Interview
Dinesh Paliwal
President and CEO,
Harman Samsung

Diesel’s big breakthrough
Ricardo’s CryoPower promises long haul trucks lower emissions and 30 percent fuel savings

Sounds of silence
Giving electric cars sound quality that’s authentic and appealing

WINNING WAYS
M-Sport’s Ford Fiestas, equipped with Ricardo transmissions, stormed to victory in the 2017 FIA World Rally Championships for both drivers and manufacturers
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This year’s Geneva auto show hosted the auto industry debut of the PAL-V, claimed to be the world’s first production flying car. The Dutch-built machine seats two, uses twin Rotax engines, and has short take-off and landing runs thanks to its gyroplane principle, which uses unpowered rotor blades. The model is already on sale at a price upwards of €300,000.

As the first electric car from a European premium brand, Jaguar’s I-PACE (below) was the talk of the Geneva show.

The market share of diesel cars in Europe fell a sharp eight percent in 2017 in the wake of negative publicity, and overall CO₂ emissions have risen as buyers switch to gasoline models. But at the same time, many in the industry also celebrated an almost 20 percent spike in the sales of SUVs, the fastest-growing sector of the market. It took independent commentators and environmental organizations to make the connection and point out that the rapid rise of SUVs, with their higher weight and inferior aerodynamics, could be a bigger influence on CO₂ emissions than changes in engine type.

In what is being seen as a landmark judgement, a court in Leipzig has ruled that German cities do have the right to ban diesel cars in order to maintain the required air quality. This further intensifies the pressure on diesel, and automakers are becoming publicly less enthusiastic about the fuel, with Toyota and Fiat-Chrysler abandoning it for upcoming passenger cars.

It had been an open secret that the 2018 Geneva Motor Show would be a landmark event – the debut of the first electric model from premium manufacturer, Jaguar. An all-electric Volkswagen concept previewing the S-Class sized replacement for the Phaeton had been widely tipped, too, as had the European debut of Volvo’s electrified premium sub-brand, Polestar.

But if there was a surprise, it was in the sheer variety of top premium electric metal on show: the extravagant Lagonda Vision luxury sedan concept from Aston Martin, a hybrid Bentley – a first in the super-luxury segment – and Porsche’s unexpected, near-production Mission E Turismo, ruggedized as a Cross derivative. And then there were Italian/Asian designer-label studies, again aimed at an affluent electric clientele.

What was abundantly clear was that conspicuous consumption is alive and well, though now wrapped in elegant ecological respectability rather than gas-guzzling aggression. Tesla’s formula is the context for all else that follows.

No question, though: as Tesla’s first head-on challenger, Jaguar’s I-PACE takes an impressively daring and different tack with its compact, cab-forward stance, rising beltline and hatchback tail. Time will tell whether its early-mover advantage will be enough to keep it ahead of the phalanx of German heavy hitters that are only a matter of months behind.

Even in the lesser ranks there was electric activity: a battery version of Hyundai’s small Kona crossover, more power for the market-leading Renault Zoe, and of course, a plethora of integrated urban mobility concepts, including the VW SEDRIC and Renault EZGO, all relying on electric power.

It might be thought that with such an intense focus on the utopia of the electric future, diesel would simply have been dismissed as yesterday’s news. Except that – see page 6 – VW CEO Matthias Müller is predicting a “second spring” for diesel, and other German heavyweights continue to invest in more advanced diesel models.
**Renewables mean business**

Onshore wind is the most price-competitive form of new generating capacity, and all renewable technologies will be cost-competitive with fossil fuels by 2020. These conclusions, in the International Renewable Energy Agency’s 2017 report, come against the background of a leaked UN draft study suggesting that it will be extremely difficult to avoid global temperature rises of more than 1.5 degrees by 2040.

The 2016 Paris Accord commits countries to holding temperature rises to “well below” 2 degrees, without specifying a time limit, but already many signatories to the treaty are falling short on their emission reduction commitments. Global sea levels are now accelerating from their earlier steady 3 mm per year, according to a research team at CRES, and University of York scientists have discovered that atmospheric concentrations of ethane and propane, (largely from natural gas drilling and distribution) are two to three times higher than earlier believed.

Yet the Agency’s findings on renewable energy costs give grounds for optimism that businesses and politicians can be swayed to help stabilize the climate before it is too late. Onshore wind costs have fallen 25 percent since 2010, and solar PV costs by 73 percent, with the latter expected to further halve by 2020. The best schemes will deliver energy at below three US cents per kWh.

**E-barges start operations**

Some 23,000 trucks per year will be kept off the roads when an innovative E-barge service begins operation between three Dutch ports in August this year. The barges, 52 m long and 6.7 m wide, can accommodate 24 seven-metre shipping containers. The batteries are contained in a similar container-sized pack, which is charged up on shore using carbon-free electricity. Port-Liner, the consortium behind the project, says that if the bridges across rivers and canals were not so low, the barges could carry even more containers. Freight on inland waterways now represents 7 percent of total EU goods transport.

**Scramble for lithium**

With the prospect that by 2025 at least one in four new light vehicles produced will be electrified, the world’s automakers are scrambling to secure adequate supplies of the rare metals needed for Lithium-ion batteries, including cobalt and lithium itself. IHS Markit estimates that Volkswagen alone will soak up 25 percent of worldwide lithium supply in 2030 to power the promised electric versions of each of its expected 300 model lines; even by 2025, with 2.5 million electrified VW Group models expected, battery demand could amount to 45 GWh per year.

Volkswagen has been in negotiations for cobalt, too, as has BMW, which is believed to be close to striking a deal for the provision of both cobalt and lithium. Toyota has taken a stake in Australia’s Grocoobre, which mines lithium in Argentina, China’s Great Wall has invested in Pilangora Lithium, also in Australia, and Tesla is in talks with Chile’s SQM.

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**NEWS IN BRIEF**

**The robot that charges**

Among the more imaginative ideas to emerge from the spring show season was CarLa, a fully automated service robot whose task it is to recharge electric vehicles. Co-developed by VW and industrial robot maker Kuka, CarLa promises to boost the acceptability of e-mobility by automatically charging a customer’s vehicle as soon as it has been parked. This could take place autonomously, though it is not yet clear whether CarLa will be able to operate with wired as well as with inductive charging systems.

**Peugeot Citroën’s real driving results**

Following on from its publication of real-world fuel consumption data, Peugeot Citroën has issued the results of its first NDx and PM tests under RDE conditions and with vehicles complying with the latest EU6dTEMP standards. The five gasoline and diesel models assessed came in well under the new limits for both WLTP and RDE procedures, even allowing for the 1.5 multiple currently conceded for RDE.

**Fall in CO₂ emissions is halted**

Average CO₂ emissions across European vehicle fleets rose for the first time in 2017 after many years of steady decline. Compared with 2016, last year’s figures showed a rise of 0.4 g/km CO₂ to 118.1. Analysts attribute the reversal to the reduction in sales of diesel vehicles compared with gasoline models; diesels now account for just 43.7 percent of all sales. Also significant is the sharp rise in SUV sales to almost 30 percent of all new registrations in Europe.

**Blockchain takes to the road**

Best known as the digital security protocol behind crypto currencies such as Bitcoin, Blockchain is now being tested in the automotive environment. Porsche, in collaboration with Berlin startup XAIN, is assessing Blockchain applications directly in vehicles. These applications, says Porsche, include locking and unlocking the vehicle via an app, temporary access authorisations, and new business models based on encrypted data logging.

**4x4 mobile phone**

A mobile phone launched by Land Rover is claimed to be as tough as the go-anywhere vehicles the company is renowned for. The Explore outdoor adventure smartphone, developed in conjunction with the Bulitt Group, is built for the toughest conditions in the world: it can survive underwater and withstand extreme temperatures, humidity and vibration, and can be dropped from a height of 1.8 m. The touchscreen can be operated with wet or gloved hands, and the battery contains enough power for two full days of continuous use.

**Bugatti pioneers 3D-printed brake**

The eight-piston Monobloc brake caliper on the Bugatti Chiron is already the largest in the world. Now Bugatti is testing a new titanium additive manufacturing process using 3D printing. The aerospace grade titanium 3D-printed caliper weighs just 2.9 kg, compared with the current aluminium component’s 4.9 kg.
Anyone hoping to see Geneva 2018’s influx of electric cars deliver the final blow to the diesel engine would have been disappointed. Industry chiefs insist diesel is essential to hitting the EU’s CO2 targets, even though hybrid-centric Toyota – which has the lowest corporate CO2 of any brand, at 101.2 g/km, has said it is dropping all passenger car diesels. The three French brands, occupying slots two to four, edged slightly upwards in CO2 as they transition away from diesel and, addressing reporters, Volkswagen CEO Matthias Müller was particularly strident in predicting a “second spring” for the fuel.

“Diesel will experience a renaissance,” he said. “The reasons are obvious: no other power source is as environmentally friendly, and we can’t turn our back on it if we want to meet the EU’s demanding CO2 goals.”

Daimler would agree. It is even launching a clutch of new diesel powertrains in top-end models to prove the point, with the luxury Mercedes S-Class now being offered as a diesel-electric plug-in hybrid, in addition to the existing gasoline-fuelled plug-in.

Yet gasoline engine development continues apace, with Mazda’s innovative SKYACTIV-X compression-ignition unit close to production and Toyota’s direct-injection two litre hitting a record 40 percent efficiency, or 41 percent in the case of the hybrid. The new modular Toyota engines, part of the automaker’s new global vehicle architecture toolkit, employ high-speed combustion technology and variable control strategies, and on hybrid versions – including an additional variant with higher performance – the electric motor supplies extra acceleration torque to allow the gasoline unit to reduce its rpm.

A new Direct Shift CVT transmission is offered on non-hybrid models, innovative in its inclusion of a geared starting ratio. This not only provides a more positive launch from rest but also allows a slimmer belt/pulley set and wider ratio span, improving fuel efficiency by 6 percent.

**Diesel’s “second spring”**

**Smart island**

Renault and Portuguese electricity utility Empresa de Electricidade de Madeira are embarking on an 18 month project to assess smart charging and bi-directional vehicle-to-grid (V2G) connection on the island of Porto Santo, in the Atlantic off the Moroccan coast.

In the first phase of the trial Renault will supply 14 Zoe hatchbacks and six Kangoo ZE light vans, along with 40 public and private chargers. Energy storage for the island’s solar and wind farms will be provided by arrays of second-life batteries taken from used EVs; further storage capacity will come from EVs hooked up to the smart charger units. In periods of peak domestic demand, extra energy can be called for from V2G-connected cars.

Renault’s aim is to build a model that can be carried over to other islands, eco-districts and cities, it says.

In Denmark, meanwhile, Renault Alliance partner Nissan is working with E.on to explore V2G solutions, while in France a partnership with oKwind has launched energy storage systems adapted for rural businesses, especially farms.

**Electric taxis take to London’s streets**

The first battery-powered black cabs are taking to the streets of London this spring, in the wake of rules which now require all new taxis to be zero-emissions capable. The new TX, while preserving the shape and spacious accommodation of the familiar diesel model, houses an electric drivetrain and a small range-extender engine running on gasoline. Drivers will benefit from a 140 km range on silent battery power, plus over 500 km on the combined power units.

While clean taxis are important in the urban environment, so too are clean vans. Small electric vans have now reached cost parity with their diesel equivalents, says a study by consultancy CE Delft, yet only have a 1 percent market share.
California, the largest state in the US, has voted over $650 million to help clean up dirty fleets, especially in deprived areas where inhabitants are in closer contact with the sources of pollution.

“This investment will continue to drive the market for new vehicle technologies,” said Mary Nichols, chair of the California Air Resources Board (CARB). “And put more ultra-clean and zero-emission trucks, buses and cars into the communities across California that need them the most.” In an accompanying release, CARB added that while diesel trucks account for only 2 percent of vehicles in the state, they emit the majority of the smog-forming pollution, and two-thirds of all diesel soot.

As evidence of the interest in cleaner trucks, many start-ups have emerged in addition to Tesla’s very well-publicized entry. One of the most recent is LA-based Thor, more of a transportation laboratory than a manufacturer. Its ET-One (above) is planned for production in 2019, using off-the-shelf components such as a Navistar chassis and Dana axles, and promising a 36-tonne payload and electric motors of between 300 and 700 hp. Fleet demonstrations are already taking place, and Thor claims its payload and electric motors of between 300 and 700 hp. Fleet demonstrations are already taking place, and Thor claims its running cost are 60 to 70 percent lower than for diesel trucks.

Elsewhere in the US, parcels giant UPS is field testing a fleet of fuel cell powered Class 6 medium duty trucks. Ten kg of hydrogen provides a range of 200 km.

In Europe, as Daimler’s all-electric Fuso eCanter medium trucks go out to their first customers, the larger eActros model is being rolled out for controlled trials with selected operators. Set for production in 2021, the eActros is available in 18 or 25 tonne GVW versions and has a range of 200 km.

In its legislative programme for 2017, the Scottish Government communicated a very clear intention to set the country on a course towards a resource-efficient and sustainable economy. A key goal is the development of a circular economy, and a crucial aspect of this is the so-called ‘bioeconomy.’ The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy.

Fortunately, Scotland has an incredibly rich and diverse set of bioresources as a consequence of its geography, its large coast and forests, its economy – which has an enormous food and drink sector – and a diverse agricultural sector producing crop residues and animal wastes.

Realizing the economic value of these bioresources is vital. To help Scotland capitalize on this opportunity, Ricardo was commissioned by Zero Waste Scotland to establish the scale and shape of a potential bioeconomy market by quantifying and mapping bioresources – non-fossil bioogenic resources which can be used by humans for multiple purposes, to produce food, substantial products, and/or energy carriers – across Scotland.

This was the first time bioresources have been quantified to this level anywhere in the UK, and possibly even in the world – making it an innovative and forward-thinking piece of work. Delivering this study has provided me with a unique and fascinating insight into the previously hidden bioresources that flow through Scotland, and the results have helped shine a light on many missed opportunities which could provide real economic value to Scotland.

It is clear to me that the findings confirm that the bioeconomy will contribute to the Scottish Government’s political agenda by supporting sustainable economic growth. Firstly, the innovative bioeconomy could be an important source of new jobs – especially at the local and regional level, and importantly in rural and coastal areas – and there are big opportunities for the growth of new markets: for example, in bio-fuels, food and bio-based products.

Secondly, Scotland and the rest of the UK need to diversify their sources of energy, and the bioeconomy can support breakthroughs in low-carbon technologies with co-ordinated research. Replacing fossil raw materials with biological resources is an indispensable component of a forward-looking climate change policy.

Finally, a strengthened industrial base with innovative bio-based and food industries will contribute to creating a circular, resource-efficient economy. The food and drink industry is already the largest manufacturing sector in Scotland. The importance of this sector in Scotland is further evidenced by Scotland Food and Drink’s recently launched ‘Ambition 2030’ which aims to grow the food and drink sector in Scotland to £30 billion by 2030.

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In the study I recommended the adoption of a whole system strategic approach which takes account of the demand and the supply of bioresources. Fundamental to this approach is that stakeholders from both sides are proactively engaged – working with industry to understand the potential to substitute raw material inputs into their processes, and working with suppliers who have available or potentially available bioresources. If successful, this collaborative approach will lead to the development of new circular business models and greatly increase the value attributed to Scotland’s bioresources.
How did the Samsung deal come about?
This sector is very active and large technology players like Samsung, Google and Apple are seeking strategic partnerships or outright acquisitions – like Samsung and Harman or Intel and Mobileye. And there will be more to come. The space is colossal: it will be valued at $36.7 trillion by 2030. For Samsung this was ‘best fit’ with absolutely zero overlap: they had the technology but not the qualified access to the automotive industry which can be very demanding – you have to earn your stripes. Harman had the stripes but not all the technology – from semi-conductors and displays to sensors and artificial intelligence (AI) – that Samsung could offer. Samsung approached us and it made a lot of sense and good value creation: the deal happened in record time.

Had Harman reached its maximum potential and needed another means by which it could grow?
Absolutely. Harman had ways and means to evolve: although we posted a record $7.3 bn last year before Samsung acquired us (and we had bought three Israeli cyber-security companies, and the software analytics business Symphony Teleca, for a billion dollars) we needed consolidation. The whole car and computer platform is being redesigned, data centres are being redefined and companies of our scale, and many of our competitors, have a lot of headwind in terms of redesigning their scope of supply. So the timing was perfect. If it hadn’t happened I would have entered into some stronger partnerships.

Samsung has predicted that automotive electronics could grow to $100 bn by 2025, excluding engine and chassis controls. What systems will that embrace?
That’s a very real number and if you look at the electronics content for vehicles – sensors, electronic software, super-computing – it’s growing. It’s estimated that [content] will hit $9600 per car by 2030. That means something has to come out and efficiency gains made. Electrification and hybridization will eliminate some of the traditional hardware, but it’s hard to define precisely. I think that a third [of the value] will be the computer platform including in-vehicle technology (IVT) such as infotainment, telematics, data: that will be very important for Samsung as the largest semi-conductor manufacturer.

What will the other two thirds be?
Another third I call sensors: lidar, laser, 3D and night vision cameras both inside and outside the vehicle. The final third will be cloud-based applications, services and software. So Samsung-Harman’s role together in data analytics and its ability to capitalize in all three sectors is very interesting.

Do you see growth into powertrain and chassis as well?
We want to play in smarts, and by 2025-30 be the leading Tier One for smart technology, sensors, AI, VI, VR, cloud-based applications – so chassis and powertrain isn’t part of that strategy. There’s a lot of hype here at CES about autonomous cars, but in reality they are further away than many forecast. Absolutely. I am a very strong believer (and it’s not just based on opinion but on technology) that infrastructure has to be in place before we can declare victory and before Level 4 or 5 autonomy happens. [Over] the next seven to 10 years progress will come from L1, L2 and L3. Level 5, where there’s no human input and we use the car as our living room or office, is a long way off. Is the technology ready? Oh, yes: we can create a concept car and run it in a specified lane in San Francisco or London, but that’s not the mainstream market worldwide. To be able to do that in Taiwan or Delhi we are still seven to 10 years away, in my opinion.
Samsung is new to the automotive sector.

**Will you be guiding them?**

We have taken engineers from European and US OEMs to Seoul and they love Samsung’s deeper engagement in developing the next generation of platforms. Although they have a host of technologies, Samsung didn’t have a licence to enter the automotive sector before, but now, through Harman, OEMs have full access to those Samsung technologies. We have just launched 5G telematics, which will give us 100 times faster data exchange, OEMs also love DRVLINE for open ADAS and Samsung’s neuro processing technology that will bring a lot of cognitive computer capabilities into play. Samsung is developing low power, high performance computing systems that don’t require a lot of cooling and are ideal for automotive applications.

**How can Samsung technology change cars?**

A lot. If you think that in 10 years time, there will probably be 100 times more screen area in your car, with your front and rear glazing becoming live and interactive – everything from I-MAX to your work monitor. We have demonstrated Quantum Light Emitting Diode screens here at CES. Samsung has sensor and camera technology and, as the world’s largest mobile phone company, that will bring power to the automotive sector. Samsung is investing billions in AI and voice enablement; it has launched Bixby, its virtual assistant, which isn’t there yet, but it’s a sign of what’s to come. Samsung is already in people’s homes with their TVs, appliances and phones so now they have the opportunity to deliver a true connected lifestyle – home, on the go and enterprise. That’s the race between the tech giants like Google, Amazon, Apple, Microsoft.

**What percentage of turnover is spent on automotive R&D, and will that grow in the future?**

Whatever was my R&D budget before Samsung took over, I have been told to increase that by 1.5 times. I am spending about eight to 10 per cent of my sales and Samsung is investing heavily in automotive R&D, including $300 m in its Automotive Innovation Fund. Plus what we don’t count as automotive are semi-conductors and display, voice and cloud technologies, which they are investing in as core competencies.

**How do your technical teams work together?**

Harman leads core automotive development, but sensors, AI and all those technologies I spoke of earlier are driven by Samsung. We tell them what is needed for the next generation of cloud or screen applications, for instance, so they can tune their R&D towards automotive. They do the fundamental platform technology and we conduct product development.

**Are you looking at further growth through acquisitions rather than organically?**

We have a $300 m start-up fund available to acquire unique and bolt-on technologies we currently don’t have.

**Dinesh Paliwal, president and CEO, Harman**

Paliwal joined Harman in 2007 after 22 years at ABB, during which he established ABB in China and rose to become president of the ABB Group and CEO of its North American operations.

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**John Absmeier, VP Smart Machines, Samsung Electronics**

**What is your role within Samsung?**

I joined Samsung from Delphi two years ago to help lead the automotive initiative working on overall corporate strategy that resulted in the Harman acquisition.

**What was Samsung’s philosophy behind the deal?**

It’s a pretty simple equation. Samsung has three business pillars: mobile with 24.5 percent market share worth nearly $100 bn a year, consumer electronics worth $60 bn and semi-conductors, where we became number one last year, with a $70+ bn business. We are number one in all those sectors so how do you grow the business? The biggest opportunity is in automotive, which is going through a disruptive time and that’s an opportunity for Samsung to succeed.

**Will 5G’s availability and roll-out impact the arrival of autonomous driving?**

If you talk about Level 4 or 5, connectivity is absolutely required to keep software current, to monitor cyber-security, and for data collection. But I don’t believe you need to depend on real-time data for safety functionality. I don’t think autonomous cars can depend on a wireless pipe, but the car will have to function whether it has the content or not.

Samsung has overtaken Intel as the global leader in chip production. **How will that impact the automotive sector?**

Samsung has developed automotive grade chips, but we are able to source production. How will that impact the automotive sector?

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**What is your roadmap for autonomous driving?**

We’re looking at it from foundry to cloud, based on five pillars: compute, sensors, AI and algorithms, cloud connectivity and, finally, user experience. We have prioritised two product launches here at CES: the open compute platform to address Levels 2 to 5 and, secondly, forward cameras. In seven years, driven by NCAP requirements in the US, Europe and China, we believe all cars will be equipped with forward cameras.

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**John Absmeier, SVP autonomous/ADAS, Harman Samsung**

Absmeier assumed his present position following the Samsung takeover of Harman in March 2017. Previously, at Delphi, he led the team that developed Delphi’s autonomous vehicle platform, and the first self-driving car to complete a US coast-to-coast journey, 2015.
Heavy duty trucks and semitrailers transport the lifeblood of the modern industrial economy, be it on North American Interstates, German autobahns, Japanese expressways or the myriad highways criss-crossing every continent. These ubiquitous vehicles ensure that the freight keeps flowing: without them, trade in everything from raw materials, fuel and foodstuffs to finished products for our shops would simply stop.

It follows that heavy duty vehicles are a very significant consumer of fuel and source of CO₂ emissions. According to European Commission estimates, the heavy duty vehicle fleet represents approximately one quarter of all CO₂ emissions due to road transport, as well as around 5 percent of the EU’s total greenhouse gas emissions – a greater share than international aviation or shipping. As a result, regulation of heavy duty vehicle CO₂ emissions is now in the process of implementation by the EU, echoing similar measures in Japan, the US, Canada and China.

But, as Ricardo chief technology and innovation officer Professor Neville Jackson explains, while technological solutions such as battery-electric and hybrid powertrains have helped decarbonize the passenger car and light duty commercial vehicle fleets, the reduction of CO₂ from heavy freight applications is a far harder task: “The challenge with long-haul heavy trucks is that the cost, mass and package envelope required for high-capacity battery systems limits the effectiveness of the type of powertrain electrification solutions that we can very successfully implement to reduce CO₂ emissions in other segments of the market. In a transport industry already highly focused on operating margins as well as capital costs, any consequent restriction on available payload or range is extremely

Combustion redefined is perhaps the best description of a game-changing heavy duty engine concept developed by Ricardo. CryoPower promises a dramatic improvement of 30 percent in long-haul truck fuel efficiency and CO₂ emissions, together with a substantial 20 percent reduction in fuel costs and potentially very low emissions. It also offers a cost effective route for use of renewable electricity in heavy duty transport. Anthony Smith talks to the team at Dolphin N₂, the new Ricardo spin-out formed to pursue commercial development of the revolutionary CryoPower engine.
difficult to implement and is a very hard to sell to the operators.”

As a result, while battery-electric solutions can be very attractive for lighter duty distribution fleets and heavy duty short-haul drayage applications such as port complexes and distribution hubs, the conventional four-stroke diesel engine remains – almost universally – the power plant of choice for heavy duty, long-haul trucks. This makes it a prime candidate for a step-change boost in efficiency – something that CryoPower can now promise.

Diminishing returns from the diesel

In response to the growing regulatory challenge and to the market demands of operators for lower operational costs, the commercial vehicles industry is devoting considerable resources to the improvement of fuel economy and the reduction of CO2 emissions. Many avenues have already been explored at a vehicle level, in terms of aerodynamics, vehicle mass, and the reduction of rolling resistance, but ultimately the focus of improvement has to come back to the powertrain.

“With the basic thermodynamic cycle of a modern diesel engine,” contends Jackson, “it is difficult to see how thermal efficiency can be improved much beyond 50 percent as you’re effectively losing around half of the chemical energy of the fuel to the exhaust and internal heat losses. In parallel with refining the base engine, many manufacturers have looked to bolt-on systems to recover some of the high-grade heat in the exhaust. Some of these energy recovery systems show promise, but the gains from these are relatively small for the added complexity.”

External bolt-on exhaust heat recovery technologies available for conventional truck engines include organic Rankine cycle units, thermoelectric generators, and turbo-compounding systems. Yet Jackson believes that there is an effective thermal efficiency limit beyond which the conventional diesel cannot go: “Even if all currently known refinements and technologies are deployed on current state-of-the-art truck diesel powertrains, there remains an effective fuel efficiency limit beyond which further gains become prohibitively expensive and impractical. While the exhaust heat is of reasonable quality – being possibly 600-700 Celsius – the temperature differential is still not large enough to deliver any fundamentally improved efficiency once you take account of the basic governing thermodynamic equations of the heat recovery systems.”

Ricardo redefines the combustion engine

By contrast, rather than incrementally improving upon existing technology, the Ricardo CryoPower split-cycle engine concept redefines the processes of reciprocating internal combustion to enable significantly improved internal thermal efficiency in comparison with today’s state-of-the-art engines. Instead of bolting on auxiliary exhaust heat recovery devices, the CryoPower concept aims to incorporate exhaust heat recovery into the engine’s
"The technical approach is critical to the success of CryoPower technology, but cost is crucial too. Instead of the expensive materials and processes required to build a gas turbine, we are using essentially conventional reciprocating engine construction and materials."

Prof. Neville Jackson, Ricardo chief technology & innovation officer

CryoPower and conventional diesel combustion compared
significant reductions in engine-out PM and NOx emissions without compromising efficiency.

**Dolphin N: taking CryoPower towards market readiness**

The CryoPower engine concept has been the subject of active research and development by Ricardo and partners including the University of Brighton for approximately ten years. During this time many of its crucial enabling technologies have been methodically researched, reducing further development risk.

But while the pathway to demonstration and ultimate industrialization is now significantly clearer and lower in risk (and there is a clear emerging requirement to reduce the carbon intensity of heavy duty transportation) the level of resource required is beyond the scope of what could be accommodated within Ricardo’s in-house R&D programme. For these reasons, Ricardo decided to adopt the approach of a technology spin-out.

A new company, Dolphin N Ltd, an independent entity from Ricardo, has been formed as a vehicle for the development of the CryoPower technology. The company will be vested with the existing CryoPower intellectual property, assets and contracts, and will also receive a cash investment from Ricardo plc; this will represent a minority holding of the share capital following successful completion of the first investment round in early 2018.

Dolphin N is led by CEO Simon Brewster, a veteran of heavy duty engine development at Ricardo. “CryoPower is a potentially game-changing, commercially and environmentally attractive technology whose time really has come,” he says. “The development of the conventional heavy duty engine is reaching the point of diminishing returns with regard to fuel efficiency and CO2; to go significantly beyond the current state of the art requires a completely new approach. CryoPower offers this and promises a step-change improvement in both fuel efficiency and operating fuel cost; the work we have already done on the development of its crucial enabling technologies has significantly reduced development risk.”

According to European automotive manufacturers association ACEA, fuel is the largest single operating cost element for a 40-tonne tractor-semi trailer combination: at 30 percent it is almost as high as operator wages and repair and maintenance combined. In a highly cost-driven market where margins are extremely tight, any reduction in fuel cost would clearly be extremely attractive to heavy duty fleet operators.

Based on the research and...
development carried out to date, CryoPower has demonstrated the potential to reduce operating fuel costs and fuel usage by, respectively, 20 and 30 percent in comparison with today's heavy duty engines; these projections already allow for the financial and energy costs of the liquid nitrogen used by CryoPower in addition to its fuel. And, as Brewster explains, this represents a very significant reduction in operational expenditure.

“We estimate that in a heavy duty truck application CryoPower would provide potential operator savings of approximately £9000 ($12,500) per year for each vehicle,” says Brewster. “Moreover, if the same technology was applied to stationary distributed power generation – another market that is extremely sensitive to fuel costs – savings would be of the order of £180,000 ($250,000) per MW of installed capacity.”

**Demonstration phase**

Dolphin N. is seeking investors for its next two phases of development. The first will see the creation of a first full-scale CryoPower technology demonstrator engine. The most likely configuration for this will be an inline six-cylinder engine, comprising two compression and four power cylinders. This is a particularly attractive configuration for heavy duty trucks, as in-vehicle packaging would be broadly similar to many existing products. While the engine would have just four power cylinders, the firing frequency would be every 90 degrees of crank rotation as the power cylinders operate in a ‘two-stroke’ mode providing a power pulse every revolution. This gives the smoothness of power delivery
that would otherwise be expected of a conventional V8.

“We estimate that we can get 30 to 40 kW per litre of overall swept volume, which would translate to a broadly similar sizing of engine compared to conventional engines,” says Brewster, “but it would be consuming 30 percent less fuel and have 20 percent lower operating costs.”

“Manufacturing costs are likely to be competitive too,” he continues. “Unlike competitor low-carbon technologies, CryoPower uses comparatively inexpensive materials and processes. It is fundamentally different to current state-of-the-art engines, and yet it could be produced using established engine manufacturing plants.”

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Beyond the initial demonstration phase, Dolphin N2 envisages a second fundraising round that will take the technology through to pre-industrialization development and pilot commercial applications. All of which could mean that the first ultra fuel-efficient trucks using liquid nitrogen alongside more conventional liquid fossil, bio-fuels or natural gas could be on the road early in the next decade.

### CryoPower comparison – long-haul HGV truck applications

<table>
<thead>
<tr>
<th></th>
<th>Life cycle cost £/100km/tonne</th>
<th>Range Km</th>
<th>Payload EU tonnes</th>
<th>Refuel time</th>
<th>Clean Air (NOx;PM)</th>
<th>CO₂ (GHG) regulation</th>
</tr>
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<tbody>
<tr>
<td>Diesel</td>
<td>1.00</td>
<td>1500</td>
<td>24 – 28</td>
<td>&lt;10 min</td>
<td></td>
<td>×</td>
</tr>
<tr>
<td>Battery - EV</td>
<td>1.55</td>
<td>200</td>
<td>22 – 26</td>
<td>~3 hrs</td>
<td></td>
<td>×</td>
</tr>
<tr>
<td>CryoPower</td>
<td>0.85</td>
<td>2000</td>
<td>23 – 27</td>
<td>&lt;10 min</td>
<td></td>
<td>×</td>
</tr>
</tbody>
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*Includes costs of fuel, liquid nitrogen and power hardware. Battery vehicle assumes one battery replacement in vehicle life.

### CryoPower comparison – distributed power generation (0.5 - 5MW)

<table>
<thead>
<tr>
<th></th>
<th>Levelised cost of energy</th>
<th>Wrong time utilization</th>
<th>Response time</th>
<th>Clean Air (NOx;PM)</th>
<th>CO₂ (GHG)</th>
<th>Portability</th>
<th>Energy Density</th>
<th>CHP</th>
<th>Urban areas</th>
</tr>
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<tbody>
<tr>
<td>Diesel</td>
<td>£187 $258/MWh</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
<td>×</td>
</tr>
<tr>
<td>CryoPower</td>
<td>£236 $418/MWh</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>£152 $210/MWh</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
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</table>

*Average small scale renewable (PV £80/MWh & onshore wind £126/MWh, average £103) + storage (in-front-of-the-meter Li-ion battery £193/MWh)

### Fundamental advantages of CryoPower engine:

- **Reduced work means higher efficiency:** As the induction air is cooled during compression by the injection of liquid nitrogen, less compression work is required for a given end of compression pressure, and hence losses are reduced.

- **True Miller cycle operation:** For ideal efficiency, a combustion engine requires less compression and more expansion, something that is difficult to achieve with a conventional architecture. The CryoPower concept uses a smaller compression cylinder (or fewer compression cylinders) than its expansion cylinder to make much fuller use of the expansion work.

- **Highly efficient internal heat recovery:** Enabled by the cooled compression process, exhaust gas heat is transferred from the hot part of the cycle at the end of combustion to the end of compression and before injection of fuel on the next stroke.

- **Inherently low friction and pumping losses:** Transfer of gas between the two cylinders is carried out at high pressure, so the mass flow is high while the volume flow is low. This means only a small valve is required and only a small volume actually moves.

### “We estimate that in a heavy duty truck application CryoPower would provide potential operator savings of approximately £9000 ($12,500) per year for each vehicle”

Simon Brewster, CEO, Dolphin N2
The scene is a remote and misty mountainside in North Wales at the end of October. Yet in place of the expected solitude and tranquility there are thousands of people generating a feverish buzz of excitement, and the atmosphere is electric. Wales Rally GB is reaching its climax, the local hero is in the lead and, this being the penultimate event of the 2017 season, the World Manufacturers’ and Drivers’ championships are both at stake.

The season had been an exceptionally closely fought one, but what had made it even more unusual was that the three major factory teams – Hyundai, Toyota and Citroën – were battling for top honours against a much smaller privately run team, Cumbria-based M-Sport. Against the predictions of many commentators, M-Sport’s Ford Fiestas had been setting the pace most of the year and Wales Rally GB was the team’s opportunity to clinch not only its fifth win of the year, but also the Drivers’ and Manufacturers’ titles too.

And, incredibly, what M-Sport’s 260 employees had hardly dared hope for just a few months back would come true that afternoon. Elfyn Evans stormed to the finish with a 37-second lead to become the first Welshman ever to win a world championship rally, as well as the first British winner for 17 years; what is more, as the rest of the field streamed home with M-Sport drivers Sébastien Ogier in third and Ott Tänak sixth, the points tallies gave Ogier an unassailable lead in the Drivers’ Championship and M-Sport top slot in the Manufacturers’ standings.

“…That was an amazing 20 minutes as M-Sport’s Ford Fiestas, equipped with Ricardo transmissions, stormed to victory in the 2017 FIA World Rally Championships for both Drivers and Manufacturers. Tony Lewin travels to M-Sport’s headquarters to meet team principal Malcolm Wilson OBE and hear the story.
those cars came home,” said M-Sport founder and former multiple rally champion Malcolm Wilson, who attends every race and rally his teams compete in. “We won the Drivers’, the Manufacturers’, the European Championship and the Bentley Endurance as well – it’s the best ever year in the history of M-Sport.”

Such success will be very difficult to replicate, cautions Wilson, underlining how ultra-competitive the World Rally Championship has become since it moved to its new regulations for the 2017 season. Yet it was with the introduction of those new rules that Wilson sensed his opportunity to get level with the factory teams: “The new technical regulations meant that everybody was starting on the same page,” he told RQ in an interview at M-Sport headquarters in Cumbria. “This was the first time in history that every manufacturer came out with a new car, all at the same time. I think that the combination of our great team of people here and our 20 years’ experience in WRC played a part in us being as successful as we were.”

Clean sheet of paper
For the 2017 season, with all the teams starting from the same clean sheet of paper, M-Sport knew that every tenth of a second would be crucial when it came to being quickest in the heat of competition on the hundreds of special stages around the world. Starting from scratch would allow absolutely everything about the new Fiesta rally car to be optimized; none of the old era’s compromises could be tolerated.

At the outset of the car’s design Malcolm Wilson had spotted a key advantage of going to Ricardo for the transmission. Rather than having to design the car around off-the-shelf components packaged to suit the new installation, a bespoke transmission from Ricardo could be designed in parallel to integrate with the car. The difference might seem academic, but in a rally world where strict regulations govern almost every aspect of a car’s specification, every possible advantage, even the tiniest fractional gain, needs to be chased to maximize overall performance.

As transmission partner, Ricardo too was inspired to think radically. Ricardo Performance Products engineering director Tim Gee recounts how the gearbox and differential systems were designed to package into the very tight spaces allowed by M-Sport’s optimized positioning of the other key components: “They send us [digital] ‘scenery’ models which show the block, the steering rack, the chassis – everything that’s going to be in the packaging environment,” he explains. Similarly, at the back, the models show the subframe, fuel tank, spare wheel. “They’ve positioned everything, and they’ve allowed some volumes,” he continues, “and then they say ‘put a gearbox in there’.”

Throughout, Gee explains, once the package space had been agreed, the overriding priority in the design of the transmission was to minimize overall mass and to keep that mass as close to the vehicle’s ground plane as possible. “All these small differences add up,” he observes. “The philosophy of minimum mass and lowest mass does add up to a car that handles better, and that’s very important for the driver. It helps him become comfortable with the car, and that’s what makes him go quickly.”

That point is confirmed by no less an authority than Wilson himself. “We were the only team with all three drivers winning events, and we won more events than anybody else,” he says, “so I suppose you’d have to say that we had the best

MASTER OF COMPETITION
Malcolm Wilson OBE learned to drive at the age of 8 and idolized Roger Clark as his rally hero. He began winning British national rallies in the 1970s and international events in the following decades, mainly at the wheel of Fords. In 1979 he founded his own Cumbria-based team, whose Ford Focus RS WRCs won the 2006 and 2007 Manufacturers’ World Championships. Now M-Sport is active in many areas of motorsport, including all levels of rallying, GT circuit racing and rallycross.

How would you sum up M-Sport’s 2017 season? Quite simply: it was our best season to date, no question, in almost everything we’ve officially competed in, the rally championships, Bentley endurance racing – even rallycross, where we scored podiums even if we didn’t take the championship.

What made the difference in the World Rally Championship? We had a fantastic package of a car, even before we signed Sébastien [Ogier]. Once we got Sébastien we had nowhere to hide – if we didn’t win the Drivers’ Championship we knew firmly where the blame would lie. I wasn’t under any illusions about signing him and putting ourselves under pressure, but Sébastien gave everyone at M-Sport a real lift and it made everybody raise their game another 5 or 10 percent.

Which was the toughest event of 2017? Maybe not the toughest but the most nerve-racking for me was Rally Germany. It was the only event in WRC that we hadn’t won, so to win it was the final tick in the box. We’ve now won every single event in the current championship calendar.

Who was the toughest team to beat in 2017? Undoubtedly Hyundai. Their biggest strength is their driver, Thierry Neuville. We know how good he is – he finished runner up in the championship with us in 2013 [when Ogier won for VW]. He’ll be the biggest threat to us in 2018, too.

You were a works driver for Ford for many years. What is your current relationship with Ford? Up until 2012 we were the official Ford works team, fully funded and supported. Now we’re independent, but obviously we couldn’t do what we’re doing without the technical support that we get from Ford. For instance, we got the new Fiesta on the [2017] Monte Carlo Rally in January, even though it wasn’t launched to the public until May that year.
car. Our strong point this year has not only been our performance, but also reliability: that has been a key aspect of the success that we have had.”

More graphically, adds Wilson, the 2017 season was the first time in M-Sport’s history that none of its three drivers has actually rolled a car. “That’s a definite first,” he grins, “and it sends out a message that the car must be very easy to drive. Drivers can simply get in it and win – two of our drivers had never won a rally before.”

**Exclusive co-operation**

A key deciding factor in steering M-Sport towards Ricardo for the new car’s transmission was exclusivity. “When we were reviewing the situation prior to embarking on the new car we obviously looked at everybody,” remembers Wilson. “We clearly had a good history with Ricardo – we won our previous championships in 2006 and 2007 with them, and we had worked with them on active centre diffs before.”

When embarking on a completely new project it is natural to expect a technical gain, he continues. “But you know that ultimately somebody will find out what you are doing and catch up – we’ve been in the position before that technology that we have developed has transferred [to rivals] and that was the one thing we didn’t want [this time]. So a very important aspect to us was the fact that Ricardo would give us exclusivity in WRC for a number of years.”

“There’s no question that the

**This was the first time in history that every manufacturer came out with a new car, all at the same time. I think that the combination of our great team of people here and our 20 years’ experience in WRC played a part in us being as successful as we were” Malcolm Wilson, M-Sport team principal**

Looking ahead, are there any other motorsport series that you would like to tackle?

We’re very happy to represent Bentley on the race side, but I’m not saying we won’t go to something else – who knows what the future will bring. We’re doing another new Bentley, which also has a Ricardo transmission: endurance racing has so many similarities to old-style rallying, and that’s why we’ve been so successful this year [2017]. Every team member plays a crucial part: it’s a fantastic team-building exercise, and I’m sure Bentley would want to do [something like] Le Mans again.

You have invested heavily in a new engineering centre here on site at Dovenby Hall [left]. What extra things will the new facility enable you to do?

We’ll be able to provide a one-stop shop for manufacturers: a first-class testing facility on site. In principle it will be quite unique in that we will be able to qualify for prototype status: there’s nowhere else in the UK, because if you go to Millbrook or MIRA there are spying eyes of every other manufacturer on you. My target would be to have major automakers do prototype development here: we will have resources such as fabrication, electrical, mechanical, design and engineering, so we could be a one-stop shop. We’ll also have a facility where we can do small body and production runs as well as bespoke products.

That tells you how good our technical and working relationship still is, but the big difference is that we’re not funded as we were when we were a factory team. There will be more involvement from Ford next year [2018] and the team name will be M-Sport Ford World Rally Team.
transmission has contributed to the success of our car,” concludes Wilson, and this is echoed by his head of rally engineering, Chris Williams. “We had quite a lot of discussions before deciding to move to Ricardo,” he reveals. “There were two contenders: we’d been working with one, and knew their limitations, and we’d also worked with Ricardo before and had good success with them. We chose to go with Ricardo because of some technology we were developing internally that we wanted to keep to ourselves. We wanted to keep the IP, and we also believed we would get better value and better service too.”

**Success in 2017 – what about 2018?**

The winning team’s success in 2017 speaks for itself: victory straight out of the box on the Monte Carlo Rally for Sébastien Ogier in January last year; four further outright wins, 19 podiums and of course the Drivers’ and Manufacturers’ World Championships for Ogier and M-Sport respectively. The Fiesta was clearly the class of the field in 2017 – but what about the new season, with M-Sport’s rivals having had the chance to draw breath and, perhaps, learn enough to catch up?

“We saw towards the end of last season that Hyundai is becoming stronger and stronger,” observes Wilson. “They’re the biggest threat, no question, and Toyota will also be really strong with their new driver line-up, so it’s certainly going to be even more competitive than it was in 2017.”

“We’re going to have to be good and consistent everywhere,” he predicts. “In 2017 we had the best car and the best driver, in Sébastien Ogier; Sébastien has stayed with us for 2018, so we really need to deliver – there is nowhere to hide.”

The latest and the most reliable technology will certainly have a key role to play, too, but such is the intensely competitive environment of the WRC circus that all innovation remains a closely guarded secret, even when it has been unleashed in special-stage action. In addition, client confidentiality between Ricardo and M-Sport rules out any discussion of the finer points of their engineering collaboration. But two things are certain: there is a lot more innovation to come, further collaboration with Ricardo is in the offing – and the complex FIA/WRC joker system could well be brought into play to deliver the Fiesta drivers further strategic advantage during the course of the season.

**BREEDING A WINNER**

Chris Williams, head of rally engineering at M-Sport, and Ricardo high performance engineering director Tim Gee answer questions on the WRC Fiesta’s transmission development

**How can a transmission confer an advantage?**

**Williams:** Efficiency through the gearbox is a key factor; also, how you can distribute the mass to optimize it – this is a key performance indicator. And with the new regulations allowing us to have an active centre diff again, there’s a lot more we can do. And we have some other technologies that we wanted to develop inside.

**Gee:** Active diffs actually make things much easier: the hydraulic control is simpler and you don’t need the handbrake disconnect system. The architecture of the transmission keeps the higher mass components low down, though for some components the chassis interface is more important and they need to be higher up. The gear-driven auxiliaries are low, too.

**The package space for the rear axle is very small.**

**What differential design did you choose?**

**Gee:** We went for a two-stage axle because of the positioning of the parts, the ratio and the packaging. Although the differential has positive and negative pre-lead, from a mechanical engineering point of view it is relatively simple.

**How do you test the transmission?**

**Gee:** First we put it on a dyno and ramp up the torque: then it is put in a car and the duty is ramped up to a full-on jumping work-out. That’s how things get ironed out: you pick up a few things on the rig, some on the shakedowns and some when it’s running in anger.

**Williams:** We can do some rig testing but it is limited and it’s hard to recreate what you actually get in rallying. We built a mule car so we could run the transmission as early as possible; we did 2000 km, stripped it, checked it and did it again. The difficulty for us is that the transmission is one of the first things we have to sign off due to the lead times, and the whole car development cycle is set around this.

**What are the most stressful conditions for the transmission?**

**Gee:** It’s the jumps. When a car takes off and lands, all sorts of things can happen. You can get a big torque surge on landing: maybe the wheels aren’t rotating and they get accelerated very quickly, or they could be rotating very fast and stop when the car lands. A one-wheel landing can send a massive torque surge through the system. The other harsh condition is on snow when you have stick-slip. When the car [suddenly] finds traction you have very high torque peaks.
In 1959, copywriting guru David Ogilvy penned what has been hailed as the greatest automotive advertising headline of all time: “At 60 miles an hour, the loudest noise in this new Rolls-Royce comes from the electric clock.” In actual fact, he was paraphrasing the technical editor of Motor magazine who went on to say in his road test, “three mufflers tune out sound frequencies – acoustically.”

Even in the 1950s, premium car manufacturers recognized that the sound a car makes is an intrinsic part of its brand character. A virtually silent interior was the Rolls-Royce Silver Cloud’s USP at the time, something that would have horrified drivers aspiring to a Jaguar or Ferrari in the same era.

A study conducted by Ricardo more recently looked at how the sensation of performance was generated by a car: it found that, particularly for European and North American drivers, about half the feeling of the performance comes from the acceleration and half from the sound.

Today, in a world poised on the brink of automotive electrification across the board, sound quality has become even more important. Most drivers accept that, though EVs are fun to drive, the noise made by an electric car does little to convey the essence of a brand. Ricardo thought so too and in 2013 embarked on a project called Realistic Augmented Sound by Ricardo (RAS-R). Rather than creating unrelated synthetic sound like some existing systems, RAS-R ‘listens’ to the electric machinery powering an electric vehicle and subtly modifies it to create a pleasing sound signature, a signature directly linked to the dynamic behaviour of the car.

Objectives are changing
Deliberately engineering the sound a car makes is not new, but objectives sought by engineers have changed considerably over time. Sixty years ago, the emphasis ranged from doing everything possible to subdue powertrain noise in the case of the Rolls-Royce, to simply quietening exhaust noise down to acceptable levels. Once that was accomplished with family cars and sports cars, their sound signature was left to chance and the choice of equipment. Buyers could be fairly confident that an Alfa Romeo fitted with a twin choke Weber carburettor, for example, would make an exciting sound.

As time has passed, the subject of sound, or noise, has become more complex for two main reasons. One of those is legislation. Manufacturers face much
RAS-R as applied to a Nissan Micra EV

Unmodified vehicle

RAS-R tuned and augmented vehicle

Electric cars offer more of a challenge. An electric motor does not produce a soundtrack that occupants normally associate with a car, and it also bears a similarity to mundane machinery like domestic appliances. Electronically generated sound is one solution to augmenting electric vehicle sound, but Matthew Maunder, Ricardo technical specialist for noise and vibration, is sure of one thing: sound that is engineered into the car must be absolutely authentic. For that reason, he does not believe that synthetically generated sound is the answer, especially for EVs. “Synthetic sound systems use processing power to replace a sensor, so to some extent it’s a cost reduction initiative. Arguably, it gives more freedom to produce exactly the type of sound you want,” he says. “We’re limited with RAS-R to some extent because the sound is authentic, but we do have strong capabilities to modify the basic sound. I would argue that perhaps starting from a clean sheet, as you do with synthetic sound, gives too much freedom.”

“If the sound you hear as a driver deviates from the behaviour of the vehicle even for a moment,” he continues, “then the brain identifies it as a separate perceptual object and, in the driver’s mind, these will never mate up again.” Synthetic sound generation systems that have been developed to date can take signals from the vehicle CAN bus, or a throttle position sensor, “but there might be a delay or lag or the synthesizer might make a sound that doesn’t relate exactly to what the car is doing. At that point, the driver’s brain rejects it because the sound just becomes a noise,” says Maunder. RAS-R is absolutely authentic because its source is the sound made by the vehicle powertrain. Initially, work was done on combustion engine systems with an automotive grade microphone positioned inside the intake manifold. The signal is processed, modified and relayed into the cabin via loudspeakers. The important thing is, it’s authentic and not synthetic. “It works well,” explains Maunder, “because that bark is still there inside the intake manifold but it can’t get out because of the turbocharger.” The driver hears a sound more akin to that of a naturally aspirated engine, but tuned to the quality, shape and intensity decided upon by the vehicle manufacturer.

The human brain is good at sensing the slightest degree of undesirable lag present in even the best turbocharged engines. The augmented sound system helps with that too, instantly delivering a change in engine note in response to the driver’s actions, and creating the impression for that split second that engine response is instantaneous too.

Electric sound: the big debate

Developing a system for electric cars was a logical progression. “Once we’d done the combustion engine we thought of EVs,” recalls Maunder. “There’s been an ongoing debate for decades about what an electric car should sound like. We had the idea that a more appealing version of the sound made by the electric motor itself was probably the best answer because it’s completely authentic.”

The first step was a desktop exercise. Maunder and his team had taken some benchmark measurements of vibration from a production EV motor and various parts of the vehicle body and had also made some interior noise measurements. “We then thought we could pep up interior sound by adding in a filtered version of the vibration signals from the motor,” he remembers. That led to finding a location for the vibration sensor which gave the best sound. It also gave a rough idea of what filtering would be needed: this essentially involved cutting out all the harsh sharp sound and high frequency whining. After the filtering, a lot of sound was left in the sub-1 kHz range. This is similar to the profile generated by a combustion engine, but is uniquely electric because the harmonics of an electric motor are different.

When the project moved from the desktop to a physical vehicle, the microphone fitted inside the intake manifold of a combustion engine was replaced by a vibration sensor attached to the electric drive motor. The signal is passed to a computer and gently manipulated to produce a sound that’s enjoyable to listen to and completely authentic. “It’s similar to adjusting the
settings on the graphic equalizer of an audio system. We cannot fundamentally change the type of sound, we can only make subtle changes to what’s there rather than generate something new,” Maunder emphasizes.

**Separate speaker system**

The sound is then played through speakers mounted behind the instrument panel rather than through the audio speakers. There are several benefits to this. The first is that the sound is not localized and comes from the front of the car as it would in a more conventional combustion engine vehicles. The sound also begins to diminish in intensity towards the rear of the car so second row passengers experience a sound that is just as authentic.

The second reason is one of practicality. Playing back the sound through the vehicle’s audio system would require tailoring for each individual model. Premium cars in particular often have quite different audio system options across a particular range; setups can include a mixture of OEM equipment and third party branded equipment. Interfacing with the different systems would make the process of integrating the augmented sound system with the vehicle much more complicated. “For example, if the user were to select a different sub-woofer or other audio hardware option this could impact on the augmented sound being played back through the system at the same time,” explains Maunder.

The sound is carefully tuned to avoid being too loud or intrusive in any way. The system adds sound during strong acceleration phases but not during in-town driving or steady state cruising. It is audible for a moment at a time, when the driver pulls onto a roundabout or out of a junction, or accelerates to overtake, or pulls onto the motorway. It’s also important that it cannot be identified as emanating from a loudspeaker.

A third option and next step in the development process would be to use a body shaker to transmit sound through the body shell itself rather than using separate speakers. “It’s a good idea in principle and probably beneficial in that shaking the whole car body rather than radiating sound from a specific speaker location would help spread the sound throughout the cabin,” says Maunder.

Body shaking systems are already in use and available as an automotive component. Again, it provides another option for separating the RAS-R from the audio system, simplifying development.
Unlocking grid capacity for EVs

Ricardo is supporting a ground-breaking trial run by UK Power Networks into using smart grid technology to unlock spare capacity for increased electric vehicle use. Smart grid technology aims to maximize the power available from existing infrastructures while avoiding costly network reinforcement or substation replacement.

The project, named Active Response, will trial a responsive, automated electricity network that is able to reconfigure itself, moving spare capacity to where the demand is. It will do this by using power electronics and automated switching to move demand from heavily loaded substations to nearby substations with spare capacity. The project has the potential to save customers £271 million and reduce carbon emissions by 448,000 tonnes by 2030. UK Power Networks delivers electricity to over eight million homes and businesses.

Drawing on the company’s extensive experience supporting the implementation of smart grid solutions, Ricardo energy specialists will develop power electronic devices, known as ‘Soft Open Points’ and ‘Soft Power Bridges’, and the intelligent control systems that underpin the Active Response project. “Unlocking spare capacity is essential to adapt to the predicted increase in electric vehicle numbers in a way that is cost effective for consumers,” commented Sarah Carter, Ricardo’s business area manager for smart grids and networks. “We are delighted to be supporting the Active Response project and to help the UK to take an important step to transitioning to a low carbon economy.”

By 2030 it is anticipated that there will be up to 1.9 million electric vehicles in use across London and the east and south east of England where UK Power Networks delivers electricity. Upgrading an electricity substation or adding entirely new substations and cabling when customers need more power takes time, costs money, and can cause disruption due to roadworks. Instead, Active Response could allow electricity companies across the UK to use these power sharing techniques to connect new customers, and those requesting more power, more quickly and at lower cost.

EV battery development collaboration

The University of South Wales’ Centre for Automotive & Power System Engineering (CAPSE) and Ricardo have announced that they intend to collaborate on electric vehicle battery systems R&D. CAPSE is based within the Faculty of Computing, Engineering and Science at the University of South Wales. Already a nationally recognized independent research, development, test and certification house in the UK, with a reputation for cutting-edge research and knowledge transfer activities, CAPSE is in the process of further expansion.

The collaboration will provide Ricardo with access to CAPSE facilities, while also enabling the University to benefit from Ricardo’s knowledge and experience of both research and production-intent programmes.
Improving urban air quality in China

The Asian Development Bank (ADB) has commissioned Ricardo to carry out a major two-year study into improving air quality in three cities in China. Until recently, cities of the greater Beijing–Tianjin–Hebei region of China were among the highest polluted conurbations in the world. Substantial work is under way to deliver improvements in air quality in the region, but levels remain well above national and international standards.

Employing Ricardo’s RapidAir® air quality modelling system, the project will provide detailed evaluation of air quality policy options; the study is designed to support the investments in improving air quality being made by ADB in north-eastern China. The work draws on Ricardo’s extensive international experience supporting local and national governments to enhance air quality in some of the world’s most challenging city environments. Ricardo is working on this project with in-country experts from Tsinghua University and the Chinese Academy of Environmental Planning.

Ricardo’s air quality team will use the RapidAir® system, a state-of-the-art air quality diagnostics and decision support tool that facilitates fast and efficient city-scale air quality modelling and mitigation scenario testing for a range of emission sources and pollutants. The team will perform a detailed cost-benefit analysis and health impact assessment of potential pollution mitigation measures. This will support policy makers to identify the optimum policy mix to improve air quality and population health. This guidance will influence the development of air quality management plans to 2030.

“Environmental Protection officers in north-east China are at the forefront of tackling some of the toughest air pollution problems in the world,” commented Ben Grebot, project director for Ricardo Energy & Environment. “The Asian Development Bank’s commitment to improving air quality and population health. This guidance will influence the development of air quality management plans to 2030.

FT recognition for sustainability

The Financial Times has identified Ricardo Energy & Environment as one of the UK’s leading management consultancies for 2018, commended for its sustainability services. The awards are based on comments made by clients and peers throughout industry.

The rating reinforces the company’s position as a leading consultancy in the arena of environment and sustainability. Ricardo’s environmental consulting business boasts a broad client base that includes local and national governments, public sector organizations, water and energy companies, international agencies and major private sector companies.
The U.S. Army has exercised Option Year 1 of the Electronic Maintenance System Next Generation sustainment contract with the C2D Joint Venture, of which Ricardo Control Point is managing partner. The Electronic Maintenance System (EMS) next Generation (nG) is a collection of software applications used by the U.S. Army to assist with the maintenance of vehicle platforms ranging from logistics support trucks to armoured personnel carriers, main battle tanks and the ubiquitous HMMWV. The EMS nG includes state-of-the-art tools to author content for vehicle technical manuals, to build the electronic manuals, view the manuals and to run diagnostics and repair procedures on vehicles. This suite of tools being developed by Ricardo Control Point greatly improves and expands upon the prior paper-based manuals by guiding operators and vehicle maintainers through interactive troubleshooting and repair scenarios based on the user’s observations and system diagnostic fault inputs.

Work performed during this Option Year 1 will include an annual software release incorporating required feature changes and bug fixes. Service pack releases may also be delivered throughout the year as critical needs are identified by an EMS customer. Ricardo Control Point will respond to software vulnerability alerts and maintain the system’s cybersecurity compliance. The joint ventures’ work will improve EMS system performance, usability and maintainability while incorporating state-of-the-art technologies. Customer support and training on the use of the EMS suite are also part of the recently awarded sustainment scope.

Ricardo JV wins U.S. Army contract

Ricardo chief operating officer Mark Garrett, operating one of the glazing machines during a recent mission (far left), and (above) with fellow See Kenya volunteers

Vision for Kenya

Ricardo chief operating officer Mark Garrett is a volunteer for See Kenya, a Sussex-based charity that works to reduce blindness and provide specialist treatment and eye care services to marginalized communities within Kenya.

As soon as he became aware of the work of See Kenya the idea of helping out appealed to him. “All my life I’ve had very poor eyesight, but I have always had access to professional eye care,” he said. “But in Kenya eye care is is extremely limited, and this holds people’s lives back – in education, socially and in job opportunities.”

Now, Mark volunteers two weeks a year in the See Kenya pop-up clinic as part of a team comprising optometrists and nurses, and volunteers like him. The professionals do the diagnostics for each patient and prepare the prescription. The volunteers are trained to do various tasks in the process, including basic procedures like eye pressure tests. They then assist the patients with frame selection, based high quality frames donated by UK manufacturers. The on-site lab manufactures the glasses and fits them to the frames chosen by the patient.

“The clinic users have just a one or two-hour wait for their prescription glasses,” said Mark. “They each leave with a pair of prescription distance and/or reading glasses, and a pair of sunglasses, together with any eye drops that they need. All of this is provided for a fee of around 50 pence, which makes it accessible to all.”

But with some of See Kenya’s lab equipment becoming old and dilapidated, there is a constant need for the charity to seek replacements. In Mark’s visit a year ago, his team was able to make over 1000 pairs of spectacles in the two-week trip, whereas this year, with the poor condition of the old glazing machines, it was just 600.

In order to support Mark and the highly valuable work of the See Kenya charity, Ricardo plc has agreed to fund a brand new glazing machine for the pop-up clinic. At a value of around £22,000, the machine will make a significant contribution to the work of the charity, while also helping with the charity’s aspirations to build a permanent eye clinic in its current location and extend the pop-up concept to other marginalized communities elsewhere in Kenya. “The contribution of a new glazing machine by Ricardo will make a real difference to the work of the charity,” commented Mark. “In doing so it will help improve the lives of our clinic users – and I look forward to using it on my next mission as a volunteer.”

For more information or to support the valuable work of Mark and the other professionals and volunteers of See Kenya, visit: seekenya.org
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