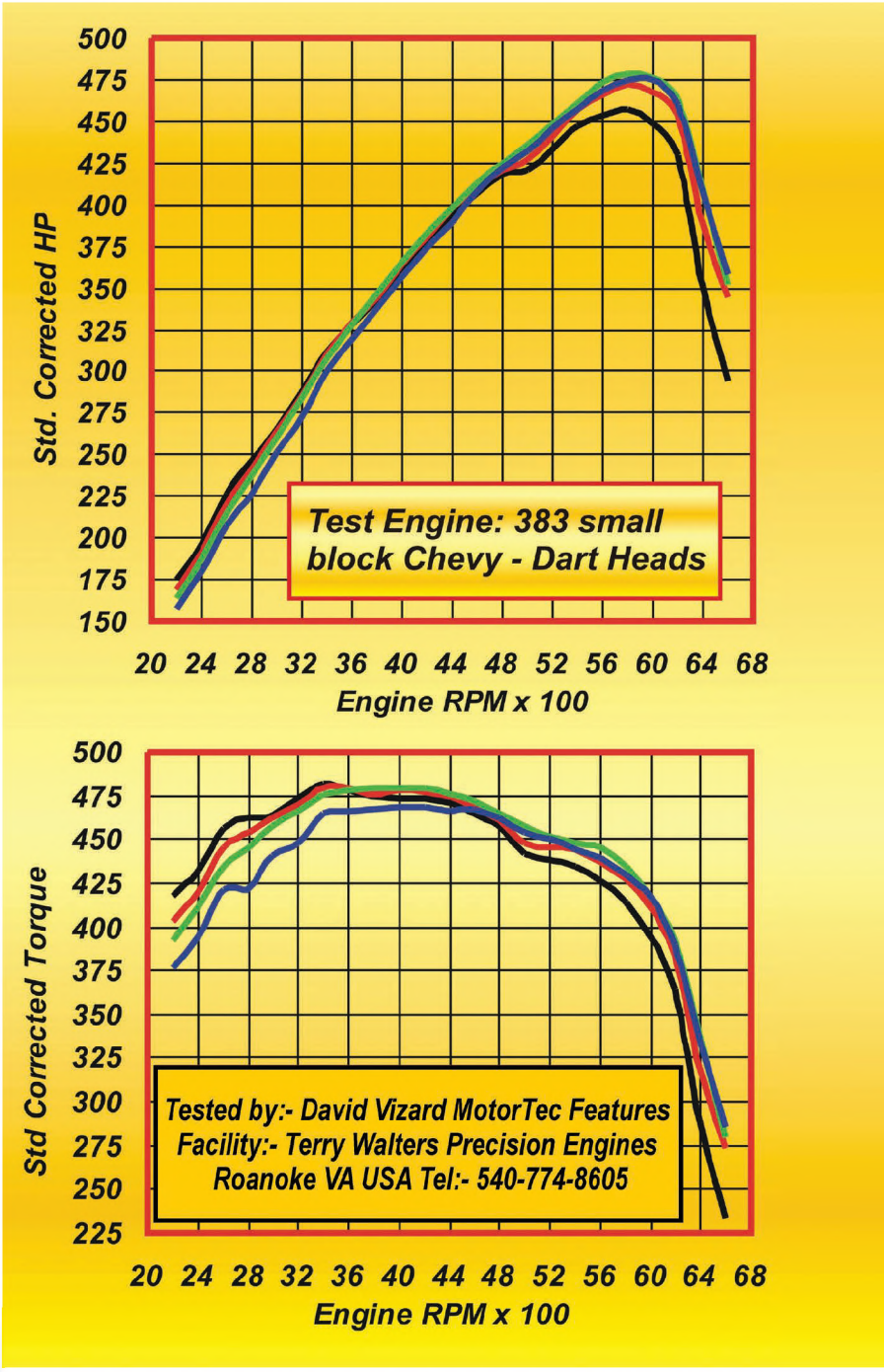

FIGURE 5 The colour codes for these curves are as per Figure 3. As can be seen the 180 cc port produced the best torque curve to 3,200 rpm. From there on up to almost 4,000 rpm it was almost as good as any until about 4,700 rpm. The 200 cc port was down on the 180 by 12 lbs-ft at 2,300 rpm but had almost recovered any deficiency compared to the 180 cc port by 2,900 rpm. As for peak power it was only 5 hp less than the best seen.

The use of the bigger 215 cc port resulted in less low speed torque but by 3,400 rpm it was there with the best. The 215 cc port also, by a small margin, produced the best top end hp. The 230 cc port, though the best flowing, failed to show any superiority anywhere in the rpm range.

These tests indicate that though the 230 cc port produced the best high lift flow, without any low lift flow compromise, the less than ideal port velocity existing countered any possible output gains. Over the rpm range tested the 200 cc port gave the most area under the torque curve.

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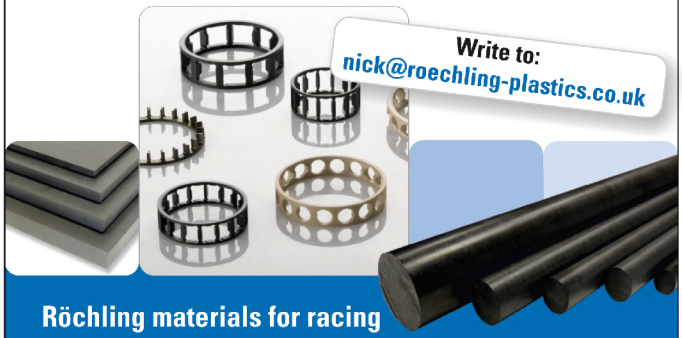

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THE POWER BEHIND THE GLORY

The Mazda Road to Indy development programme has been transformed this season with a new Indy Lights package. **Chris Pickering** investigates the engine designed to help budding Indy stars graduate to the big-time

WHAT did all 11 rows of the grid at this year's Indy 500 have in common? Aside from the obvious spec parts on the cars lining up on the Brickyard's hallowed tarmac, there was another universal feature. Every single row contained at least one driver who'd risen up from IndyCar's official feeder series, Indy Lights – partly because winning the Lights series grants you a scholarship to IndyCar, including a drive at the following year's Indy 500.

At the beginning of this year the one-make Indy Lights series went through a substantial makeover. A new chassis was brought in from Dallara, while the old naturally aspirated 3.5-litre Nissan V8 gave way to a two-litre four-cylinder turbo engine from AER, based loosely on the Mazda MZR production unit.

AER had considered a number of different inline-four turbo designs from its back catalogue before settling on the engine that's internally designated the P63.

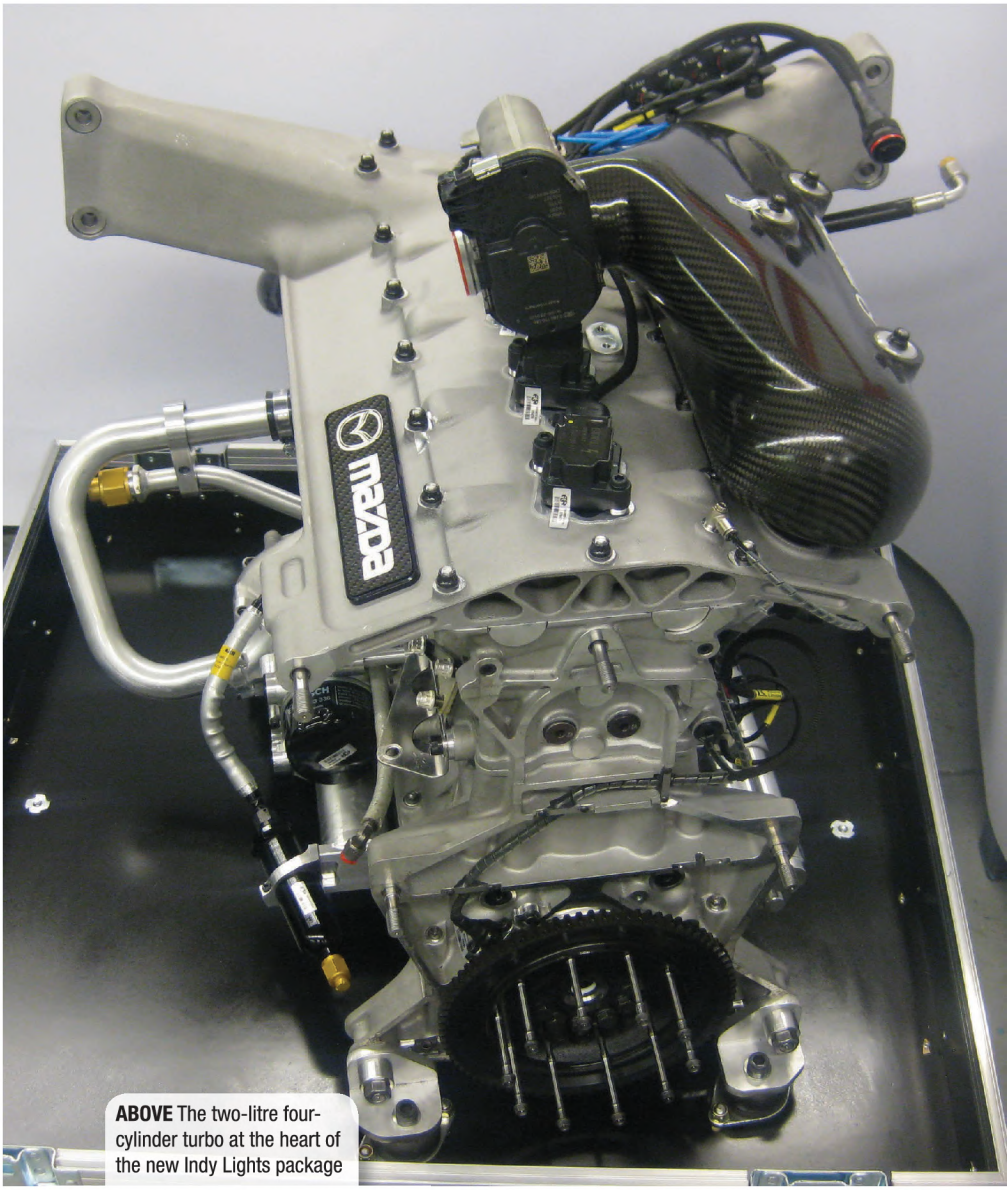
Without any competing engine suppliers to worry about, the priorities were to make the engine strong and light. Some of the more expensive design features found within the range were deemed unnecessary for the one-make series, where the engines are leased to the teams for $88,000 (circa £58,000) per season.

"Andersen Promotions made it very clear that the engine had to be light, powerful and robust," recalls AER managing director Mike Lancaster. "The target was 6,000 miles between rebuilds, allowing it to run a full Indy Lights season. They were also very clear that we needed to achieve a very small tolerance in power levels, both between the individual engines and over the course of its rebuild life."

A FAMILY AFFAIR

This isn't the first time AER has worked with the Mazda MZR engine. In 2006 the company developed the MZR-R engine for sportscar racing, but the new Indy Lights engine also takes a lot of inspiration from the MZR-R's predecessor, the AER P07.

In design terms, you could say it's an amalgamation of the two. The reciprocating assembly owes much of its design to the MZR-R, with pistons and rings from Capricorn, coupled to an Arrow Precision crank via a set of Matzinger rods. Meanwhile, the block and cylinder head architecture is closer to that of the AER P07. It uses a fairly substantial all-aluminium structural design, which incurs a little more weight than the MZR-R, but ▶



ABOVE The two-litre four-cylinder turbo at the heart of the new Indy Lights package

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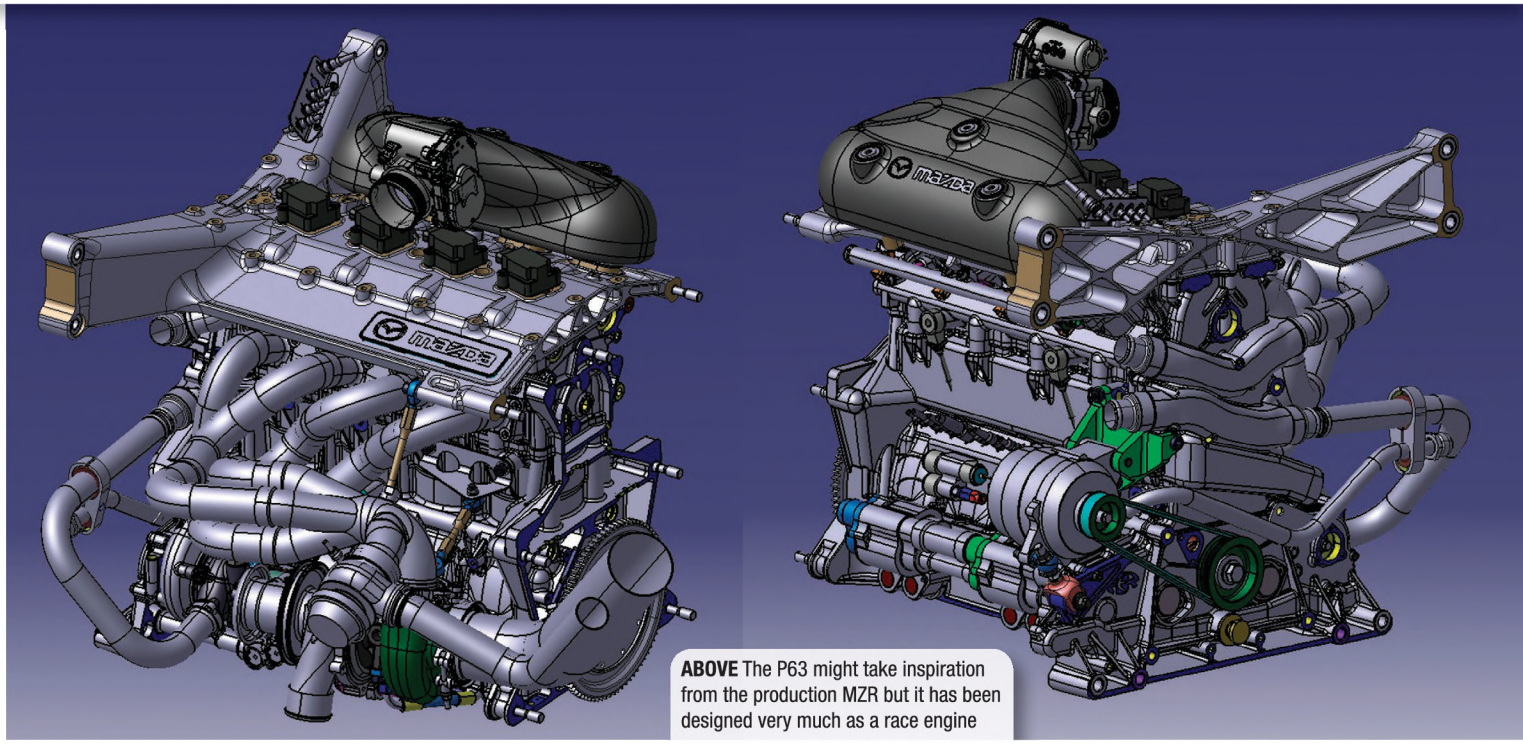

ABOVE The P63 might take inspiration from the production MZR but it has been designed very much as a race engine

improves longevity. In total, the P63 weighs around 104 kg (230 lb) dry.

The cam drive on the P63 also takes its lead from the P07. It uses a split chain and gear drive for the valvetrain, whereby a short chain takes the drive up to a set of gears controlling the camshafts. At the relatively low engine speeds encountered in Indy Lights – the rev limit is set at 8,000 rpm – AER's engineers found this solution enabled them to achieve similar tolerances to the MZR-R's gear-driven system at much reduced cost. It's also a maintenance-free system for the rebuild life of the engine and it rules out a number of potential issues with torsional vibration, without the need for torsional dampers within the gear train.

"If you're attempting to achieve extremely tight valve control tolerances at very high engine speeds, like you are with some of the smaller sports car engines, you need to use very accurate gears all the way up the front of the engine," says Lancaster. "The tolerances for the gear centres require the use of very expensive ground gears and you can spend tens of thousands on the gear drive alone."

The P63 is by no means a production engine, but it does have some structural similarities to the MZR (and hence Ford's derivative, the Duratec) Lancaster explains: "The structure of the MZR is very strong, so we take some inspiration from that even though it's a purpose-built block. Likewise, the valvetrain layout is broadly similar in terms of valve angles and positions.

"It's very much a race engine, though. The problem with taking a pure production engine and turning it into a race engine is that you end up doing all the work again. What works well for emissions, for example, in a road car engine doesn't necessarily suit a race engine."

> *"Part of the remit was to produce an engine that reflected current trends in top end motorsport"*

Part of the remit from Indy Lights was to produce an engine that reflected current trends in top end motorsport, and the IndyCar series in particular. As such, the organisers were keen to see the use of a relatively small capacity turbocharged engine with features like paddleshift and push-to-pass.

One thing that's been omitted, however, is direct injection (DI). While the various engine suppliers in the full-fat IndyCar series use DI, the added cost and complexity of this approach was deemed unnecessarily costly for Indy Lights.

Instead, the P63 uses a set of port-mounted fuel injectors fed by conventional high pressure pumps and a fuel pressure regulator. The carbon fibre inlet plenum has its own drive-by-wire throttle body, connected to a set of carbon fibre intake runners. The whole system is controlled by the F88 ECU from AER's sister company, Life Racing.

As with most of the AER range, the P63 uses a Garrett turbocharger. Strictly speaking, it's a collection of different components taken from the Garrett parts catalogue, including specially selected housings and core assemblies to get the right level of airflow and inertia.

Again, it was a question of balancing costs with tough performance and reliability targets. "The sort of turbos you'd find in something like the WEC are a work of art, with titanium bodies and thin-wall magnesium compressor housings, but they're not cheap," says Lancaster. "The Indy Lights engine had to be reliable, well-packaged and capable of producing a lot of power, but it also needed to be cost-effective. We've ended up with a very good quality part that costs about a quarter of the cost of a WEC turbo."

KEEPING IT TOGETHER

Producing 450 bhp and 470 Nm of torque in normal running, the four-cylinder AER engine outperforms its V8 predecessor. More to the point, it's been designed to do so consistently for a whole season with minimal maintenance.

"The P63 does produce a lot of power for a small engine that has to last for 6,000 miles between rebuilds. It's quite a high duty cycle, particularly for an engine used on ovals [where there's a lot of full throttle running]," Lancaster points out.

Racing in the Indy Lights can be quite ▶

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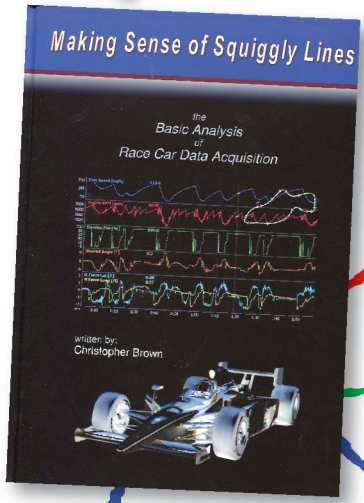

BY *CHRISTOPHER BROWN*

The basic analysis of racecar Data Acquisition

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physical at times, so the P63 – which is a fully stressed chassis member – has to be built to last. High speed ovals and very bumpy street courses mean the engine has to be structurally as well as mechanically tough.

All the engines are assembled onsite at AER's facility in the UK and then dyno tested to ensure they meet the required performance criteria. In a one-make series it's vital that the power output and torque characteristics are consistent; it wouldn't be a particular problem if every engine on the grid made a few horsepower more than the claimed figure, but it becomes a major issue if half of them do. Consequently, the manufacturing tolerances on things like port sizes and compression ratio are rigorously enforced. The turbochargers, too, are very closely monitored to ensure that wastegate performance is identical across the grid. Finally, the standardised calibration has very tight controls on things like boost pressures and temperatures to ensure consistency.

AER worked closely with Indy Lights chassis supplier Dallara on the integration of the engine. The two companies have collaborated previously on projects such as the World Series by Renault and GP3, but this was their first time working on an oval racer together.

> *"A self-learning algorithm allows the ECU to automatically identify which gear ratios are being used"*

"[Being inline] the P63 is quite narrow for a stressed member, but it works well," comments Lancaster. Mechanically, the power is transmitted to a six-speed semi-automatic gearbox from Ricardo via a Tilton carbon clutch, but it's electrical integration that's often more of a headache on modern racecars.

AER arrived quite late to the party. By the time Lancaster and his colleagues came onboard the series organiser had already specified the chassis electronics. That meant the Life Racing ECU needed to work with the dashboard display, data logger and wiring loom provided by Cosworth.

In the end this proved to be relatively straightforward, he explains, not least because the F88 ECU also controls the paddleshift system. This means there's no need for potentially problematic CAN data streams between the engine and the transmission to control the gearshift strategy, although both units are connected to the vehicle's network for things like data logging. Its party-piece is a self-learning algorithm that allows the ECU to automatically identify which gear ratios are being used, removing the need for the race engineers to re-calibrate it.

That's just one of a number of clever features in the ECU. It also features a closed-loop knock control system with two ▶

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ABOVE Indy Lights has forged its reputation with close racing, the new era proving no exception

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sensors – one monitoring cylinders one and two, while the other looks at cylinders three and four. The ECU switches its attention to whichever sensor is closest to the cylinder firing at that particular time, providing individual control for each cylinder.

"The fuel used in the series is good quality, all the engines run the same calibration and they all make the same power so it's not as if they're being forced into areas where they're likely to experience detonation," Lancaster points out. "But it's always a good idea to have knock control running in the background. It does help to prevent engine trouble. We've had no knock-related problems at all."

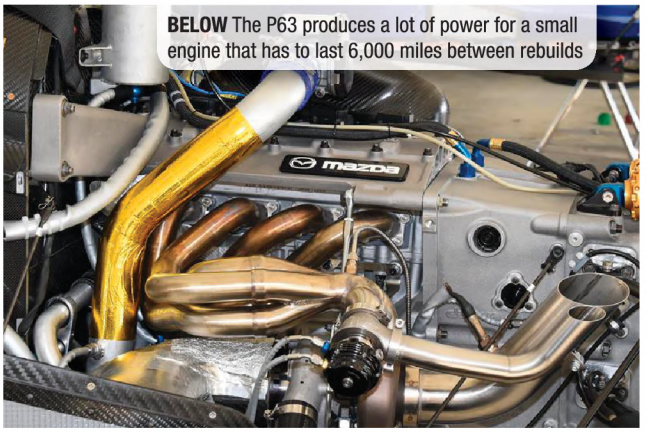
Another interesting feature is the push-to-pass system, which is something the organisers were keen to see included to help the drivers as they progress towards other series. It temporarily increases the boost pressure and modifies the ignition timing to raise the engine's power output to around 500 bhp.

"It's taken the drivers and the teams a while to get used to push-to-pass," notes Lancaster. "Gearing is quite critical as to how you use the system, as obviously is position on the circuit."

POTENTIAL

AER ran a test car through much of the 2014 season, during which time different performance levels were evaluated, along with various tweaks to the installation. This year marked the full-scale introduction across the series, and the new package has proved a hit.

"The engine has been fundamentally reliable from day one, but there have been little things like pipe layout, wiring and sensor



BELOW The P63 produces a lot of power for a small engine that has to last 6,000 miles between rebuilds

locations that we've had to move round, plus a few adjustments to the throttle bodies," notes Lancaster. "We've also worked with our alternator suppliers WOSP on some upgrades to the alternator to iron out a couple of teething issues."

The new car seems to have stirred a renewed interest in the Indy Lights category, where order books are swelling and bigger grids are expected for next year. One thing that's not expected to change in any significant respect, however, is the engine. Lancaster says there's plenty of potential left, should the base power output or the overboost need to be increased in the future, but having proved its worth in 2015 it looks like the AER P63 will remain largely unchanged next year. By that point at least one more Indy Lights driver will be on their way to the gird at the most famous race of them all.

Photos @ Indianapolis Motor Speedway, LLC Photography

ABOVE The new-generation engine is mated to an IL-15 Dallara chassis billed as stronger, safer and sexier!

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ABOVE Bilstein's 4-way MDS provoked much interest

SHOW SEASON KICKS-OFF

As the racing season winds down, the show season gears up with loads of new products being shown for the first time, as **William Kimberley** discovered when walking the PMW aisles in Cologne

THIS year's PMW exhibition had relocated to a hall that was its original home a decade ago, where more than 230 exhibitors were ready to do business. One such was **Bilstein** with its new 4-way MDS motorsport suspension taking pride of place. With independent damping force adjustment in one rebound and three compression stages, it offers a wide range of individual adjustment options. There are 10 clearly discernible clicks from one (soft) to 10 (hard) to meet the demands of every circuit or vehicle.

"There has been so much interest in it that we've had to revise our production plans," commented Martin Flick, Bilstein's motorsport manager.

Its proven 2-way version of the MDS, meanwhile, has been revamped especially for the so-called Modularen Querbaukasten (MQB) for cars from Volkswagen with transversally-installed engines and gearboxes. The suspension experts also demonstrated the adaptability of the modular damper system with a special 2-way version of the MDS for Formula E cars.

Proudly on display on the **bf1systems** stand was the steering wheel for the 800-plus bhp, all-carbon fibre Aston Martin Vulcan. Key functions including the starter button, neutral, pit lane limiter, indicator, flash-to-pass, adjustable ABS, traction control and wipers are grouped in a logical manner on the wheel. The gearshift paddles are on the back of the wheel, rather than steering column, so that they turn with the wheel and are therefore always placed at the driver's fingertips.

"The wheel is made up of over 250 individual carbon pieces, with the electronics sitting within the wheel's structure," said Carol Calver, sales administrator at bf1systems. "It is trimmed with soft grips and hand-finished in Alcantara. Each wheel is supplied to Aston Martin in a bespoke carry-case finished with a plaque marked with the unique serial number allocated to the car."

This special track-only supercar also features bf1systems' tyre pressure monitoring system with auto learning capability. This allows any wheel to be fitted onto any corner of the car with the system automatically detecting the sensor and starting to monitor it. This removes the need for engineers to assign wheel sensors manually. When the car is on the track, the wheel sensors transmit at 1Hz, ensuring the driver is able to monitor their tyre pressures with a resolution of 14.7 mbar, and to see tyre temperature changes with a resolution of 1°C. The on-car system is also supported by the hand-held mini analyser which allows engineers to check the status of the tyres before they are fitted to the car, ensuring they are always in their optimum condition.

Launching at the show was a 2016 update to the current learning TPMS which brings the auto learning capability currently available to GT cars to all closed-wheel racecar applications, including LMP1, LMP2 and LMP3. The update works with the ▶

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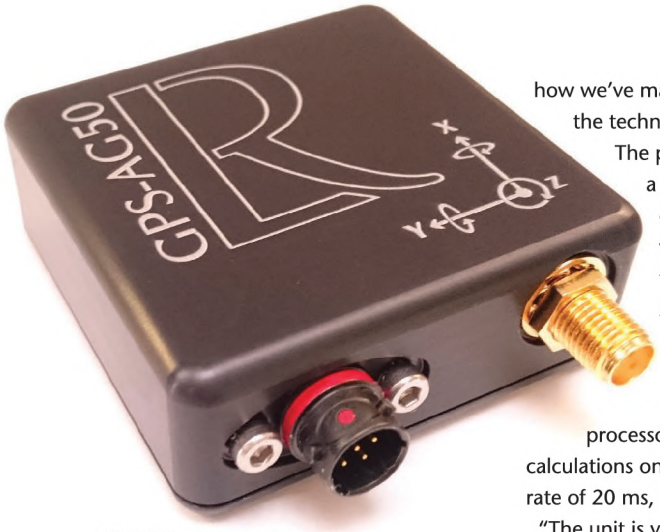

ABOVE The order books are filling up for Life Racing's GPS-AG50

existing TPMS equipment, reducing the current six components of antennas and triggers down to four combined trigger antennas. Each is mounted in the wheel arch and both activates and receives data from the wheel sensors.

"The new learning TPMS has attracted a lot of interest, both from existing customers looking to upgrade, but also from new customers who understand the benefits of the auto learning system we have provided to GT racing for over five years," reported Calver.

Life Racing was showing its new GPS-AG50, the world's first true 50 Hz low latency GPS module with combined 6-axis motion pack designed for the professional motorsport industry. It uses advanced correction from SBAS (WAAS/EGNOS) to achieve high levels of positional accuracy to within 2.5m. It stores satellite information when powered off by means of a rechargeable lithium battery, allowing hot starts in less than three seconds.

The motion sensor pack consists of a 3-axis accelerometer up to 16G and a 3-axis gyroscope up to 1,000 deg/s with individual software programmable filtering levels. All GPS ad motion sensor information is available on CAN with update rates of up to 1,000 Hz.

"At 50 Hz you can do all your track analysis as well as motion analysis and things like touch control, launch control which is where you need low latency and high accuracy GPS data," said Jason English, senior applications engineer at Life Racing. "One of the main questions at the show has been how we've managed to achieve 50 Hz, and the technical answer is very simple. The processors that are used in a lot of GPS systems that are commercially-available are not very powerful. They receive the information at a low speed – 1 Hz or 4 Hz – and extrapolate the position from there. We've selected an extremely powerful processor that's able to do those calculations on the fly and give an update rate of 20 ms, which is 50 Hz.

"The unit is very compact and ideal for a huge number of vehicles and even boats. The aerial is external so the antenna can be run out to the car for full signal coverage. One new feature we've added is that all the circuit information, such as the start/finish line and sector splits, can be pre-programmed into the box. A number of circuits can be stored so when you get to one, it automatically knows where you are and begins acting as a lap beacon; the timings are sent out on CAN and also as an analogue input to work with existing systems. Full-scale production is happening right now and the order books are already looking good."

ABOVE & BELOW DC Electronics' EPAS Pro Street MGU (above) and Pro Race ECU (below)

The **DC Electronics** stand featured two new electric power-assisted steering systems (EPAS) – Pro Street and Pro Race – to complement its current steering product range.

Designed for markets such as classic cars, hot rods and low volume sports car builders, the Pro Street System brings electric power-assisted steering to road cars, without the need to change the steering rack or fit a hydraulic system. It is available in two styles – a complete height adjustable, collapsible steering column (Pro Street Column) or a shortened motor/gearbox to go in line with the existing steering column (Pro Street MGU). Because the systems come from an OEM production vehicle and retain the OEM controller and software, they are suitable for road use.

The Pro Race System is a cost-effective EPAS system for motorsport use only that comes complete with motor/gearbox, ECU and wiring harness. The ECU and software is custom-made by DC Electronics. Although the system retains the five user-selectable steering maps that can be found in the company's existing EPAS Ultra system, these are factory fixed and not adjustable and there is no CAN Bus feature on this model.

"What we've found is that a lot of people don't necessarily need the programmability that's in the ECU," said Martin Dewey, general manager at DC Electronics. "All they want is to plug it in and race, so the Pro-Race version is around 60% of the price of the motorsport one. We were also getting a lot of interest from people who run classic cars, so we introduced the Pro-Street version, which is around half the price again of the Pro-Race one, which makes it extremely affordable for people running those cars or hot rods and track day cars."

In response to customer demand, British manufacturer **Lazer Lamps** has released a genuine game-changer to the world of aftermarket lighting. Its latest Triple-R 1000 light now comes with unique 'E-Boost' technology, which allows the lamp unit to effectively be two units in one shapely package. ▶

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ABOVE 'E-Boost' technology effectively transforms Lazer Lamps' Triple-R 1000 into two units in one package

By the simple removal of the patent-pending E-Boost cap, the lamp can be effectively switched to a fully road legal and ECE-approved driving light, running at 60% of its lighting capacity and switchable by the car's main-beam dip switch. Add the E-Boost cap back in, though, and the lamp unit becomes an incredibly bright and effective motorsport-quality lamp, which offers crystal clear clarity and natural white light to ensure safe and effective night-time driving.

In ECE-approved mode, the set up offers over 900 metres of clear, visible light, with 1 Lux of lighting power available up to 450 metres of that area. In unrestricted trim, things move up a notch or two: 1.2 kilometres of lighting power, with 1 Lux now available at 600 metres. This is the same kind of performance usually only enjoyed by Lazer Lamps factory-supported motorsport teams, which include the likes of Aston Martin, Bentley and M-Sport.

The thinking behind this lighting option is to satisfy enthusiasts that need a dual-purpose lamp for motorsport, leisure or professional use. For road rallying, these lights are an essential and for responsible off-roading, they allow the driver to arrive at the venue in fully road legal trim before switching in an instant to much greater power. Fully legal in every EU country, these units are also proving to be popular in both defence and rescue applications.

The manufacturer of specialist starter motor systems and high quality flywheels for the motorsport industry, **Ark Racing** was displaying a new range of carbon fibre wheels. However, this was just part of the story because according to managing director Nicholas Beere, the company is producing uprights to get a big brake package into a sports car it is building. "We then thought we'd go to the stage of producing carbon fibre rims," he said. "We're not scared of the technology."

Piper Cams was displaying its new range of cams for the 1.6, 2.0 and 2.3-litre Ford EcoBoost and the new BRZ FA20 Subaru and Toyota GT86. "We do stuff for Mountune which has done very well in the British Touring Car Championship in the Motorbase Focus. That has brought us to the attention of many potential customers," said John Crabb, Piper Cams' technical director. Next stop for the company is the PRI, with expectations that its cams for the 2.3 EcoBoost engine, already in use in the Ford Mustang, will prove to be popular along with the general engine downsizing that is already occurring in the US.

Established in 2001, **SKF Racing** focuses on bespoke projects rather than selling catalogue products. "We have a wide product range and can provide support from standard to fully customised rolling bearing solutions," said Jean-Sylvain Migliore, the SKF Racing unit director. "But what our customers are looking for is the technical support we can provide on a short lead time, even in a matter of a couple of hours when required. We are a small team of just 15 but can call on another 65 people or so when required."

"We came out with our 2016 catalogue just before SEMA and have that here," said Chris Brown, **ARP**'s director of specialty products. "We also show our distributors and dealers the new kits we have, which are highlighted in the catalogue by being printed in red. It's to let them know that we are not standing still and churning out the same stuff but making them aware of the new kits we are developing.

"The other thing is that the two displays that we have here at the show are everything that are not in the catalogue, showing people who aren't familiar with us what we can do. The reason we put them in open-cased displays rather than behind glass

> *"We want people to pick them up and feel them"*

is that we want people to pick them up and feel them and this has been very successful to help them understand the quality of our products. It also shows them that we produce bespoke items as well."

According to **Elite Transmissions** managing director Mark Bloor, it was a good show for them, the company having exhibited there since the start. "It's all about getting your product out to the Europeans and is a good meeting point to see existing customers and talk about new things we might be developing," he said. "We provide product for a wide range of racing series from stock cars to Formula 1 and also historic."

Another regular PMW exhibitor is German company **Fluro-Gelenklager** that as usual was showing its full range of spherical bearings and rod ends for motorsport applications. Of particular interest was a bearing it has produced for Porsche owners. It featured a completely new housing made from titanium, into which was mounted its rod ends for motorsport applications. "We were originally commissioned to produce between five and 10 pieces, but now we are selling them in quantities of 30, 40 and 50 items," said sales manager Gino Fusco.

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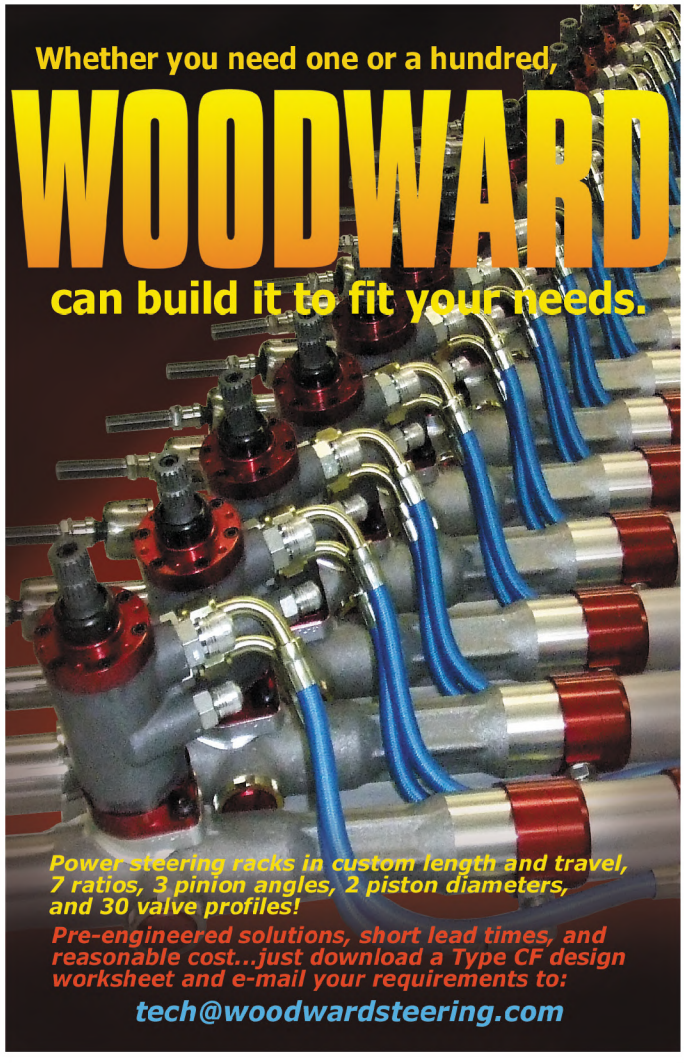

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NEW TECH HEADING FOR INDY

William Kimberley previews some of the innovations that will grab the headlines when the PRI Show is back in town this month

C&R Racing is coming to Indianapolis cock-a-hoop at having scooped a couple of prestigious awards at the SEMA Show in Las Vegas in November. Its new Ice Barrel intercooler won the SEMA Best New Performance-Racing Product of 2016, while it also landed two global media awards for its new transmission oil cooler kits.

The Ice Barrel intercooler, which has been designed for the drag racing market, uses C&R's revolutionary seamless round leading edge tube design with internal fin. It utilises a straight-through tube arrangement like the "liquid to air" barrel, but the Ice Barrel is designed specifically to run dry or regular ice. It incorporates a wide 18 mm tube pitch, a finless ice compartment, sealed access lid and a CO2 breather fitting and drain plug.

C&R's patented dimpled plate and fin transmission oil coolers are made from 100% aluminium, which makes them extremely strong, lightweight and compact, offering heat transfer and easy mounting. The plates re-direct oil flow and the unique louvered fin design provides high heat transfer and low pressure drop. C&R claims that transmission oil temperatures are reduced and that they can either be used in conjunction with a factory transmission cooler or used standalone.

ABOVE C&R Racing arrives at PRI with award-winning products for the drag racing market

ABOVE Turbosmart's e-BoostHP electronic boost controller

Another company coming to the PRI on the crest of a wave is **Turbosmart**. Its e-BoostHP, an electronic boost controller capable of handling up to 120 PSI of boost pressure with extreme precision, picked up SEMA's runner-up award for the best new street/performance product and five global media awards. The e-BoostHP is able to manage six boost groups, which can be correlated to gear, rpm or elapsed time, plus an auxiliary output such as methanol or nitrous injection.

It features a new, very robust high-range MAP sensor design and cutting-edge boost control algorithms, incorporating push-lock fittings and high pressure hoses to ensure durability and relentless performance under a wide range of extreme boost pressures. Technologically advanced, yet easy to use, it will be available for sale in early 2016.

Turbosmart will also be displaying its Pro-Gate50 Lite wastegate and Race Port Sensor. The Pro-Gate50 Lite is a new external wastegate that combines big wastegate flow and performance in a compact package. This makes it perfect for kit builders and other applications where performance of a larger wastegate is required, but space for turbo components is at a premium. With a 50 mm valve size matched to a compact cap, it fits in the Turbosmart external wastegate line up between the Hyper-Gate45 and the full-size Pro-Gate50.

It features Turbosmart's precision-engineered wastegate body designed to have a superior flow path, improving the wastegate's performance relative to its valve size. Its unique locking collar allows for quick spring changes, and a heat-shielded, Nomex-reinforced diaphragm for excellent heat resistance.

Turbosmart's new race port sensor cap adds revolutionary data-logging capabilities to the company's highest-flowing blow-off valve. The sensor cap enables the user to gain an insight into the blow-off valve's behaviour under different engine operating conditions. This is the world's first blow-off valve with valve position logging.

The race port sensor cap allows an upgrade to existing – locking collar-style – race port blow-off valves to obtain data via an analogue position sensor. It is compatible with a wide range of popular data loggers. Information such as blow-off valve reaction time and valve position versus manifold pressure can be readily obtained thanks to the sensor cap. This data can in turn be used to maximise turbocharger performance. ▶

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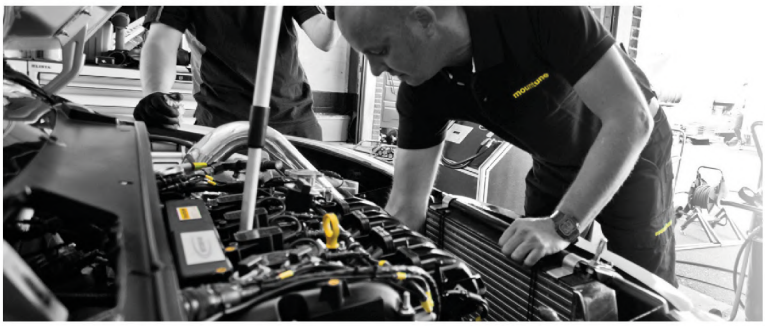

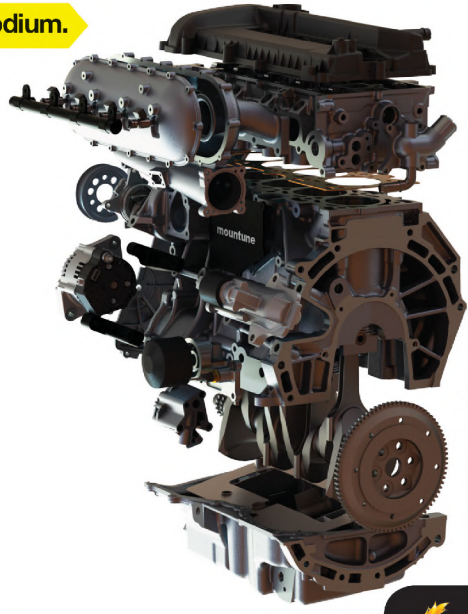

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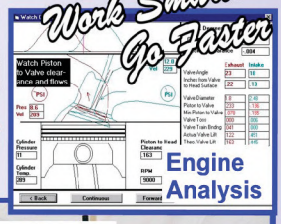

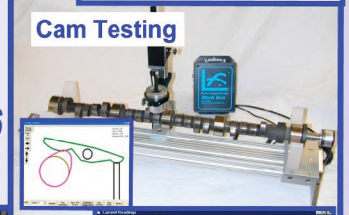

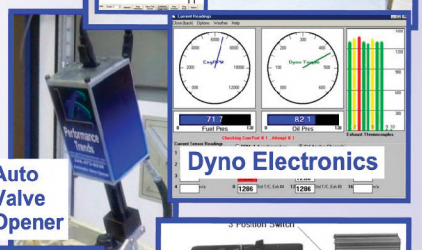

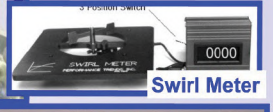

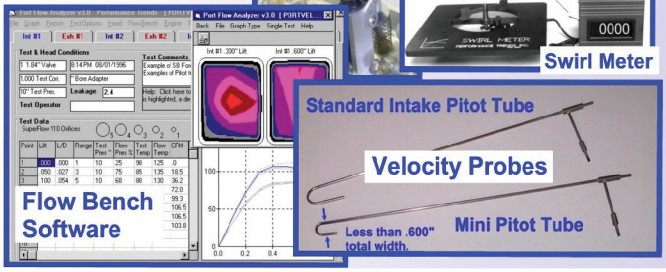

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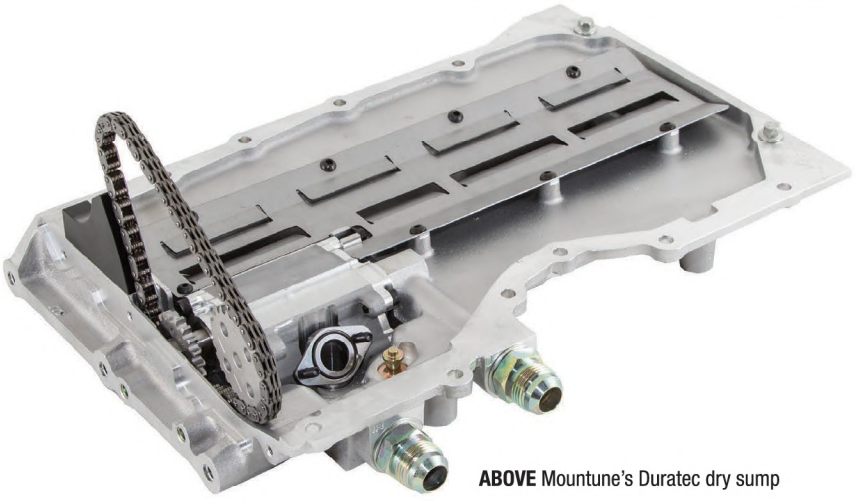

ABOVE Mountune's Duratec dry sump

Turbosmart has also released details of its Kompact Shortie Plumb Back blow-off valve for the Ford Fiesta ST. With its billet aluminium construction and a lightweight brass/aluminium two-piece piston, which is then perfectly matched with precision-engineered springs, the Shortie provides razor-sharp boost response and significantly greater boost handling abilities, up to 30 psi.

SPA Design will be exhibiting its new fire suppression system with APS – Advanced Propulsion System – technology that has recently been homologated by the FIA. It effectively 'snuffs-out' the fire, rendering the area safe and virtually removing the threat of reignition. This is largely achieved through the use of a slave compressed gas cylinder in conjunction with a clever new internal chamber system that forces whichever suppressant has been selected at high speed through the auto-flo nozzle to reach the target area and fully suppress the fire.

It has undergone an extensive testing, development and validation programme in order to comply fully with the new stringent FIA regulations. These state that the system is deployed in both the engine bay and the cockpit, meaning that teams will use two bottles. It is now available for teams to run trials in preparation for the 2016 World Rally Championship.

Another SEMA award winner attending the PRI is **BBS of America**, which was honoured for its two-piece Motorsport Tuner Wheel. "This is a combination of our successful three-piece E88 styling and LM aftermarket wheel," says Erich Gissler, who heads up BBS Motorsport in Germany. The company will also be promoting its new FI-R, an ultra-lightweight forged wheel it has been working on for over a year.

ABOVE BBS' two-piece Motorsport Tuner Wheel

Samco Sport is another company heading to PRI on a high. It was a winner at SEMA for its AeroFlo product, a simple and secure solution for quick-release radiators and intercoolers that eliminates the need for complex tube bending. The flexible silicone hose dramatically reduces the risk of bent or broken tubes in an accident.

"Unlike Wiggins-type assemblies, it has the flexibility of a Samco hose on the end of it; so in the event of a shunt, it's still possible to finish," says product development manager Mark Hale. "It's a high temperature and high pressure Aramid-reinforced hose capable of 250°C that's ideal for most race applications. We've run it over the last few months with the Ford team in the British Touring Car Championship. They are impressed with it and will continue next year."

Hale says that the company is now looking to get it into the US market, particularly NASCAR and off-road where the cars are subjected to vibration, shocks and bumps.

Although **ARP** exhibited at SEMA and then the PMW Expo in Cologne, Chris Brown, the director or specialty products, believes it's a different crowd that attends the PRI. "Typically, it's more the end-user that comes to the PRI," he says. "We'll be having our new catalogue there and have far more ability in real estate to have more of a display. It's also a question of supporting the dealers and talking to the end users, the engine builders."

Mountune Racing will be attending the show with its portfolio of performance products. They include its new E063 low-line dry sump for the 2.0 and 2.3-litre Ford EcoBoost and Duratec engines and the 2.0-litre Mazda MZR.

Engineered for maximum oil control, it is manufactured from heat-treated, high quality aluminium for maximum strength and lightness. Complete with internal baffling to control windage, it features a highly efficient 2-stage internally-mounted scavenge pump driven by a concealed chain making installation easy, even in the tightest applications. Designed to integrate with the existing high-pressure pump, an externally accessed pressure relief valve is also included for ease of tuning and adjustment.

It is also suitable for longitudinal applications such as the Ford Escort with a World Cup cross member along with typical transverse mounting. Ground clearance is also substantially improved over the original wet sump.

Performance Trends is exhibiting the new features it has recently released for its popular flow bench software port flow analyser, namely the ability to record and analyse port sound. It works on computers with Windows XP through to Windows 10, and communicates with other commercial data loggers and flow benches, or with Performance Trends' own black box II logger. A very affordable, accurate EZ Flow flow bench can be built using these tools, which can flow from 50 to over 700 cfm.

Other Performance Trends flow bench tools consist of pitot tubes for measuring port velocity – including the "Mini Intake" to get into small ports and spaces – swirl meters, tumble fixtures, recording switches, manual and automatic valve openers, and depression control. Its Engine Analyzer Pro simulation program can simulate almost any type of motor, including 5 hp kart motors through ▶

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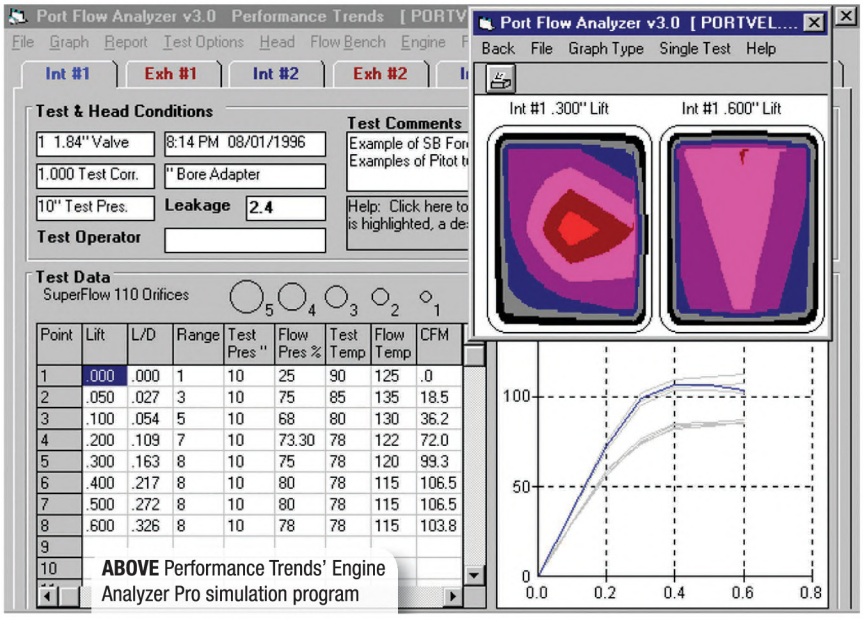


ABOVE Performance Trends' Engine Analyzer Pro simulation program

to 3,000 hp blown alcohol dragsters, gas, methanol, ethanol, diesel, turbocharged, naturally aspirated, or supercharged.

MSD Performance will be showing its virtual dash App that it showcased at SEMA. "We came up with this because when the cars are being warmed up in the pits, it's not always possible to see the dash with people working on the car," says MSD Performance president Tim Anderson. "The virtual dash can be seen while sitting in the pits or in the trailer for that matter. In fact, it's a lot easier to use than the real dash as it's customisable."

Innovate Motorsport will be showing its new ethanol content gauges. "One of the things that is big in the US is E85. It allows more boost without worrying about more detonation, and it's low cost," says Charles Cort, Innovate's general manager. "There is the ECF-1 dual system gauge that displays ethanol content, fuel temperature, air/fuel ratio and fuel pressure. There is another similar gauge that includes boost pressure, and the MTX-D that just shows ethanol content and the fuel temperature.

"They can all be viewed in metric or imperial and they are all configurable to what the customer needs. Typically on Late Model vehicles signals from the gauges for ethanol content will be sent to either a factory or aftermarket ECU, so we provide all those programmable analogue outputs."

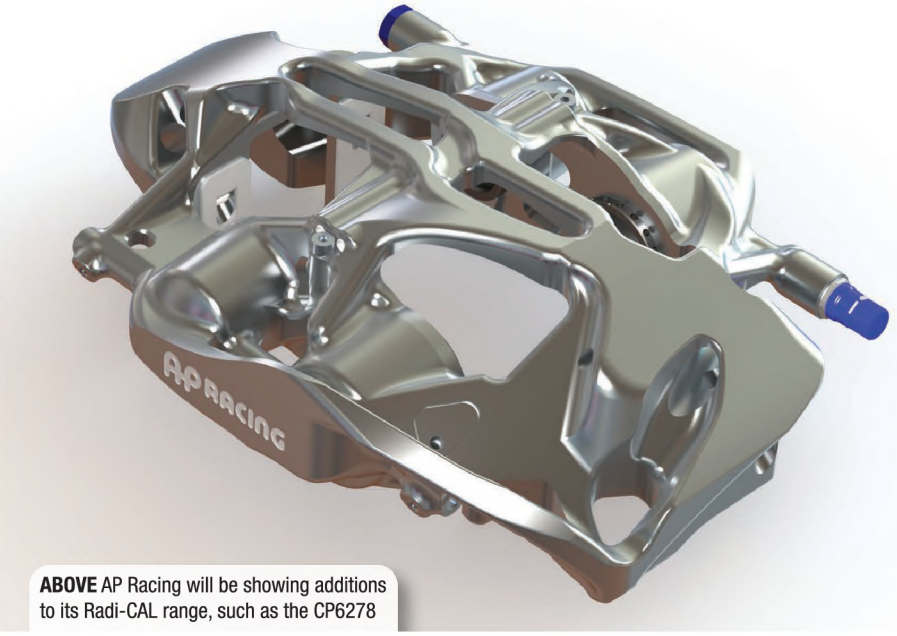
AP Racing, which is located on the **Essex Parts Service** stand, will be showing additions to its innovative Radi-CAL range with two new brake callipers, the CP6277 and CP6278. This six-piston Radi-CAL calliper is machined from solid monobloc aluminium alloy and features a radial mount with 210 x 42 mm centres. The CP6277 is suitable for all GT and Endurance racing.

The CP6278 is a rear calliper four-piston Radi-CAL design suitable for all GT and endurance racing, and features the same cutting edge technology as the CP6277. This includes a radical asymmetric design concept as well as ducted air cooling and a monobloc aluminium body. Callipers are supplied with pistons to suit a 25 mm thick brake pad. Optional extras include dry-bleed fittings and a body thermo-sensor, as well as ceramic piston insulation caps when used with a 32 mm brake disc.

AP Racing has also expanded its Pro 5000 R range, with three brand new entry-level brake callipers. The CP9444 is a four-piston calliper that is suitable for 13" wheel applications. The smaller bore version, CP9445, is of the same design but is suited for rear applications. Both callipers are internally ported. Of similar design, including a forged, two-piece aluminium alloy body, the CP9668 is a six-piston calliper that again incorporates the Radi-CAL design philosophy and features a radial mount with 180 x 42 mm centres. The pistons and wear plates are made from stainless steel, while a bolted pad retainer with a quick-release spring clip is also supplied.

The RL-600 high-performance brake fluid, for street or track use, will take centre stage on the **Red Line Synthetic Oil** stand. Cameron Evans, director of sales and marketing, explains that it has undergone a huge amount of testing during the year: "RL-600 is engineered to maintain viscosity, lubricity and compressibility at extreme temperatures to help safeguard against brake fade and vapour lock in racing, performance and street applications.

"We do brake fluid testing on all our IMSA and in-house cars and know that most of the customers are not reaching the kind of brake temperatures that they need to go to at that level. Also, when they start running some of these fluids, they lose a little bit of that pedal feel that is needed to dance on the edge of ABS and that's a big feature of our new brake fluid. Not only is it priced correctly but the formulation is such that gentlemen drivers prefer it."



ABOVE AP Racing will be showing additions to its Radi-CAL range, such as the CP6278

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IS NISSAN KEEPING A 'PET'?

Jim Hall. Colin Chapman. Ben Bowlby? At what point, asks **Sergio Rinland**, does an innovation become a pet idea?

CREATIVITY. Innovation. 'Pet Ideas'. Much has been said in the past using the first two words.

Creativity is the capability or act of conceiving something original or unusual. Innovation is the implementation of something new.

Artists are creative when they combine materials and/or colours to create a work of art. Innovation is to show that work of art in a railway station instead of an art gallery.

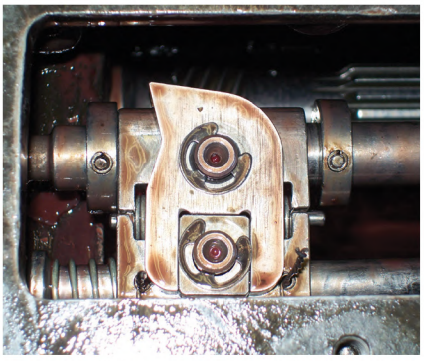
We could say that every designer in our motorsport world is a creative person: they are normally faced with a problem or a challenge that needs a solution, so they create parts which overcome that; some more successfully than others.

Innovation is something different. When I was growing up my role models were Jim Hall of Chaparral and Colin Chapman of Lotus, the two archetypal innovators of the modern era. They were the products of a time when regulations were open and fertile minds could make big steps to achieve success at the racetracks.

They were not always successful. Chapman's sequential gearbox (the infamous 'Queer Box') was hated by drivers and mechanics. It was imprecise and fragile. Jim Hall's automatic gearbox often failed, his fibreglass monocoque was on the heavy side and not stiff enough and the cars were generally unreliable. When they held together though, they were unbeatable, light years ahead of more conventional competitors. Many of Hall's and Chapman's innovations are the norm today due to the advances in technology, materials and manufacturing techniques used by modern designers to overcome the fragility and unreliability of the original ideas.

Those two innovators had many detractors. Both were criticised for the fragility of their cars, and beaten by more conventional but reliable cars such as Ron Tauranac's Brabham in F1 and McLaren in Can-Am. Most of the unsuccessful innovations failed due to the compromises they had to make for its implementation: when that happens, innovations are transformed into what are called 'pet ideas'. If too many compromises are made, an innovation has fewer chances to show its benefits.

It is often said that to finish first, first you have to finish. It has been proven time and time again, particularly in those years when reliability was poor compared with these days with better predictive technologies. The factors conspiring today against innovation are the current restrictive rules, the amount of money involved and the urgency of sponsors and manufacturers to get immediate results. Lack of patience is today a management style.

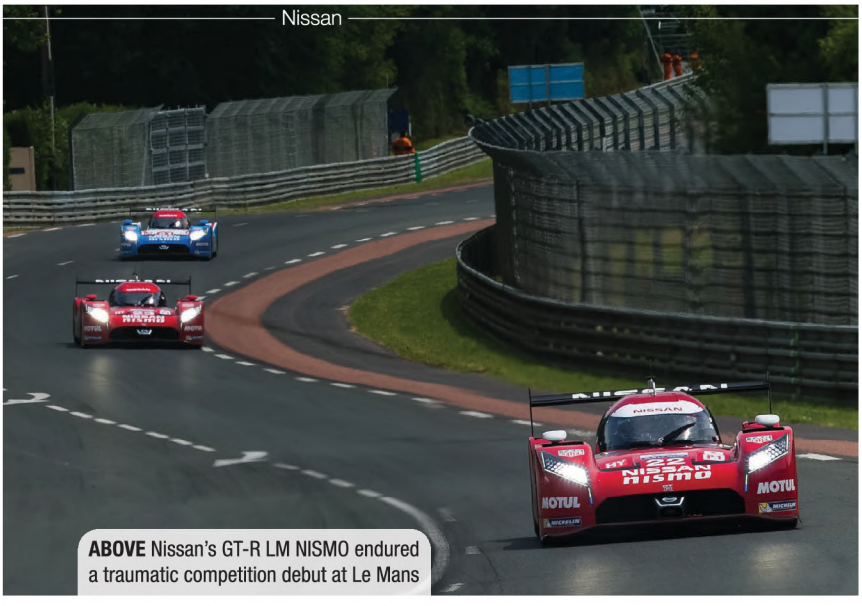


ABOVE Colin Chapman's sequential-shift 'Queer Box' was hated in-period, but the theory was finally vindicated in historic racing when materials science had progressed

There are not too many doors open these days for innovations, but the Automobile Club de l'Ouest left one open where Nissan managed to squeeze through with its radical GT-R LM NISMO car. It had a similar purpose to that of Lotus and Chaparral in the past: to win races with an 'unfair advantage', as Mark Donohue used to say. Have they gone a step too far? Only time will tell. Is the concept flawed? It appears that too many compromises have been made to implement the front downforce freedom the ACO left open. Did that become a 'pet idea'?

With Chaparral and Lotus, others adopted their concepts without the compromises, applied better execution and became more successful than its originators. I bet Nissan's competitors are investigating their ideas and we will see a variation of them in the near future. Perhaps not the full-blown concept, but surely they have shown an opening in the rules to be exploited?

Nissan has gone way outside of the envelope with its LMP1 car. It has shown some interesting concepts and left some unanswered questions. I only hope they have the chance to improve the 'carrier' of their ideas before someone else applies them to better effect. In this day and age, they have shown great courage and for that alone they deserve success. RT



ABOVE Nissan's GT-R LM NISMO endured a traumatic competition debut at Le Mans

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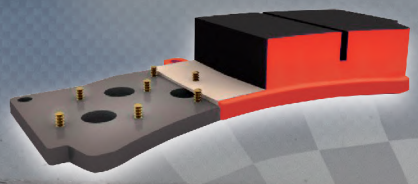

Double DTM Champion Mattias Ekström has clinched his first-ever FIA World Rallycross Championship victory after a flawless drive in the Audi S1 EKS RX in Holjes, Sweden. In his RX campaign, Mattias relies on the supreme stopping power of PAGID RST racing brake pads – high initial bite, constantly high friction over temperature with excellent modulation over the whole temperature range. With the highest degree of braking performance, PAGID RST racing brake pads deliver the competitive edge that successful drivers demand.

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