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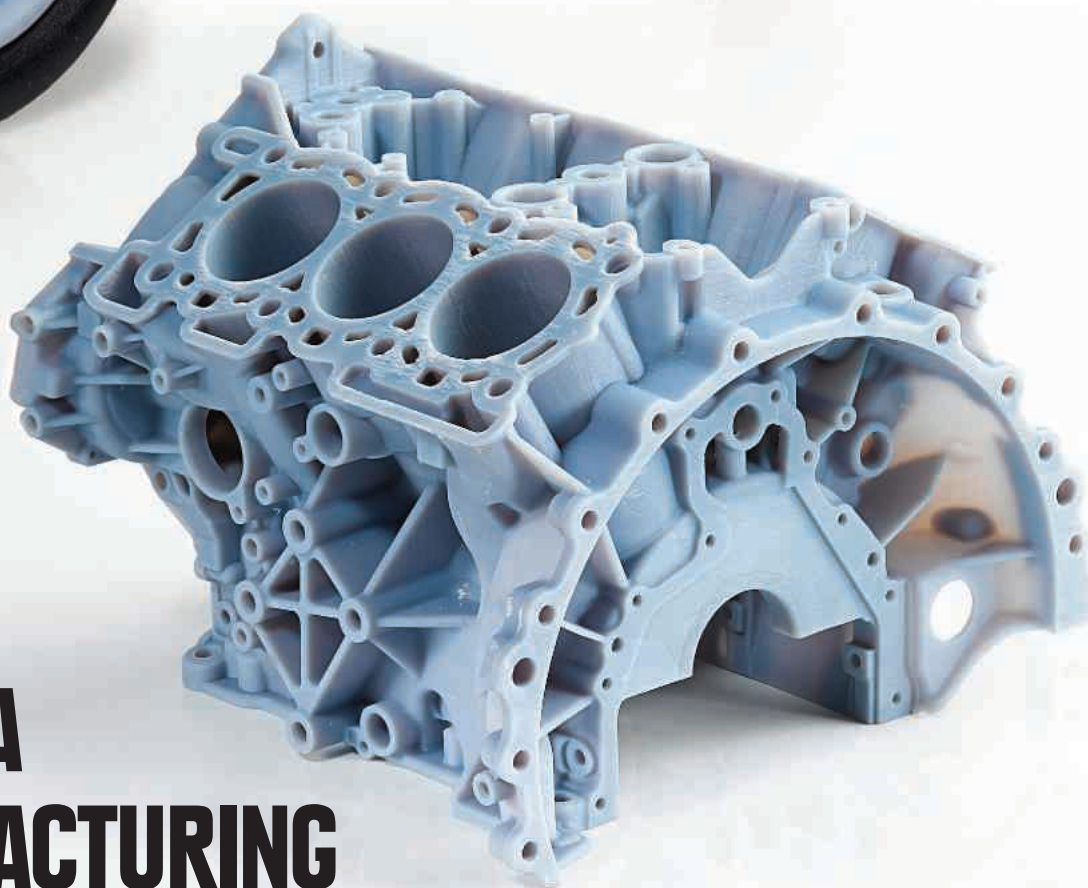
**Towards 2020:
exhaust and emissions
solutions**

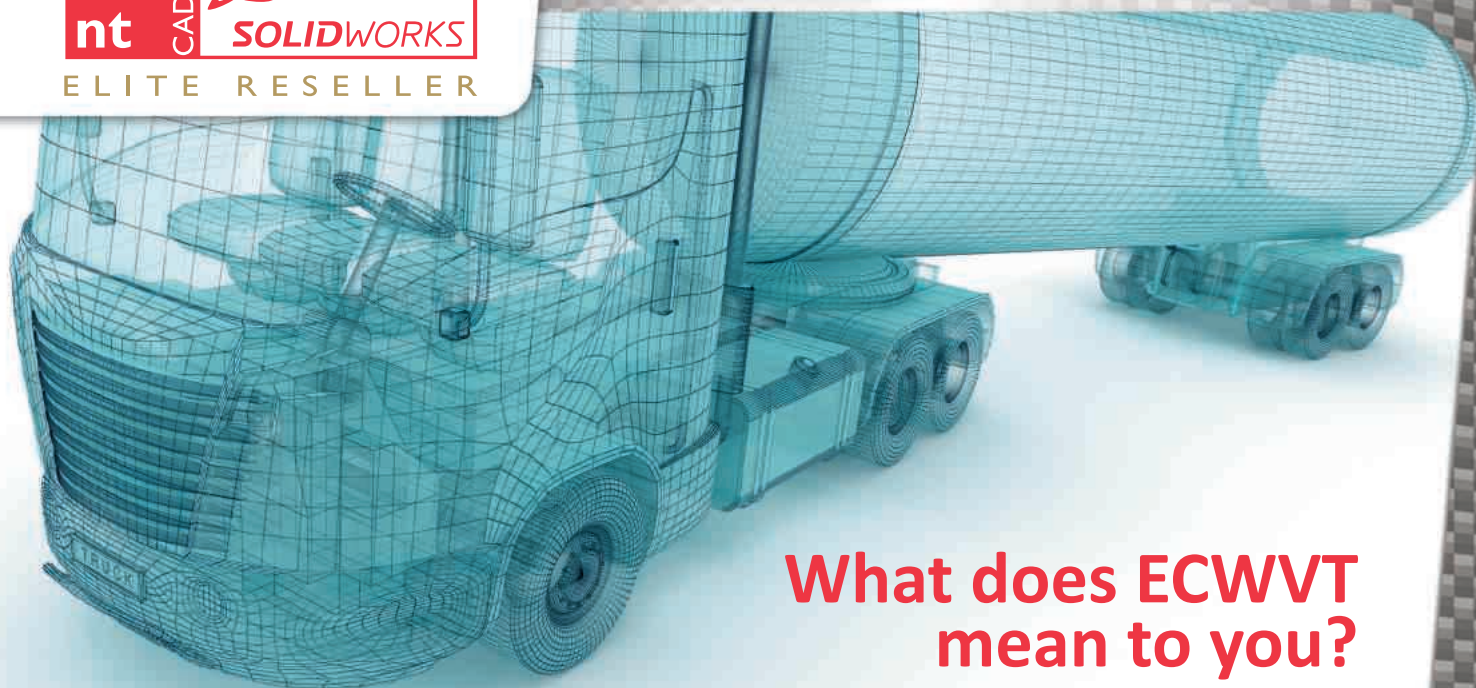


3D

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A NEW ERA**

IN MANUFACTURING





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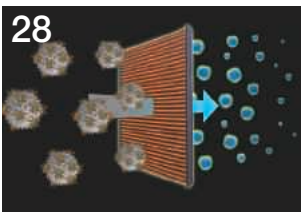
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- ✓ Enhanced collaboration and innovation with SolidWorks EPDM



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A year of accomplishment and opportunity

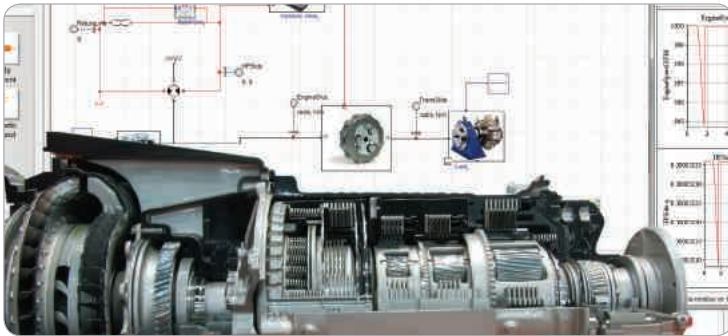
Frank O. Klegon, SAE International President

29 60 second interview

Dr Sae Hoon Kim, Hyundai-Kia Eco Tech Research Institute

From Months to Days

Do you want to develop complex multi-domain models quickly?



Electro-Hydraulic Clutch Actuator

1 month to 3 days

A highly realistic clutch actuation system incorporating effects from seven different domains in one model.



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Imprint of a new era



Is the automotive industry, and manufacturing in general, on the cusp of a new era? That's certainly the case if you listen to, and believe, what someone such as Stratasys CEO David Reis has to say on page 20.

There's certainly a growing belief that 3D printing and direct digital manufacturing (DDM) will have an impact on the way componentry is produced. Traditional manufacturing uses 'subtractive' techniques that create waste and require lengthy assembly processes, DDM is an 'additive' process that is virtually waste free, as well as enabling assemblies to be produced in a single build.

Stretch your imagination far enough into the future and it's possible that car assembly plants as we know them today won't exist: instead, there will be vast 3D printing and DDM machinery, producing entire vehicles in one hit. Fanciful? Yes, but NASA has been reported as investigating the feasibility of putting 3D printers into orbit and then delivering base materials to the space stations to assemble entire spacecraft.

While the prospect of building space ships in orbit may be more 'Star Wars' than 'Car Wars', back in the real world it seems that the industry is on track to meet the onerous 95 g/Kms CO₂ target for 2020. According to a report from the European Federation for Transport and Environment (T&E), OEMs will only need to make annual improvements of 3.8% to meet the 2020 objective.

Just what technologies they will require to achieve this is the subject of a year-long series of features that starts on page 24 of this issue with an examination of exhaust and emission technology.

Meanwhile, Ryan Borroff discovers that sound is just as important to seating systems as comfort and lumbar support. To find out how and why, go to page 30.

Ian Adcock, Editor in Chief

SUV efficiency gets a boost

It only exists on a computer screen, but Schaeffler's Efficient Future Mobility North America concept contains real technology and some interesting ideas. With each technology contributing, the total fuel consumption savings are in the region of 15% in the US City cycle. The company claims a working prototype of the four-wheel drive, mid-size crossover SUV will be built by model year 2017.

"The new technology is based on our product know-how, but it only exists at a prototype stage at present," says Peter Gutzmer, chief technical officer.

So the optimisation of the belt drive and valve train provides 1.5% savings, balance-shaft bearing optimisation 0.6% and optimised wheel bearings 0.5%. A thermal management module, which allows the engine to reach its operating temperature in the shortest possible time and maintains that temperature more precisely, gains 1%, adaptive grille shutters 0.2% and an optimised engine stop/start system 6%.

Schaeffler's all-wheel drive disconnect device, which decouples the secondary drive train at the power transfer unit to reduce the friction of spinning drive shaft and differential, is said to potentially save 2% in the city, but up to 6% on the highway.

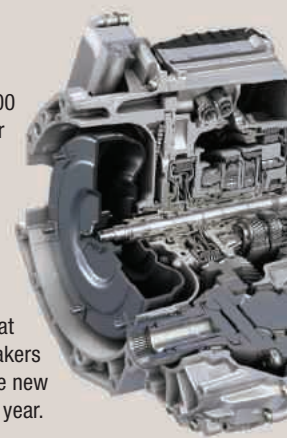
Innovations in the optimised start/stop function include a permanently engaged starter/generator that reduces vibration and noise, but speeds restarting, and a new latching valve, which stores the engine's kinetic energy as hydraulic pressure to help restarting.

Nine-speed auto debuts

Transmission and chassis-component manufacturer ZF has debuted two new transmissions at the NAIAS. Both are torque converter automatics: an eight-speed unit for longitudinal applications and a nine-speed for transverse applications. Both transmissions will be built at the company's new production plant in South Carolina for American OEM customers.

Built and equipped at a cost of €323.6 million, the plant employs 1,200 staff and

has a capacity to produce 800,000 transmissions a year. ZF's CEO Dr Stephan Sommer refused to be drawn on which manufacturers have signed up for the new transmissions and wouldn't comment on rumours that Chrysler will be using the nine-speed unit. But he did confirm that ZF is talking to three OEM car makers and that one would be putting the new transmission into production this year.



Premium interior previewed

Johnson Controls has demonstrated its interior seating, natural-fibre moulding and electronic display technologies at the Detroit Show, in the form of a complete interior buck. Called 'Bespoke Interior', the technologies are combined and mixed together to create a premium interior for a crossover utility vehicle. Using existing and all-new ideas, the interior is

also assembled in a new way, using 'zero gap' door panels, which eliminate the gap between the door and the dashboard panel, allowing greater space for heating and ventilation outlets, and a larger glove box.

The Gen 3 Synergy seat targets the weight and complexity of the conventional seat, together with eco-friendly materials to reduce the environmental impact. The seat back is a fibre-reinforced composite, with attached lugs and mountings to further reduce weight.

"We use an injection moulding and woven fabric, which we place into the mould," says Andreas Maashoff, director of industrial design and craftsmanship. The seat contains a remarkable array of technologies, with a coconut and



Range extender enjoys success during field trials

German engineering specialists KSPG has provided more details about the field trials of its elegant range-extender system, unveiled at Frankfurt IAA in 2011. The 800cc, 30kW vee-



configuration, twin-cylinder and twin generator system has been on trial with FEV on German public roads for six months now. Mounted in the spare wheel well of a battery powered Fiat 500, it has been successfully supplementing the power of the main drive battery, with no hardware problems, according to Horst Binnig, member of the executive board.

"It gives the battery car an unlimited range, apart from the fact you have to put fuel in it," he said. "The range extender will drive the car without battery assistance on a 3% gradient at speeds up to 100km/h."

"You cannot feel it and you cannot hear it," he said, proving at least part of his point with a video showing a one Euro coin balanced on its

edge on top of the 665 x 550 x 355mm unit when it is started and run.

Binnig thinks the next development is in software to integrate the range extender more fully into the car, so it will predict steep gradients ahead and prime charge the battery, ensuring it can clear the summit with charge to spare. Only cost seems to be a problem, with Binnig admitting that the system is over-specified with expensive dense copper alternators, which might need to be changed for cheaper, less efficient, examples for production.

• The company also showed its simple bolt-on system for variable valve actuation and complete cylinder



Mazda hails two industry firsts

Mazda is claiming two industry firsts for its i-ELOOP regenerative braking system and i-stop stop-start system.

The i-ELOOP is the first to use a double layer capacitor as its storage system; the 23 kilo joule capacitor stores sufficient electricity to power the car's electrical system, which can be consuming 500-600w, for up to 60 seconds, depending on ambient conditions and which systems are in use.

A DC/DC converter steps down the electricity from 25V to 12V, so it can be used for the vehicle's electrical components,

latex base cushion, which offers greater comfort thickness-for-thickness, compared with foam.

A twin-layer foam on top allows more precision in the seat shape and there's a choice of breathable leather finishes or 'climate fabrics', which breath and move moisture away from the passenger's body. The target weight reduction is "between 10 and 30%", according to Maashoff, but the seat provides other advantages, such as allowing more interior space and reducing the cost of seat coverings.

The door panel mouldings use a mix of natural fibres, including pine resins and thermoplastics, which are stamped and then injection moulded to give the stiffening ribs and lugs on the back. The edges are perfectly matched to the required size, which eliminates trimming and waste. The company remains gnomish about the exact details of the production process, but says "it is less capital intensive than anything we are doing in natural fibres today".

deactivation, which it predicts will be in series production within three years. The system augments an existing overhead-camshaft configuration with hair-sprung levers, which are interposed between the camshaft and the valve, and controlled with a third electronically actuated shaft. It's simple, but therein lays its appeal, says Dr Stefan Knirsch, president of the Mechatronics division.

He says that the company's own tests on the system suggest that, on its own, it can provide CO2 reductions/fuel savings in the NEDC of 7-8% on a naturally aspirated engine and between 5-6% on a turbo. It is suitable for diesel or petrol applications.

explained deputy programme manager Masaki Kodama. The system took three years to develop, he adds, and a capacitor was chosen over other battery systems on cost grounds, as well as its ability to withstand multiple rapid recharge and discharge cycles.

Mazda is also claiming that its new i-stop technology is the quickest yet, with the petrol

engine starting in 0.35 secs and the diesel in 0.4 secs. Both systems are unusual, in that they rely on whichever piston is in the optimum position for instant combustion to start the engine, rather than depending on the starter motor or generator to electrically start the engine, although the starter motor does engage once the initial ignition has occurred.



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Inductive charging

OEMs will be installing inductive wireless charging technology for mobile devices into their production cars within 12 months. That's the view of Delphi, which used CES to unveil its system.

Likely locations for the technology to be hidden include front seat storage areas and door bins. However, it's also expected to be integrated into front seat head rests. With a tablet PC attached, this would, for example, allow younger rear passengers to watch films, while extending battery life.

Geo-fencing goes live

Delphi has partnered with US mobile phone network Verizon to launch a 'geo-fencing' device for consumers.

The product is a black box the size of a cigarette packet that plugs into a car's OBD port. Geo-fencing is the principle of setting up a physical area where the vehicle is permitted to drive, triggering a text message alert, if it moves beyond the boundaries. The device will be available for American drivers to buy from Verizon retail outlets.

Robert Furst, Delphi's director of product line management, explained its appeal. "If a newly qualified driver wanted to use the family car to commute to and from college, you could set it up to allow that. As soon as he or she went off the route to visit a friend, it would alert the parent."



Hand on the pulse

The world's first gesture recognition technology for controlling in-car infotainment systems has been unveiled, with the promise it will be fitted to production models within two years.

Developed in-house by Harman, the innovation allows the driver to control certain features by waving a hand close to a sensor. The company's CES demonstrator included two of these, integrated into a centre console, one mounted vertically, so users gesture in front of it, and the other horizontally, so movements can be made above. A production vehicle would probably have one or the other.

The interface has been designed to be highly intuitive. For example, to move between menu pages, users 'swipe' their hand past the vertical sensor. To turn up the audio volume, they hover their hand over the horizontal one for a second, then raise it a few inches. In order to mute the music, you simply 'double tap' over the sensor.

Hans Roth, Harman's director of technology marketing, explained: "The benefit is that it's a safe and intuitive experience. Hand gestures are the most natural movement, requiring very little attention from the driver."

The Bee's knees

Visteon used CES to give a North American debut to its e-Bee concept, revealed for the first time last November.

Based on the Nissan Leaf, it is designed to promote car use, rather than ownership, and targeted at a society where micro-rental is more prevalent than today.

The e-Bee has a completely revised interior, with airbags relocated into the roof and the HVAC system under the bonnet. Driver preferences – such as display set-up or cabin lighting choices – are stored in the Cloud and automatically updated as a new user gets in.

Storage solutions, such as cup holders and an iPad sleeve, are described by Visteon as 'physical apps' and collected direct from a 3D printing shop.

Simon Harris, chief designer for Visteon European Innovation and Design, said he would be showing the car to customers over the next 12-24 months. "Its purpose is to show them we have considered the challenges the industry faces and that we will face them together."

On the question of a production timeline, Harris wouldn't be drawn, adding: "It's nice, if a customer says they like a specific technology in the car, but as important is the concept as a whole. It shows Visteon is a forward-thinking company and ready to meet the challenge of the future."



World's largest touchscreen

The world's largest in-car touchscreen was unveiled by QNX Software Systems, part of its 'connected cockpit of tomorrow' concept, built into a Bentley Continental GT.

The 17-inch full HD display was supplied by Texas Instruments and features the firm's Digital Light Processing (DLP) technology. The screen curves slightly towards its base, where the only physical control – an inch-wide ring dial – is mounted.

The centre of the dial displays menu information, but defaults to showing a digital recreation of Bentley's famous Breitling clock. QNX, which is owned by RIM, makers of Blackberry smartphones, worked in conjunction with the Crewe company to ensure the upgrade was in keeping with its luxury brand values.

The system includes 3D navigation developed by Elektrobit, while Crank Software's Storyboard Suite was used to develop the user interface. Two HD front-facing cameras, one each for driver and passenger, have been built into the dashboard to allow the screen to host videoconferencing while the car is parked. The advanced voice technology, for a more realistic sound, includes what QNX calls 'stereo telepresence' for making remote callers sound as if they're sitting close by. A voice recognition system, based on AT&T's Watson (SM) technology, is accessed via a "Hello, Bentley" greeting by the user. The car responds, appropriately enough, in a British accent.



3D surround sound arrives

The world's first two examples of 3D surround sound in-car audio made their impressive debuts at CES.

The 'third dimension' is height and both systems feature speakers fitted into a car's headliner.

Audi revealed a 23-speaker hi-fi, developed by Bang & Olufsen, in its Sound Concept car and confirmed it that it will be available in the all-new Q7 SUV when it goes on sale next year.

Meanwhile, Harman unveiled a concept version of its QuantumLogic 3D set-up in a BMW 7-Series.

The car's speaker count has been increased from 16 to 25, including five that are built into the ceiling. Harman said it is in discussion with potential OEM customers.



'Augmented reality': the real thing?

The next generation of Head Up Displays will feature 'augmented reality' images that react in real time. It means sat-nav route directions projected on to the base of the windscreen will feature arrows that point out exactly where the driver needs to go, seamlessly shifting as the car gets closer to a turning or junction (see Question Time, page 32).

The system has been developed by Harman, and other uses will include collision warning technology. As the driver approaches a slower vehicle from behind, the display will highlight this in red to alert the driver to the danger. The company confirmed it is talking to OEMs.



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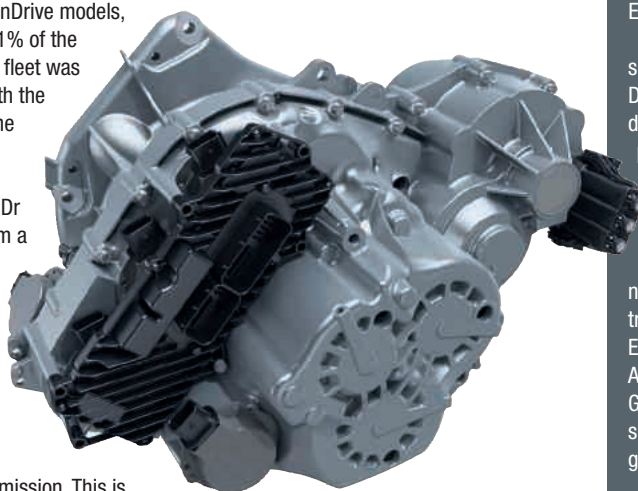
How many gears is enough?

This was the theme question tackled by the 2012 Symposium on Innovative Automotive Transmissions and the responses were as varied as the presenters – from Sung-Ho Cho of Hyundai, who at last gave official confirmation that the Korean group was developing a 10-speed planetary automatic, to Volkswagen's Dr Tobias Lösche-ter Horst, who insisted the single speed of VW's TwinDrive prototype was sufficient. Presenting the results of the 20-car field study with TwinDrive models, Lösche-ter Horst revealed that 51% of the total mileage of the diesel hybrid fleet was covered under electric power, with the remainder accomplished using the diesel engine and its single-ratio transmission.

Another paper presented by Dr Robert Fischer of AVL argued from a theoretical viewpoint that, while current engine technology ("too sensitive for large gear steps") was pushing towards more gear ratios, a downsized and optimised concept engine showed very little reduction in efficiency with a four-speed, as opposed to a seven-speed, transmission. This is

especially marked when a hybrid element is added, leading AVL to predict that, after an initial rise, the average number of ratios will begin to fall.

Finally, with today's engines, seven speeds were the optimum for a DCT, said Getrag chief technology officer Didier Lexawith, with only minuscule gains to be had by going to eight or nine – "but only if you don't use a ratio span of 10, but keep below 8.5".



Surprise auto for 1-litre Focus

Ford, which has partnered with Getrag to popularise dual clutch transmissions in the small and medium segments, is to announce a US-sourced, six-speed planetary transmission as the automatic choice for its latest European Focus, with its innovative one-litre, three-cylinder gasoline engine. Yet the smaller Fiesta with the same engine will use a new-for-Europe dry clutch Powershift DCT.

While the Fiesta pairs happily with the six-speed dry DCT from the US, said Ernie DeVincent, vice president of product development at Getrag, the weightier Focus poses more of a challenge. "With the larger platform, there is too much inertia and you can't get the acceleration that's needed," he revealed at the CTI conference in Berlin.

No launch date was revealed for the new engine/automatic pairings, nor which transmissions would be used on other, larger, European Ford models. But he did reveal the Asian market would be the main target for Getrag's new wet clutch 6DCT150, the six-speed, lower-torque derivative of the new-generation 7DCT300 seven-speed core model.

Porsche reveals 918 Spyder hybrid workings

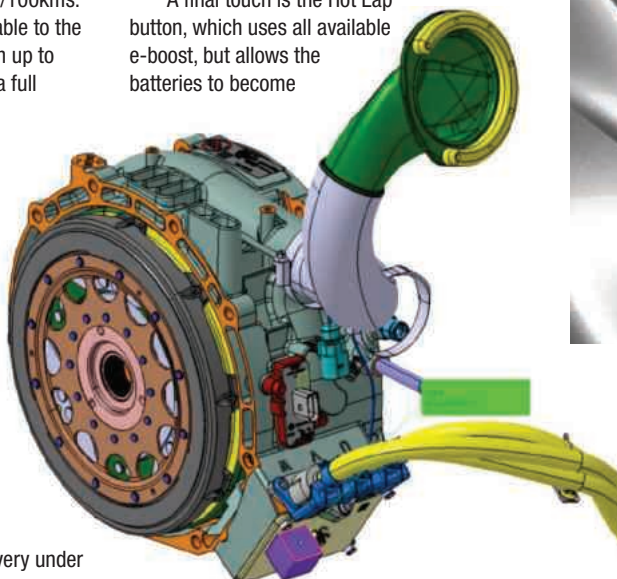
Porsche engineers have revealed carefully selected details of the hybrid powertrain of the radical 918 Spyder supersports car, capable of 320km/h, yet with fuel economy of 3l/100kms.

Five powertrain modes are available to the driver. E-drive allows the 918 to reach up to 150km/h on pure battery power, but a full flooring of the throttle pedal will fire up the 447kW V8 engine; Hybrid mode provides the optimum fuel economy by strategically selecting the most efficient blend of power sources, and with regenerative braking being limited to 0.5 g. Sport Hybrid, on the other hand, engages both gasoline and electric drive elements, with the combustion engine also recharging the batteries.

The more extreme Race Hybrid mode deploys the 918's active aerodynamics (thus increasing both downforce and drag), but also activates an extreme charging strategy, with maximum energy recovery under

braking, and peak boost from the 95kW front and 85kW rear electric motors for the best possible acceleration out of bends.

A final touch is the Hot Lap button, which uses all available e-boost, but allows the batteries to become



depleted, thus maximising the engine power reaching the rear wheels. The proof of the hybrid system's effectiveness comes with a claimed Nürburgring Nordschleife lap time of 7 mins 14 secs – better than that of the V10-engined Carrera GT.

News in brief

Supercar transmission

Xtrac has designed a hybridised, automated, seven-speed manual transmission, designated 1010, that will allow supercars to meet the 95g/km CO₂ emission requirement for 2020. The transmission can handle engine torque capacities ranging from 800-1,000Nm, dependent on vehicle gross weight and the particular application. The electric vehicle speed range has been set just below 95mph (150km/h), allowing torque infill up to fourth gear during high performance acceleration and in all gears up to the threshold speed during low-speed driving when it is desirable to keep the engine revs low, thus improving vehicle efficiency.

Lotus lightweight strategy unveiled

Lotus Engineering's 'Phase Two' body structure design, based on a 2009 Toyota Venza CUV, and utilising advanced materials such as high-strength steels, aluminium, magnesium and composites, along with advanced joining and bonding techniques, has achieved a substantial body and overall vehicle mass reduction, without degrading size, practicality or performance, it reports.

Body mass was reduced by 37% (311lbs or 141.6kg), contributing to a total vehicle mass reduction of 31% (1,162lbs or 528.3kg), including the mass savings of other vehicle systems (interior, suspension, chassis, closures etc) previously identified in 'Phase One'. Computer Aided Engineering (CAE) analysis indicated that a 31% mass-reduced vehicle, with a 37% lighter Body-in-White (BIW) structure, has the potential to meet US Federal impact requirements.

Although the mass savings in the BIW design results in an increased BIW cost of \$723 (£456/€568), the overall vehicle cost is reduced through savings of \$239 (£150/€188) across the whole vehicle, and including manufacturing and assembly costs.

Correction

In the last issue, figures in the article 'ZF slashes supply chain' should have read: €20 billion is the target for total turnover in 2015 and not the growth. And the total turnover for 2011 was €15.5 billion and not €5.5 billion, as stated.

Sailing ahead

If you're cruising along in the automatic version of the new seventh-generation VW Golf, with the vehicle Mode selector set to Eco and the instrument display configured to show instantaneous fuel consumption, the read-out will disappear as you lift your foot off the accelerator. In its place comes 'Coasting'.

Coasting used to be frowned upon by safety experts, who argued that travelling with the drive between the engine and the wheels disconnected could impede vehicle control in an emergency. Now, however, Volkswagen is able to

conventional cars to save further fuel by sailing with the engine stopped, rather than idling. The company's investigations with a high-end, stop-start package showed a fuel saving of some 0.6l/100kms when comparing what it calls high-speed float with so-called passive sailing, with the engine on in both instances.

Presenting a paper on start-stop potential with manual transmissions at the CTI Symposium on Innovative Transmissions in Berlin last December, Schaeffler e-mobility programme manager Dr-Ing Eckhard Kirchner declined to



Dual mass flywheel and pendulum damper as examples for improved and new Schaeffler products for high performance - high comfort engine - start-stop systems

build coasting into the operating logic of the new Golf. Thanks to the versatility of the dual clutch automatic transmission, both clutches can be opened at the same time, so the transmission is effectively in neutral, though a gear is always engaged. This enables the Golf to 'sail' along under its own momentum, with no drag from its engine to waste the kinetic energy it has built up. As soon as the driver touches the throttle or brake, drive is immediately re-established.

The real reason why coasting – or 'sailing' when translated from German – is on the agenda is that it can yield a useful improvement in CO₂ emissions. Volkswagen was not quite the first to introduce coasting to conventional cars. That honour went to Porsche where, again in the context of a DCT, the latest-generation 911 Carrera introduced a fuel-saving sailing mode under certain specific conditions. Ford has also made provision for the feature in some of its US-market Powershift DCTs. Yet, in each of these instances, the engine is kept at idle while the drive is disconnected, whilst hybrids break the link not only to allow electric propulsion, but also the combustion engine to be shut off when not needed, even at speed. Schaeffler, among others, argues that it could be logical to allow

quantify the fuel-saving benefit, if engine switch-off is also enabled, hinting it would be significant.

He stressed, it would be a very quick re-start of the engine in the sailing condition. A flywheel-pinion starter systems would take "too long, at 1.2 sec," he said. Instead, permanently engaged or belt drive solutions would be required, with the pendulum tensioner arrangement able to restart the unit in 400msec.

These are technologies developed to deal with the crucial 'change-of-mind' scenario for engine stop-start systems. Strategies will have to be devised to deal with engine restart after loss of speed during extended periods of sailing, one conundrum being whether manuals should undertake a downshift to ensure the engine is able to provide a sufficient reserve of power when the restart takes place.

Schaeffler's thinking is extending further towards high-end, stop-start solutions providing elements of hybrid functionality. These could include energy harvesting, front end accessory drive disconnect to liberate torque, engine torque support under acceleration, electric creep for manoeuvring and reversing, and load point shifting to improve the IC engine's efficiency.

ContiTech strengthens business in hose lines

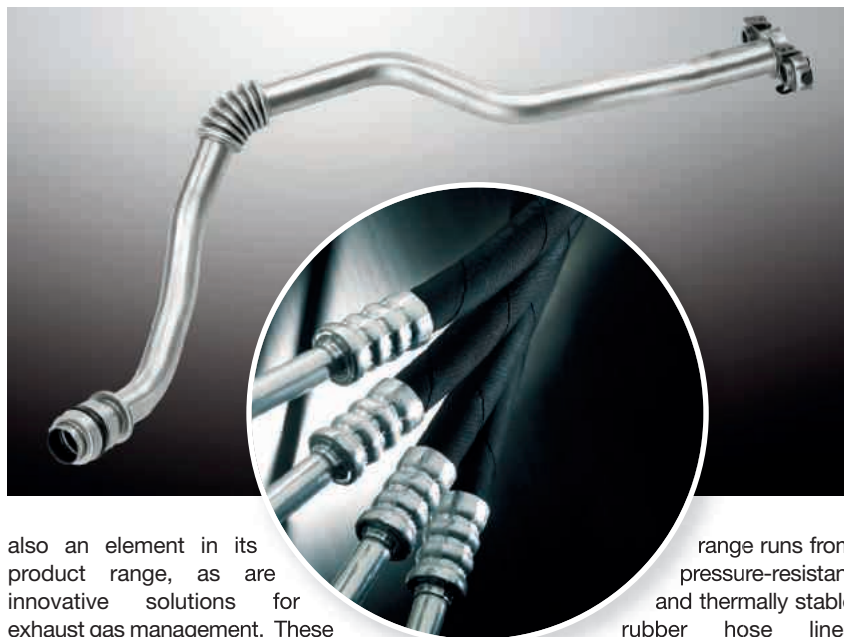
The stainless steel corrugated tube for the oil return line can be used wherever ambient temperatures can exceed 220°C. Below: Air conditioning lines.

Hanover, January 2013. ContiTech Fluid Technology 2012 has strengthened its business in hose lines for the automotive industry by the acquisition of the automotive air conditioning business of the Mobile Climate Systems division of Parker Hannifin Corporation. It manufactures refrigerant control and containment components for passenger car and light truck vehicle air conditioning applications. ContiTech also invests some €13 million in a new plant for air-conditioning and power steering lines in the Russian city of Kaluga, and a new production facility in Subotica in northern Serbia assembles hose applications for use by European automakers in powertrain systems. The company also expanded its Somersworth/USA location to its second competence center for plastic lines.

ContiTech Fluid Technology develops and produces a broad range of components and systems that make cars both more sustainable and more comfortable. As development partner and original equipment supplier the company channels the full gamut of media flows in the auto and many other key industries. The development and production of perfect-fit connection technology likewise demonstrate the company's systems expertise.

The business unit of Hanover, Germany-based ContiTech AG scores, moreover, with its wide-ranging material and process competence, extending from rubber technology through to plastics technology.

Customized all-in-one solutions that transport the media required to guarantee that the engine is supplied with fuel are



also an element in its product range, as are innovative solutions for exhaust gas management. These include heatable hose modules developed for "Selective Catalytic Reduction" (SCR) technology, as well as hoses and hose lines for particulate filter systems.

The optimum integration of hoses, tubing and fittings enables ContiTech Fluid Technology to produce tight connections for AC units. So the revamped ECO AC product range made up of air conditioning lines and internal heat exchanger make air conditioning units more efficient.

Charge air hoses and lines have to withstand ever higher pressures and temperatures. ContiTech develops and produces solutions that meet the most demanding performance requirements for tricky clearance situations. In the case of brake and clutch systems, the product

range runs from pressure-resistant and thermally stable rubber hose lines through to compressed air brake line harnesses with a practical plug connection. What is more, ContiTech Fluid Technology develops and manufactures all types of intake hoses for use in supplying air to the engine as well as pneumatic pressure hoses for controlling automotive power units.

All components and complex modules developed – also for heating and cooling circuits – meet the most exacting requirements in terms of flexibility, pressure and temperature resistance.

With over 14,000 employees, ContiTech Fluid Technology produces hoses, curved hoses, hose lines and tubing at 34 locations all around the world. In 2011, it realized sales of approximately €1,3 billion.

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Green revolution



How green can a car plant be? Hugh Hunston travels to Tangiers to discover if Dacia has the answers

As a Renault campaign veteran, whose 35-year career with the French company has spanned from the developing of Alpine sports cars to overseeing its powertrain operations, engineer Jacques Prost is not prone to exaggeration or overly flamboyant language.

So when he enthuses about his role as Renault Morocco's director with specific responsibility for Dacia's newest production outpost on an environmentally pioneering greenfield site near Tangiers, the words carry weighted significance.

Commenting on his stewardship of arguably the greenest plant in the Renault-Nissan Alliance system, Prost

says: "This is probably my greatest and most exciting career challenge, with its ecological, technical, logistical and personnel elements.

"Management roles in Europe and France are not easy on any front. But, with growth continuing to happen for Dacia and the plant's development evolving, you set your horizons virtually each hour, day and week. We will export from Morocco to 100 markets and Africa has the promise to be the automotive sector's next Eldorado."

ROYAL ASSENT

Underpinning this €1.1 billion joint venture with the Moroccan government, and endorsed enthusiastically by prime

mover King Mohammed VI, it embodies the imperative of creating a nominally zero carbon and effluent factory.

The latest of four Dacia factories, which have applied the budget brand's industrial footprint in Romania (Pitesti), Turkey (Bursa), and India (Chennai), the Tangiers facility should have an annual installed capacity of 340,000 vehicles by the end of 2013.

Located within Morocco's tax-friendly free trade zone, with its inward investment magnetism, the factory, boasting a modest 16% robotisation factor across assembly processes, has at its heart two biomass boiler units. These were developed jointly with Veolia, hot water production, waste management and recycling specialists, and provide a closed water loop, plus re-processing and re-cycling water.

Powered by heat generated through burning olive stones, wood chips and argan shells, from a locally produced crop, the boilers crucially provide the paint shop with pressurised (30 to 40 bar) water at 220°C. A further source of green fuel will involve planting eucalyptus trees locally. The biomass approach saves





CV

Jacques Prost

Jacques Prost took over as managing director of the Renault Group's Moroccan operations in November 2012, with the remit of ramping up production of Dacia's Tangiers greenfield site, while also being responsible for Renault and Dacia sales in Morocco.

A career Renault engineer since joining the engine department in 1978, he graduated from the Ecole Nationale Supérieure du Pétrole et des Moteurs. His first management role within Renault was as head of the Alpine sports car studies department. Prost later project-managed the A610 sports car.

Other project management roles have included Laguna 1 between 1990 and 1994, plus Clio III and Modus as vice president director of B sector models.

Powertrain and manufacturing expertise was combined in 1997 with a five-year stint managing the Cleon engine and transmission plant in Normandy, which specialises in producing diesel engines for the Renault-Nissan Alliance.

In the seven years leading up to his Moroccan appointment, Prost, as a senior corporate vice president, headed powertrain engineering, including electric powertrain development. He has been a member of Renault's management committee since the beginning of 2008.



daily consumption of 2,500m³ of water locally, on the basis of a daily 60 vehicles a day output, or, as the Renault press material quantifies it, the capacity of 175 Olympic swimming pools annually. As a result, there is 70% less withdrawal of water for the industrial processes, compared to a similar capacity plant, and no local environmental discharges.

SUSTAINABLE APPROACH

This has particular resonance in Morocco where water supplies are of major social, economic and strategic concern. Ironically, severe flooding over the 2010-2011 winter held up construction of the Tangier factory, recalls Prost, providing "more than a little local difficulty".

Emphasis on sustainable energy, he points out, is consolidated through electricity from wind farms located on the hills surrounding the plant, while the Moroccan authorities plan greater hydroelectric power utilisation and an increase in surprisingly low solar panel energy-sourcing levels.

At present, the Tangiers complex, with its 2.5kms long production line, claims a 98% reduction in CO₂ emissions, compared to an equivalent conventional plant producing 400,000 units annually. That equates to saving around 135,000 tonnes of CO₂ a year. Greater solar sourcing, plus tree planting and buying carbon credits, should attain the 100% target within two years.

These interlinked virtuous energy and emissions circles also involve ash from the burned chips, stones and shells going to manufacturing cement, while hazardous "post-industrial" waste extracted from filtering the water through membranes is burned to produce concrete.

Plant manager Tunc Basegmes, a Turk instrumental in setting up the Turkish Bursa Dacia factory, is pragmatic enough to admit that LPG-powered incinerators use electricity to start up when production begins on Mondays at 6am. This acts as a stop-gap until the switch to exclusively thermal electricity comes in.

GENETIC IMPRINT

He claims the green approach is "built into the genes of our factory and from 2014, when we reach production cruising speed, we will be closer to 100% with the second line".

Just as with fiscal incentives of zero corporation tax for the first eight years of the plant's life, then only 8% for the following 20 years and zero VAT, official Moroccan enthusiasm for the project is believed to extend to subsidised energy bills.

When asked about the cost of establishing and operating this ground-breaking facility, Prost says: "It was no greater than it would have [been] with a conventional plant, due to focusing on sustainable production. Extra and better solutions did not lead to additional investment costs. Government co-operation and subsidies were part of that equation."

The sustainable investment in the Moroccan factory's development was €40m, and Renault claims that will improve the project's competitive edge as the cost gap between renewable

Automotive Design Interview

and fossil energy sources widens. Prost is intent on growing the cluster of tier one suppliers within 30kms of the plant, and domestically provided components from 18 "local" units represent 44% of parts by value and 70% in volume terms. On a volume basis, the remaining share of components is split evenly between Europe, "India and elsewhere".

CRITICAL MASS

He envisages an automotive city within the Tangiers-Med free trade zone, acting as "an attractive hub for tier one and, equally importantly, tier two and three providers. It is difficult to hire smaller suppliers just for us, which is why we have no anxiety about other manufacturers establishing assembly units here".

He is not drawn on those OEM candidates, but both Kia and VW are known to be discussing potential output with the authorities, which Prost says would provide the scales of economy and critical mass for a wider cluster of suppliers, adding: "we cannot do this on our own".

Equally, the factory and nearby €800 million Tangier-Med super port, with its dedicated Dacia wharf, is just 14kms across the straits of Gibraltar from mainland Europe, from where Spanish-built diesel engines and Romanian petrol units are shipped. A dedicated rail spur, linking the factory and port, was also provided by state agencies.

Prost reasons: "Our project will be a complete success when tier two and three suppliers are established in force. And we also must ensure that Moroccan suppliers evolve, in terms of repeatedly consistent levels of quality."

SKILLS TRAINING ON SITE

Currently, the main tier one companies within 30kms of the plant are Valeo (seats), Saint Gobain (glass), SNOP (small components), Yazake (electric cables) and Faurecia (dashboard modules.) Another facet of the partnership between the Renault-



"Anyone creating manufacturing resources here wants labour rates to remain low"

Jacques Prost

Nissan Alliance (Nissan has a dormant section of the plant for potential future use) and the north African state is the establishment of the onsite automotive skills training centre, bankrolled by the Moroccan government.

Having trained 4,000 personnel since the beginning of 2011, the standalone unit will also be offered to suppliers and has a 40% skill failure rate, a seemingly woeful figure. This is countered by Basegmes pointing to an anticipated 50% factor in a country with little or no industrial, let alone automotive manufacturing, culture.

Dacia employees are paid up to 15% above the going industrial rate at around €280 a month or €1.50 an hour, while Romanian line workers receive €400 monthly.

Prost denies that the arrival of Kia and/or VW could lead to wage

inflation and some of the elite established section of his workforce being lured to higher wages by the incomers. He reasons: "Anyone creating manufacturing resources here wants labour rates to remain low, at between 12% and 15% of production costs. I don't know if their plants will be established in the free trade region, while it will be at least four years before they are operational. Our staff attrition rate here and in our older factory in Somaca (near Casablanca) is very low at 3%."

LEARN AND SHARE

One novel and apparently isolated exception to that was 220 staff, mainly former agricultural workers, failing to return to their Tangiers Dacia

factory work stations after the Ramadan festival holiday.

While Dacia's four plants will "learn and share from each other's experiences", Prost

does not see these particular green technologies being applied retrospectively across older brownfield sites.

As well as potentially amortising the cost of developing the energy and emission-reducing systems across the Dacia network, much of the processes involved have been or are being patented.

Tangiers is on track to raise the 57,000-unit 2011 production tally of Lodgy MPVs and Dokker LCVs, (plus car derivatives) to 340,000 vehicles, "market conditions prevailing", and plans to add Sandero hatchback and its Stepway SUV counterpart in right-hand-drive form to that production portfolio.

Prost summarises establishing the Moroccan facility as: "a uniquely liberating experience and unique technical challenge. Dacia as a brand would not exist without innovative plants like Tangiers. Renault would be 1 million short in global output terms".



The shape of things to come

As the auto industry reshapes itself, one company is in the forefront of EMC and RF testing; providing everything you need to meet tomorrow's challenges. AR has high, medium & low power amplifiers for component, subsystem and total vehicle level testing as well as interoperability testing. AR amplifiers have the performance, dependability and quality needed to reduce test time while adhering to stringent standards. Staying on the forefront of development, AR has created amplifiers with "sub-ampability"; the ability to add incremental power based on demand and when budget dollars become available.

With over three decades serving the automotive industry, AR is the number one source for all components for complete test systems from RF and microwave power amplifiers to power-matched complimentary accessories.

Our RF Conducted Immunity test system adheres to automotive standards with an unmatched level of reliability, flexibility and ease-of-use. We offer three separate systems covering frequency ranges from 10 kHz to 400 MHz with output powers up to 150 watts to meet industry standards including DO-160, ISO, IEC, MIL-STD-461 as well as unique customer requirements. As your one stop shop, AR can supply all of the ancillary accessories needed to build your complete system.

To assist with pulse testing, AR's PL7004 pulse laser electric field probe allows measurement of the frequency bands from 1.2 to 1.4 GHz and 2.7 to 3.1 GHz. In addition we supply automotive



New electric field analyzer kits from AR are dramatically faster and provide more detailed information

manufacturers with the ability to generate high pulsed fields with our extensive line of traveling wave tube amplifiers (TWTAs) and high power antennas.

AR also continues to be the industry leader in solid state amplifiers with units ranging from 10 kHz to 18 GHz to meet your radiated immunity testing needs. As always, our amplifiers are compliant with IEC and MIL-STD-461 standards. At the forefront of RF systems, AR recently introduced our line of MultiStar products which includes the fastest EMI receiver on

the market and our revolutionary MultiTone Radiated Immunity Tester and Field Analyzer. AR supplies a multitude of unique RF solutions to companies around the world – including most major automotive manufacturers. With these new products, AR strives to make testing easier, more accurate and more cost-effective.

We know that each customer has unique requirements. AR's system integrators are available to work with you to create a customized solution. Our sales and support network is second to none with offices in Europe and distributors worldwide. AR is your partner both before and after the sale with every product we sell backed by our comprehensive product warranty.

So for all of your EMC and RF testing needs, one company has proven to be your strategic partner for years and is dedicated to your continued success, AR.

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Stop, thief!

Luxury cars seized within the EU by thieves are generating a staggering €6.75 billion a year in revenue. But a new facial recognition system may be about to stop them in their tracks as Ian Adcock discovers

Although the rate of theft of motor vehicles – which includes cars, motorcycles, buses, lorries, construction and agricultural vehicles – has fallen steadily over recent years within the EU, with member states recording a 10% decrease between 2006 and 2009, there are some worrying underlying trends.

According to Ari Huhtinen, European branch president of the International Association of Auto Theft Investigators, it is luxury brands such as BMW, Mercedes-Benz etc that are mainly being targeted.

RICH PICKINGS

A Europol report says a thief can net €15,000 (£12,600) from a premium product, estimating that half the vehicles stolen within the EU are shipped to neighbouring states, where they generate annual revenue of a staggering €6.75 billion.

This situation has been

exacerbated by the availability of cheap OBD devices that can cost as little as £100 (€118) and which can be hidden in fake mobile phone cases, meaning that many high-end cars are becoming increasingly vulnerable to professional gangs who steal and export them to Eastern Europe, the Far and Middle East, as well as some European and African countries.

Delphi, however, might have a found a solution with a newly developed facial recognition system. Uniquely for this type of technology, it uses a light source and camera to project a line pattern onto the subject's face. The camera then 'sees' and records the subject's two-dimensional (2D) facial equivalent of a fingerprint, comparing that image to a database of stored 2D facial prints for a possible match. A 'positive' match with the proper stored image means the person is recognised and recognition then triggers unlocking the car door.

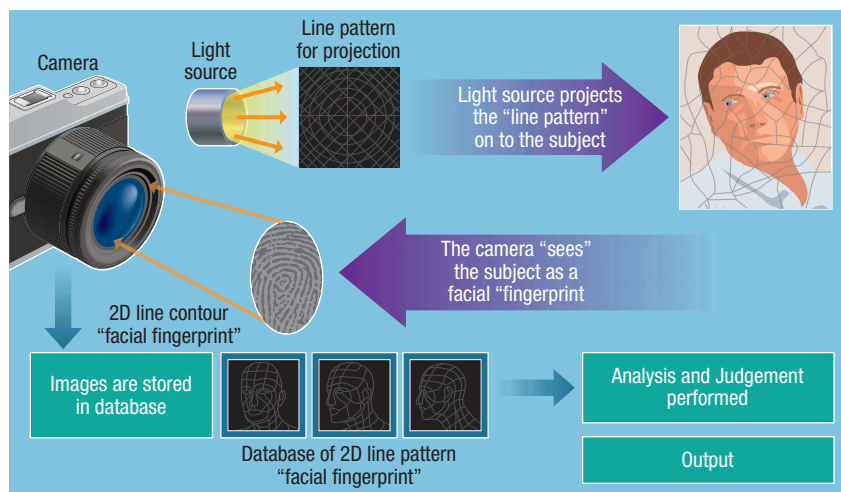
According to Virgil Darga, Delphi's licensing manager, Delphi

Technologies, Inc. (DTI) the patent-pending facial recognition system was originally developed "to recognise vehicle occupants and make automatic personalisation adjustments to the vehicle controls, such as the seat, radio and climate control settings." Potentially, it could, also be used to disable the vehicle, even if the thief has managed to break in or steal the car, having physically removed it on the back of a lorry.

NUMEROUS ADVANTAGES

"Delphi's unique system is considerably different from other facial recognition systems out there on the market today," says Darga. "Most facial recognition systems are designed to create a geometric 'map' of the subject's face, using points such as the nose, mouth and eyes. This method requires large processing capability and additional time to determine the location of those facial features contained in the image."

Delphi claims its technology has numerous advantages over other systems currently available, namely that it utilises a non-intrusive infrared (IR) light source; doesn't require unique recording equipment or materials; increases recognition accuracy versus state-of-the-art systems; the identification programme is resistant to hacking and is secured by two layers of defeat security; it enables recognition, even with minor physical changes to the subject's face; reduces recognition and confirmation time; and, finally, utilises smaller data files, providing lower system costs.



A year of accomplishment and opportunity



As I approach the end of my tenure as SAE International President, I'm struck by two equally significant and divergent facts. One is that we have accomplished a great deal and two is that there always is more work to do.

I set some very specific goals – or focus areas – at the beginning of the year. They included increasing the engagement of Tier 1 and 2 suppliers; expanding our involvement with middle and high schools; exploring associations with local science centres; increasing visibility of social media, including job search and career development opportunities; engaging in cross-industry sharing by maintaining SAE International leadership discussions; and continuing to build relationships with key government agencies and policy influencers.

In many ways, all of these goals are intertwined, because they help to advance the mission of SAE International. Separately, they highlight different strengths of the organisation, while using the various talents of SAE International volunteers and staff.

UNITED SUPPORT

At SAE International events throughout the year, top suppliers from around the country, representing all three industries served by our organisation, provided support

through sponsorship and technical programme development.

SAE International's award-winning 'A World In Motion' programme continued to bring to life science, technology, engineering and mathematics (STEM) in classrooms across the nation. Such learning is even more powerful, because it blends traditional classroom learning with hands-on teaching from industry volunteers. We expanded those learning opportunities by creating a new agreement to manage the F1 in Schools Challenge in the United States.

GLOBALLY CONNECTED

SAE International has increased its presence on the Web, especially in the world of social media. Our members have the ability to connect, regardless of where they are in the world, especially through the means of EngineerXchange, which offers users powerful networking tools, career counselling/management tools, and advanced access to SAE International technical content.

Last year, our Board of Directors held a meeting in Washington, DC. While there, we met with several lawmakers, committees and agencies, reminding our colleagues in government that SAE International can and does serve as a relevant source of information – information that can help them make better-

informed decisions, especially those regarding mandates and regulations. And, over the past year, I've had the opportunity to meet with many executives from the aerospace, automotive and commercial vehicle industries. We've shared candid conversations of how SAE International can better serve their needs, and how the industries can better work together to share innovative ideas and technologies, as well as business solutions.

However, as I mentioned, for every accomplishment there are even more opportunities; there are chances to begin new programmes, products and services, and make existing ones even better. This can seem daunting to some, but I choose to see it for the promise that it holds.

SAE International and its members have represented the innovation and hope of mobility engineering for more than a century. That has been the hallmark of this organisation and I know that it will continue.

I am proud to have served as SAE International President, of our accomplishments, and excited for what lies ahead. I want to thank all who have helped to make my tenure a memorable one. I will stay involved with SAE International and its never-ending mission to enhance mobility engineering across the globe.

focus@sae.org

Manufacturing reformation

When the Obama administration pledges \$100million towards developing a new technology, it has to be taken seriously. Additive 3D printing could well revolutionise manufacturing, as Ian Adcock discovers

Direct digital manufacturing (DDM) and 3D printing were recently dubbed by 'The Economist' as the "third industrial revolution", transforming the way goods are manufactured, in the same way the mechanisation of the textile industry did in the late 18th century – and Henry Ford, when ushering in the progenitor of the modern assembly line in 1913.

That's certainly a view held by Objet's CEO David Reis, as he told me at the launch of the company's latest and biggest 3D printer yet: the Objet 1000. "The [US] Government sees 3D printing as a means of bringing back home manufacturing. If you go to President Obama's White House website and look for additive manufacturing, you will see that he has initiated a programme, and allocated \$100m research into 3D

printing and direct digital manufacturing.

"It's a similar phenomenon here in Europe, with a comparable investment that is funding 3D printing and research. Europe lost three million jobs to Asia, with similar numbers in the USA, and governments think that 3D printing is one of the pillars to bring manufacturing back home. There's a lot of excitement about it."

RAPID MARKET GROWTH

The market is growing on a quarterly basis, according to Reis, with projections that it will be worth about \$6 billion by 2019, three and a half times bigger than today, adding: "In the last 36 months, we've seen 20-25 new entries in the industry, with different technologies to solve various problems in both plastic and metal printing.

"We took the automotive users to see the prototype and get their feedback on the product; they wanted easier material handling and, where you open the covers to replace the canisters, they wanted a window at the side to see that everything is working well.."

David Reis, Objet CEO





rubber through to transparent, as well as ABS grade, engineering materials, including a flexible range with Shore A values from 27 to 95 at their fingertips. It is also capable of printing up to 14 different material properties within a single model.

It was the automotive sector that drove the development of the Objet 1000, which can accommodate models weighing up to 200Kgs, although it is equally happy working on much smaller ones, says Reis. "Up to now, OEMs had to print two halves when doing a large job, like a fascia, and then glue it together.

USER WISH LIST

"We took the automotive users to see the prototype and get their feedback on the product; they wanted easier material handling and, where you open the covers to replace the canisters, they wanted a window at the side to see that everything is working well. They wanted a 1:1 model of the final part, without giving up on the capability of using different materials. That's really the driving force behind the Objet 1000.

"At the end of the day, it's all about the product development cycle, reducing that time and minimising design errors.

"By having digitally printed prototypes in days, rather than weeks, over the course of a whole product development means



months are saved."

Reis sees Objet's 110 patents – including pending – that cover fundamental 3D printing technology, as well as in relation to inkjet methods and processes and the resins chemistry where it has 20 chemists working purely on that aspect, as core competencies over its rivals.

With its 1000mm bed, Reis believes the next step forward will be more accurate and faster inkjet technology, before going on to explain the company's future road map. "Objet is going in two directions. One is towards DDM [see sidebar], which is basically industrial machines with plastic-like materials. The biggest challenge here is the material development; doing it bigger, faster. I'm not saying it's easy, but it's relatively simple. As Objet improves the resins, we will capture a larger part of this section, because the technology is very good.

New force in DDM and 3D printing

Objet has joined forces with Stratasys Inc to form a leader in 3D printing direct digital manufacturing (DDM) under the Stratasys brand, with Objet's David Reis assuming the role of chief executive.

The company will offer three leading technologies: FDM for functional prototypes and production parts; inkjet-based PolyJet for prototyping parts with high feature detail and fine surface finish; and Solidscape Drop-on-Demand (DoD) thermoplastic ink-jetting technology for complex wax patterns, for investment casting of finished parts.

In addition to the Objet range of 3D printers, the

merged businesses will offer Stratasys' range of affordable desktop 3D printers for idea development, a range of systems for prototyping and large production systems for direct digital manufacturing. The company's range of more than 120 3D printing materials is believed to be the widest in the industry, and includes over 100 proprietary inkjet-based photopolymer materials and 10 proprietary FDM-based thermoplastic materials.

Stratasys also manufactures Solidscape 3D Printers and operates the RedEye On Demand digital-manufacturing service.

Cover Story

"The other direction is smaller desktop 3D printers with ease of use, bringing this technology to the desktop in a very simple, accessible way. Small design jobs will be done on the desk and, when you need to print something bigger, it will go to the rapid prototyping centre.

"I think, if we do our job properly in the auto industry, we will deepen our penetration to the rapid proto-

typing centre, but, at the same time, bring the technology to the engineer's desktop," he asserts.

Objet 1000 goes on sale with an introductory price of €500,000, with the final price determined in the second quarter of this year.

ALTERNATIVE VERSION

It struck me as being somewhat ironical that, as I left the Frankfurt's

IAA, where the Objet launch had been held, my route should take me past a 21.5m-tall kinetic structure by Jonathan Borofsky. One of four – the others are in Seattle, New York and Seoul – the 'Hammering Man' seems to be working metal at a constant pace – a stark reminder of how things were once made. The question is: will it eventually be replaced by a giant 3D printer?

Bentley does it

Luxury car maker Bentley has been using 3D printing in one form or another since it developed the 614 Project – better known as the Continental GT that was launched in 2004, says Dave Hayward, operations and projects manager for its Crewe-based design studio. It now has an Objet 30 and Connex 500, and is trialling a Up!Plus+ desktop printer for very accurate interior parts, such as knurling on knobs and other switchgear.

The Connex is used for a variety of parts from the interior, as well as exterior, features, such as grilles and radiator shells. "Even though the machine can only make parts to around 500mm, we stitch them together to make a 1.2m trim part; the abilities of the machine don't hold us back, in terms of what we want to make," he states.

"Because the 500 has the ability to make both rubber and solid parts, we can make a rubber simulated engine hose with a solid core end to fit it to a vehicle and see how it flexes. In our own capacity, we make 1/10th and 1/3rd scale rims with the inclusive rubber tyre, so it looks more realistic when the model is complete and viewed."

SWIFTER UPDATES, MORE ITERATIONS

The main advantage of using a 3D printer, claims Hayward, is swifter design updates and more iterations than would otherwise be possible, allowing a part to be refined and reviewed within 24 hours. Bentley predominantly uses Objet Vero White as the finished component, he states, which is invariably painted, chromed or finished in DI-NOC. Although it uses Vero Clear and Tango Black, Bentley is investigating the possibility of employing green ABS Light for 3D parts fitted to moving vehicles, as it's "more stable".

While Hayward agrees that the new Objet 1000 would allow Bentley to produce a one-third scale model in a couple of days, compared to the two or three



weeks it takes to prepare a similar-sized clay, the payback time on the half million Euro investment would have to be calculated, as well as investigating other potential uses within the company. Currently, Bentley outsources large 3D projects to third parties.

With Bentley's emphasis on bespoke trim and finishes, its sales and marketing department and Mulliner personalisation division use the 3D printers to produce models for specific requests from clients.

"In the past, we used rigid foam, but now we can turn their ideas into reality very quickly for them to review; typically, that's glassware and holders for different bottles of champagne or decanters etc.

"The possibilities for this technology are almost endless in what it can do," Hayward concludes.

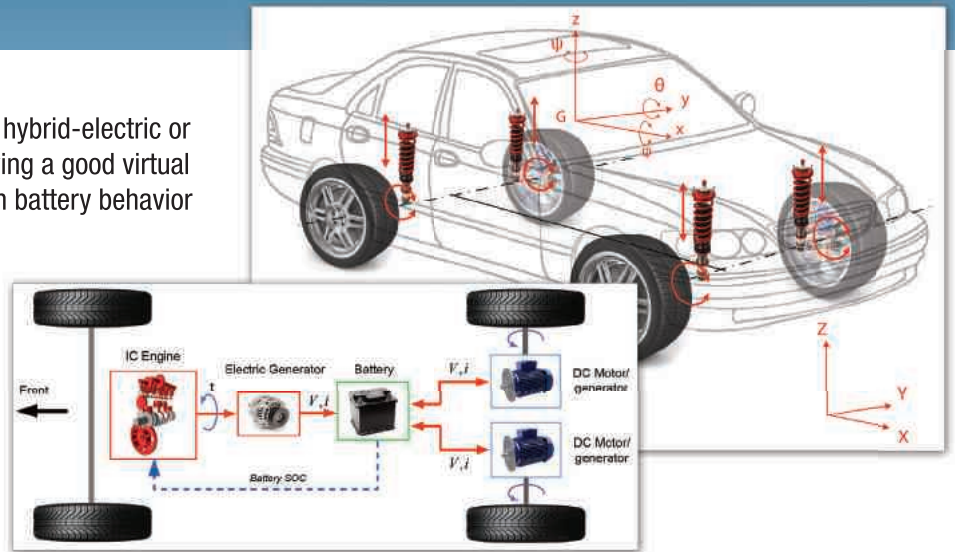
Advanced Research Produces High Fidelity Battery Models

One of the most important components of a hybrid-electric or fully electric vehicle is the battery itself. Having a good virtual model of the battery is essential so that both battery behavior and the physical interaction of the battery with all the other components are properly reflected in the model. Because the battery plays such a vital role in the vehicle, capturing these interactions is essential to designing an efficient, effective electric vehicle.

Dr. John McPhee, the NSERC/Toyota/Maplesoft Industrial Research Chair for Mathematics-based Modeling and Design, is working to develop high-fidelity models of hybrid-electric and electric vehicles, including the batteries. They chose MapleSim, multi-domain physical modeling and simulation software from Maplesoft, because they have found the symbolic approach in MapleSim to be an effective way to develop simulation models that have fast real-time speeds for hardware in the loop (HIL) testing and very high fidelity compared to models created in conventional modeling tools.

Battery Electric Vehicle (BEV) Model

Batteries in vehicles are subject to periods of high current draw and recharge and large temperature variations, which can have a significant effect on the performance and lifespan of the batteries. To capture these effects, Dr McPhee and Mr. Seaman needed a model of lithium-ion battery chemistry over a wide state-of-charge range, widely varying currents, and various temperatures. Starting with an electric circuit battery model, they implemented the components in MapleSim, using a custom function component to represent the nonlinear relationship between the state of charge and the electrical components. They modified the battery equations to simulate a battery pack that is composed of series and parallel combinations of single cells. Next, they developed a power controller model in order to connect the battery pack to a motor. They then incorporated a one-dimensional vehicle model into the model. The simple vehicle model drives on an inclined plane, which is in turn controlled by a terrain model. A drive cycle model was included to control the desired speed of the vehicle. The resulting differential equations, generated by MapleSim, were simplified symbolically and then simulated numerically.



Hybrid-Electric Vehicle (HEV) Model

The team used MapleSim to develop a multi-domain model of a series HEV, including an automatically generated optimized set of governing equations. The HEV model consists of a mean-value internal combustion engine (ICE), DC motors driven by a chemistry-based NiMH battery pack, and a multibody vehicle model. They modeled the battery inside MapleSim by placing the governing equations of the battery processes directly inside MapleSim custom components.

MapleSim automatically generated an optimized set of governing equations for the entire HEV system, which combined mechanical, electrical, chemical, and hydraulic domains. Simulation results showed that the model is viable and, as a result of MapleSim's lossless symbolic techniques for automatically producing an optimal set of equations, the number of governing equations was significantly reduced, resulting in a computationally efficient system.

"With the use of MapleSim, the development time of these models is significantly reduced, and the system representations are much closer to the physics of the actual systems," said Dr. John McPhee. "We firmly believe that a math-based approach is the best and quite possibly the only feasible approach for tackling the design problems associated with complex systems."

For more examples of cutting-edge applications using MapleSim, please visit: www.maplesoft.com/compendiumAutoDesign

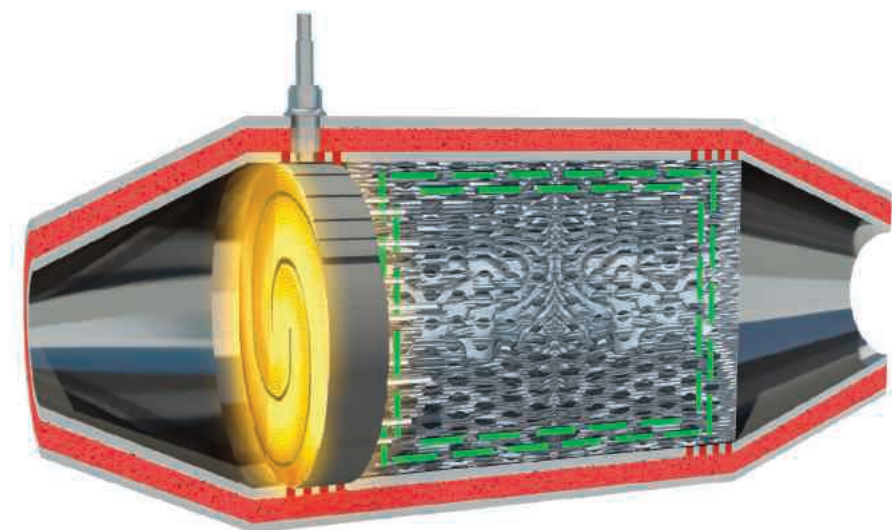
CO₂ CHALLENGE ENTERS A NEW DIMENSION

Now that the challenge of meeting the 2015 European corporate average fleet CO₂ emissions level of 130g/km has been broadly delivered, the sights of engineers have been refocused to the year 2020. Barely a single model generation away, it is then that OEMs will have to meet the much tougher target of 95g/km – something that will really concentrate the best minds in the business. Tony Lewin reports

The real challenge is that the next, far tougher, target of 95g/km CO₂ emissions level needs to be achieved in parallel with ongoing reductions in regulated emissions. Inconveniently, the flipside of most of the new technologies that curb an engine's CO₂ emissions tends to be an increase in raw engine-out NO_x – which just happens to be the pollutant that will be hit hardest in the transition from Euro 5 to Euro 6 in two years' time.

DOUBLE DUTY

It is clear that the exhaust system and all its associated catalysts, particulate filters, NO_x-reduction units and control systems will play a crucial role in dealing with the undesirable side-effects of the new wave of low-CO₂ engines. Yet the exhaust's primary role as an enabler of low-emission engine technologies is likely to be complemented by a new and exciting secondary function as a source of free energy – energy that is normally wasted, but which can be put to good use in reducing fuel consumption by as much as 5%. As even the most

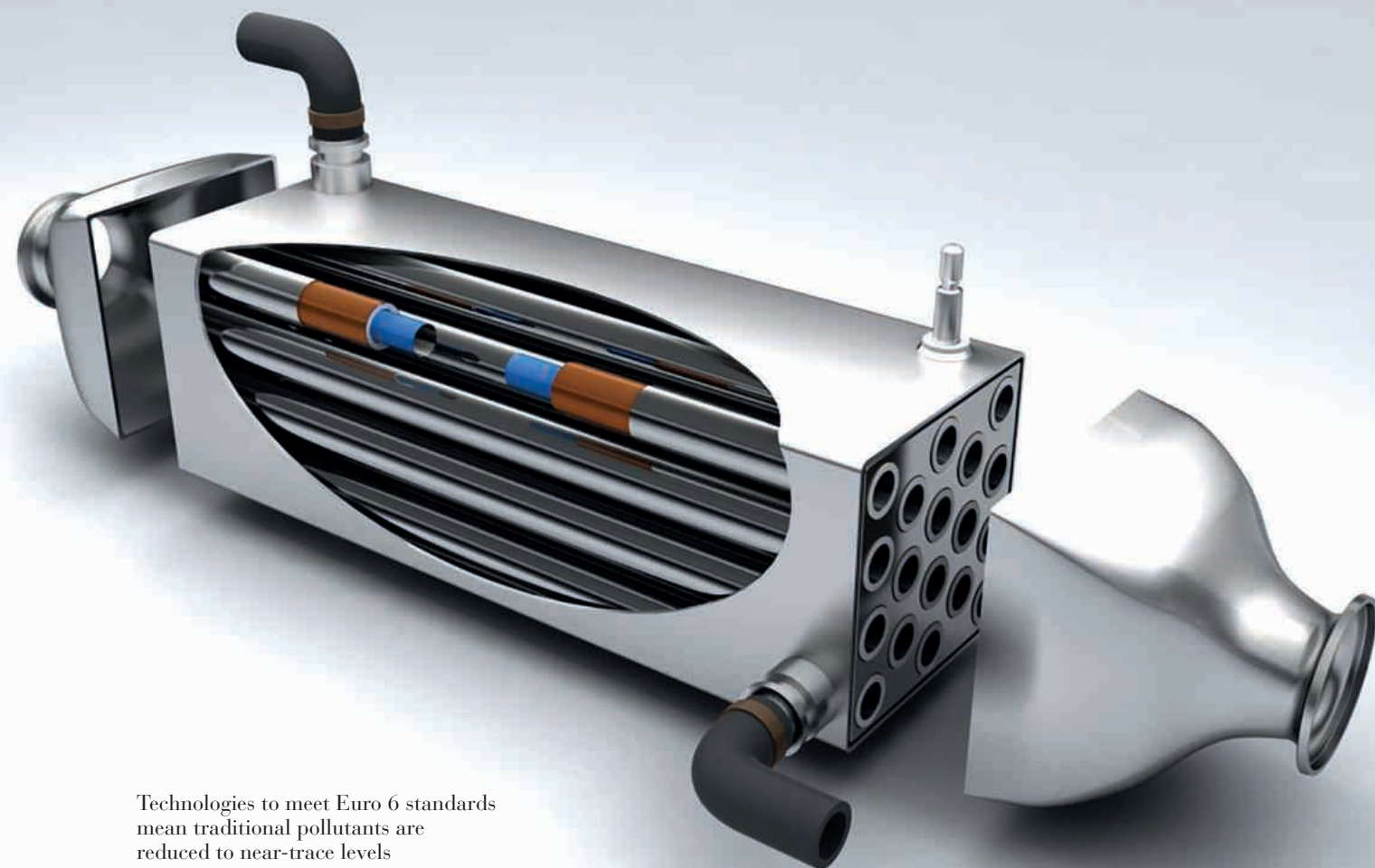


cursory glance at the energy loss matrix for a typical vehicle will show, just 38% of the fuel's energy content is translated into mechanical power: 29% goes into the cooling system and one third is wasted in the flow of hot gases out of the exhaust tailpipe.

Studies that have been released by a variety of companies, such as BMW, Ricardo, Faurecia and Eberspächer, suggest that a useful fraction of this exhaust energy could be recovered, perhaps yielding as

much as 1kW of electrical or mechanical power.

A study by John W Fairbanks of the US Department of Energy showed a steady output of 500W at 120Km/h (75mph) from a thermo-electric generator on a BMW X6, resulting in a 5% improvement in highway fuel efficiency. Savings in everyday use could be double those that show up in the NEDC drive cycle, says Fairbanks, with an 8% gain on a BMW 750iA. While this system



Technologies to meet Euro 6 standards mean traditional pollutants are reduced to near-trace levels

uses an Amerigon Seebeck-effect electronic generator, other possibilities include turbine generators (which could yield as much as 5kW, according to Ricardo) and even using the exhaust as a heat source for a Stirling engine or – as in the case of a recently announced Bosch truck project – a steam generator.

Faurecia's EHRS system under development with Ford for the 2013 Fusion hybrid transfers some 1 to 4kW of exhaust heat into the coolant and is claimed to provide faster cabin warm-up, resulting in less HVAC-prompted engine running time.

Other systems explored by Ricardo for the Low Carbon Vehicle Technology Project use phase-change materials or exploit the hot coolant as an energy source to power

an absorption cooling air-conditioning system, reducing cabin cooling electricity demand by 2kW – equivalent to saving 1 to 2 litres per 100kms on a hot day.

Technologies to virtually eliminate emissions of traditional pollutants, such as CO, HC and particulate matter (PM), are very well established, and Euro 6 standards reduce these to near-trace levels.

ALTERED CHALLENGE

The challenge, as explained by a diesel expert from Delphi, has now moved on: "Diesel engines provide an outstanding solution to the problem of CO₂ reduction but, until now, the requirement to reduce NO_x and CO₂ simultaneously has been a challenge," the Delphi man concedes. Developments such as cooled EGR

and the moving of aftertreatment components closer to the hot end of the exhaust system help to reduce NO_x and speed up light-off of each element. Yet, says Delphi, deNO_x aftertreatment systems will be essential on light duty passenger cars to enable manufacturers to meet the fleet average of 95g/km.

The actual technology selection will very much depend on the vehicle size and on the test cycle applied, but tightening standards in markets where cars are heavier are likely to force the use of selective catalyst reduction (SCR) systems on a broader range of models. This NO_x-reducing technology, which like many diesel technologies originally appeared on trucks, is now used on certain German premium diesel cars in the US.

Exhaust & emission technology

"SCR systems are expected to be seen in most markets," predicts Delphi. "They will soon be widely seen in off-highway markets and the use in passenger car applications is expected to rise sharply as more stringent CO₂ requirements take effect," it says. Delphi's new SCR dosing system, due in 2015, is optimised to work with a SCR catalyst placed closer to the engine for faster light-off.

Improved catalyst performance can directly help reduce overall CO₂



output, too: with lower and more consistent tailpipe NO_x levels, engineers can afford to re-optimize engine calibrations in order to further reduce CO₂.

The alternative to complex SCR systems, which require the driver to top up a reservoir of special fluid at specified intervals, is simpler, lean NO_x traps that store nitrogen oxides on a coated surface, releasing it at intervals as harmless nitrogen when the engine provides a rich spike. The advantages of this solution, equally applicable to gasoline engines, are a low light-off temperature and good, cost-effective NO_x removal rate, according to BASF.

Techniques to deal with particulate emissions from diesel engines are very well established and engineering debate centres principally on the most energy-economical methods of regenerating them, especially on city-type vehicles where overall system temperatures remain low. Here, the new CB2 (Catalytic

Bypass Burner) from HJS is an innovative development and could later find passenger car applications.

Where the engineering establishment was taken by surprise was with the realisation that direct injection gasoline engines could have quite high levels of particulate emissions. An SAE paper, again emanating from Delphi, stated in 2011 that GDI engines could have higher numbers of smaller particles than diesel. "The mass requirements [for Euro 6] can be met without after-treatment, but the number is more challenging," said the author.

EU 6 norms specify identical 4.5mg/km particle mass and 6.0×10^{11} number limits for gasoline and diesel, though the gasoline values may be revised for EU 6.2 in 2017/8. Papers by Dow Automotive and Corning both outline design priorities for dedicated gasoline

particle filters (GPF), and Eberspächer has teamed up with NGK

Europe on what the two firms describe as an innovative approach to future EU 6 compliance on PM numbers for GDI engines.

Separately, PSA, St Gobain and several other organisations have begun working on GDI filters for future Euro 7 standards, with one of their proposals being a "single filter medium" able to "simultaneously and synergistically" treat both particulate and gaseous emissions.

OBSTACLE OR OPPORTUNITY?

Not all new engine types achieve low CO₂ at the expense of high levels of engine-out NO_x; several companies are working on engines that run on gasoline, but use elements of a diesel's compression ignition process. Delphi, for one, claims to have marked an advance over earlier HCCI designs with its GDCI unit. In a 2012 SAE paper, the authors cite results that "suggest that aftertreatment for NO_x and PM might be reduced or



Moving aftertreatment components closer to the hot end of the exhaust helps to reduce NO_x and speed up light-off

possibly eliminated, depending on legislated limits".

Diesel hybrids pose a particular problem, with the intermittent operation of their engines causing high levels of raw NO_x and PM each time the relatively cold engine restarts. This can require a large and complex aftertreatment installation, though the lack of cold gas flowing through means an already warm system will stay warm.

Yet thermal management remains critical to performance optimisation and, in the opinion of one supplier, in order to achieve Euro 6 levels the catalysts need to be active after 1 to 2 minutes after a cold start at minus 20° C. "The ideal objective is to achieve this level of warm-up times of the exhaust system by design and to have no active warm-up measures which cost fuel," said the company.

Range-extended electric vehicles, where the engine rarely runs, are a different matter: Emitec, for instance, has developed a special catalyst system with pre-heating and thermal insulation that helps reduce cold-start emissions by 90%.

Slippery wheels

Ford's Atlas concept pickup promises some key fuel-efficiency technologies. Here's a taste of what's to come writes Lindsay Brooke

Ford's Atlas concept pickup, unveiled at the 2013 North American International Auto Show, provides a glimpse at some key fuel-efficiency technologies engineers are readying for the 2015 F-150 pickup.

Besides the shift to high aluminium content in the front end and cab, aimed at reducing the 2015 truck's curb weight by up to 317kg, versus the current F-150, and a next-generation EcoBoost powertrain featuring stop-start, Ford is putting serious focus on reducing aerodynamic drag, says Raj Nair, group vice president of Global Product Development.

ACTIVE WHEEL SHUTTERS

The Atlas shows a few of the results of "our extensive aero development" on the next-generation pickup, Nair tells Automotive Design.

An unexpected feature on the Atlas is active wheel shutters. These are in at-rest position behind the wheel spokes when the vehicle is

stationary and at up-to-moderate road speeds. As vehicle velocity increases to above 60mph (97km/h), its wheel-speed sensors signal a dedicated battery that powers the shutters. They deploy in a fan-like pattern (think of a Chinese fan being opened), closing off the openings between the wheel spokes and thus enabling smooth airflow across the wheels.

Active grille shutters and an automatic-deploying active front air dam work in conjunction with the active wheel shutters, Nair explains. The Atlas concept truck also features power running boards that tuck in close against the truck's body at speed, also helping to reduce drag.

Ford's simulations and early testing indicate the aero package, as shown on Atlas, is capable of providing a fuel-efficiency gain of more than 0.85 l/Kms at highway speeds, without diminishing towing or hauling capability. Full-line automakers such as Ford will have to improve their light-duty trucks' fuel economy to approximately 32 US

mpg (7.3l/100kms) to comply with the new US CAFE regulations that require a 54.5 US mpg (4.3 l/100kms) fleet average by 2025.

SHARED TECHNOLOGY

The 2015 F-150 is also expected to feature a 10-speed planetary automatic transmission, currently under development, according to Ford and supplier engineering sources. As previously reported by Automotive Design, Ford and General Motors are in discussions on sharing advanced transmission technology, as they have done with the highly successful six-speed transaxle programme.

Other technologies revealed on Atlas that have potential for the 2015 production truck include a 360° point-of-view camera that provides the driver with a 'bird's-eye' view of the vehicle; driver-controlled trailer-backup assist; dynamic trailer-hitch assist that helps line up the hitch with the trailer coupler; a dual-purpose tailgate step/cargo cradle; and LED headlamps and tail lamps.



A breath of fresh air

With 98% of cars sold in Europe featuring air-conditioning as standard, there's big pressure on the suppliers to maximise their efficiency.

Ian Adcock reports on the latest trends

With heating, ventilation and air-conditioning systems (HVAC) capable of sapping between 5-12% of power from an engine, that becomes significant as downsizing and stop-start become more prevalent. "You're right," says Dr Prasad Kadle, director of advanced engineering, Delphi Thermal Systems, "which is why we have just introduced our 100cc Compact Variable Compressor, which goes on small passenger cars, as opposed to the 145, 165 and 185cc

versions for bigger cars. We can control it electronically, so it destrokes to 10cc when it isn't required and then increases displacement as the load demands."

Denso took a slightly different route back in 2009 when it introduced injector technology that can reduce the compressor's power consumption 25% by employing a small refrigerant injector, installed in the system's evaporator, that recovers expansion energy previously lost in the expansion valve.

SMART THINKING

Meanwhile, Valeo takes yet another approach to solving the same problem, claiming a 3% efficiency gain en route, by using enhanced components, such as an adaptive expansion device, high-performing evaporator, high-efficiency internal heat exchanger and externally controlled compressor. In addition,

Aluminium has replaced copper and bronze in cooling systems for lighter weight

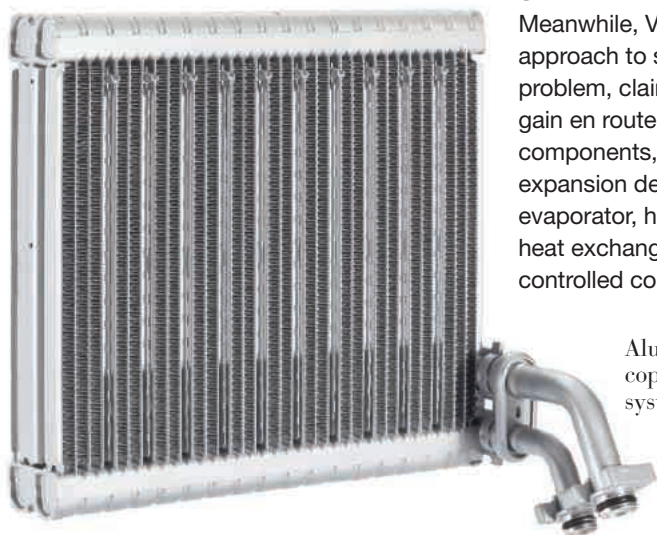


Delphi's Dr Prasad Kadle

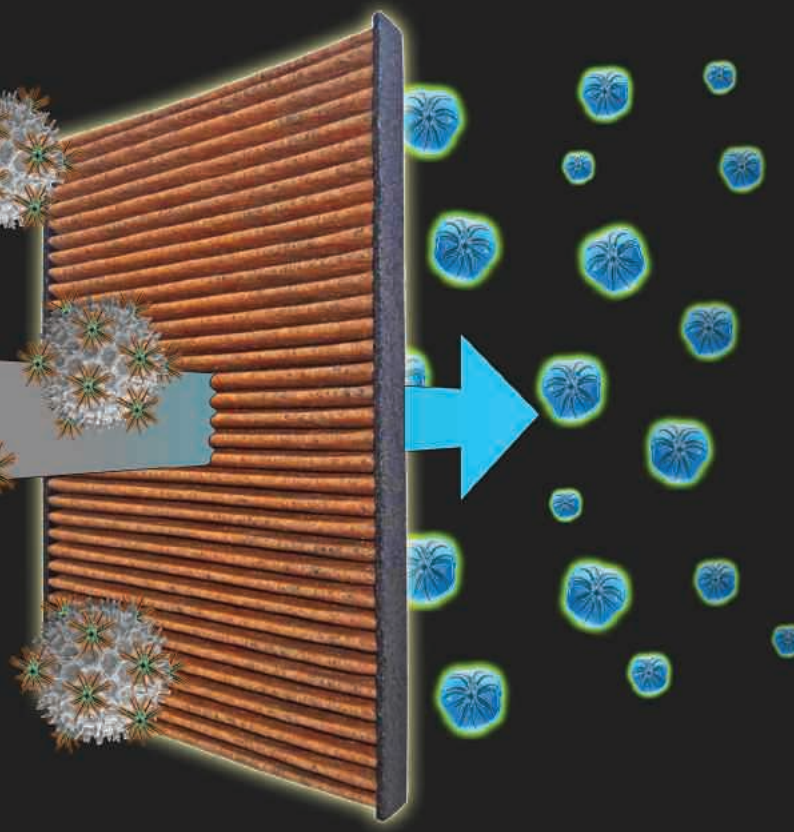
the control of the blower and the fan is made by pulse width management (PWM), enabling significant consumption savings in real conditions. But it's the development of electronics and the integration of smart phone technology into cars that is driving advances in HVAC technology as much as anything else, says Kadle, who predicts that within a decade the SatNav system will be linked into the HVAC and, together with pollen alerts, automatically switch it to recirculation mode to prevent noxious odours or pollen entering into the car's cabin atmosphere.

By the same token, he doesn't set much store by personalised aromas being injected into the air stream to make the interior atmosphere more agreeable. According to Valeo, surveys have shown that the quality of air inside a vehicle can be from two to five times worse than that of the air outside, so it is proposing several filtration technologies to keep air in the cabin healthy and pleasant.

The first level is a filter protecting



HVAC



Filtering out the allergy causes

For the first time in Europe, Valeo has developed a filter that stops not only dust, toxic gases and odours, but also neutralises pollen allergens.

In industrialised countries, the number of people suffering from pollen allergies has doubled in the past 30 years. By 2040, it is calculated, 40% of the European population will have an allergic predisposition.

Yet the probability of allergy sufferers being involved in a traffic accident is 30% higher. The symptoms of these allergies (sneezing, itching, watery eyes, runny nose, breathing difficulties, fatigue, irritability and headaches) are not just a source of discomfort; they can also significantly impair driver concentration. Improving vehicle interior air quality can also help improve road safety: when travelling at 80 km/h, a driver will cover 25m with his or her eyes closed when sneezing.

Delphi's PCM Evaporator



the occupants against particles measuring between 0.5 and 10 microns present in the air in urban areas. The second involves a combined filter that removes particles and provides protection against pollutant gases and odours, thanks to a layer of active carbon. These filters can be supplemented with an anti-allergen function by applying a natural surface treatment that deactivates the allergens present during periods of pollination.

HEAVEN SCENT

Unlike Delphi, Valeo offers a fragrance dispenser to further improve the occupants' comfort. This new system, which is separate from the air-conditioning, includes two perfumes and an intensity control. It's not surprising to learn that weight and packaging are two of the major drivers: Kadle talks of compressors weighing only 5Kgs, evaporators reduced from 90mm to 38mm, and the increased use of aluminium over copper and brass. And although Delphi and Renault experimented with placing the HVAC unit under the floor of a mini-

van, Kadle remains convinced that the traditional bulkhead location will continue, albeit with much smaller components and "smart heating and cooling with thermo electric elements which save a tremendous amount of energy".

Visteon is also moving in that direction, as evidenced by the HVAC system supplied to Ford for its Brazilian designed and manufactured EcoSport that includes a compact, centre-mounted HVAC system; compressor; condenser, with integrated receiver dryer; and air-conditioning lines, with 'zero leak' metal seal fittings. The EcoSport's air-conditioning system is amongst the

Valeo's innovative filtering system and evaporator (below), and high efficiency heat exchanger (top left)

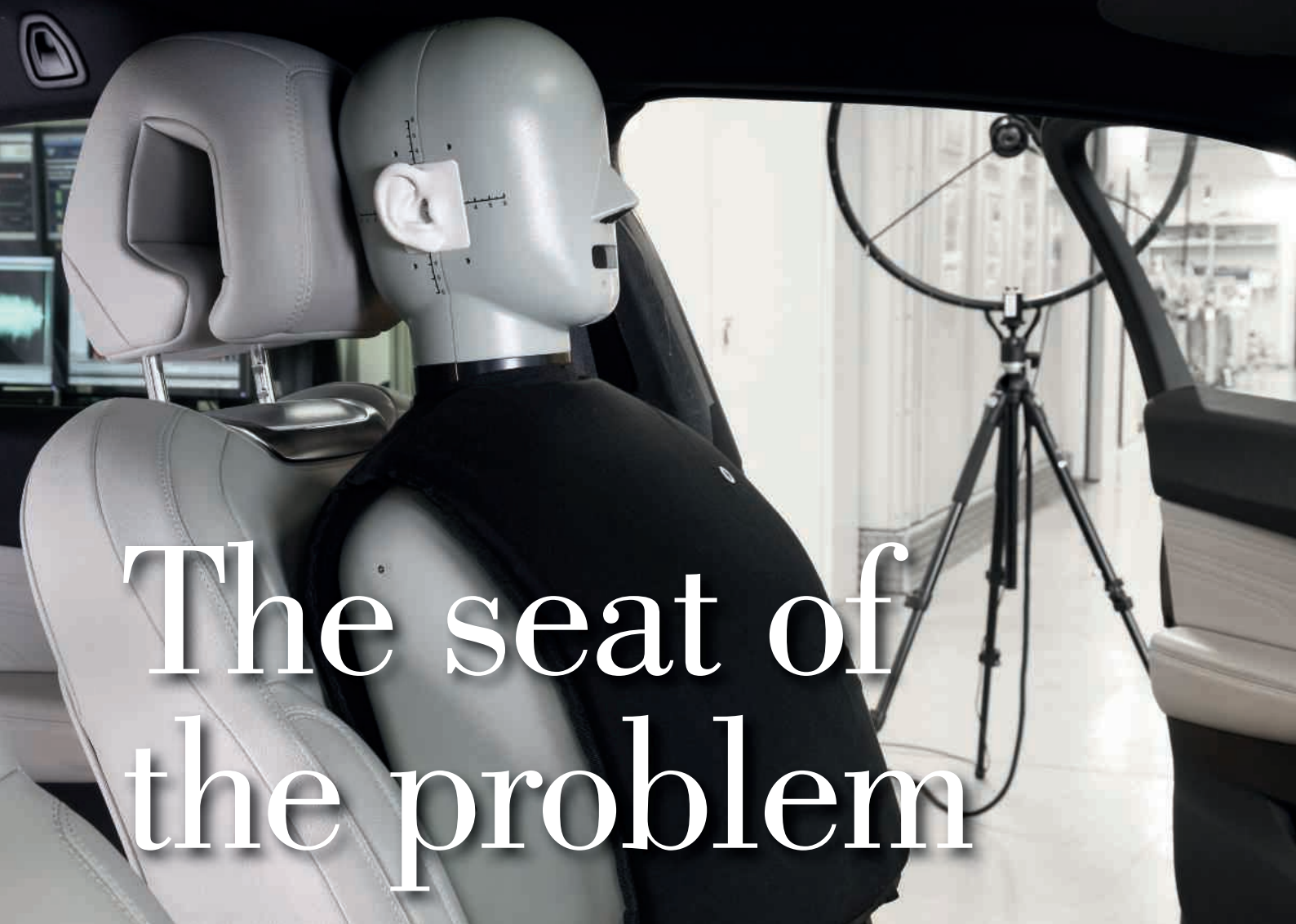


first to apply a 45mm 'tube-fin' evaporator construction for maximum performance in transferring heat out of the cabin, for quick, efficient passenger cooling.

STEMMING LEAKAGE

Visteon's patented metal seal fitting is engineered to eliminate refrigerant leakage stemming from air conditioning connections in vehicles. Moreover, it is currently the only fitting classified as a metal gasket under the SAE J2727 refrigerant emission chart, thereby achieving the highest level of vehicle CO₂ credits for a fitting under the US Environmental Protection Agency Greenhouse Gas Emission Standards for reduced leakage air-conditioning systems.

Progress won't happen overnight. Nevertheless, Kadle is confident a 30% reduction in energy consumption over and above where Delphi is today is achievable within the 2015-2020 timeframe for 'high-end' cars and across the board beyond 2020.



The seat of the problem

There's much more to engineering a car seat than just comfort and lumbar support, as Ryan Borroff discovers

As cars become more refined, unwelcome noises in car interiors are increasingly noticeable. This is particularly true for electric vehicles (EVs) where the near-silent driving experience means an unwanted squeak or rattle is likely to be more troublesome. Approximately 65% of all seating complaints are related to noises that annoy the vehicle owner – and most of these are at 'kilometre zero' – so it has the potential to be an expensive problem.

The Sound & Vibration Lab at Johnson Controls in Solingen, Germany, employs a team of acoustic specialists to deal with sound testing and tuning during product development. The goal is to eliminate unpleasant noises and ensure that the seat sounds 'good'. But it's a contentious issue, because not

everyone has the same auditory range and thus the same perspective on what defines 'good'.

"We encounter innumerable products with individual sounds in our everyday routines...from the dependable noise of the cap of a shampoo bottle being closed...to the sonorous hum of an automotive seat when the height is adjusted," says Stefan Lingnau, head of the Sound & Vibration Lab. "Our customers want us to be able to objectively measure seating acoustics throughout the seat development process.

REMOTE TESTING

"But there are challenges. For example, some of the noises are only heard when the seat is coupled with the floor pan for the vehicle and it can be subjective. People need to be very experienced to know the difference between good and bad

sounds. This was why we have a remote testing system."

What's especially interesting is that such sound engineering is not just being utilised to tune-out unwelcome frequencies. It is also being used to communicate the quality of the seat to the end user. Mechanically complex, potentially there are numerous sources of noise – motors, gears, rails, springs – and all of them have the possibility to be reduced in mass and weight, or re-engineered to combine function or be constructed from a different material.

"The less a seat weighs, the lower its mass and the fewer parts it is made from, the harder it becomes to control the sound quality," says Lingnau. "The future is to develop new seating systems with acoustics in mind. For example, reducing the mass and weight of a motor can save a good deal of weight but the motors

Seating systems

“The less a seat weighs, the lower its mass and the fewer parts it is made from, the harder it becomes to control the sound quality”... Stefan Lingnau

become so light they create more vibrations. So the focus is how to attenuate this sound so that it is acceptable.

“When we receive a new specification from a customer, we visit to assess what the right noise is and what is the right sound quality,” says Lingnau. “This has to be done face to face. Some customers want a silent seat; some want a powerful-sounding seat, because the seat is for a sports car. But the process is so subjective, it is often difficult for the customer to decide.

“We have the experience to find out what a customer wants in a very short time. For example, initially a customer may want a silent seat, but we will then work to develop a noisier sound because, if a seat mechanism



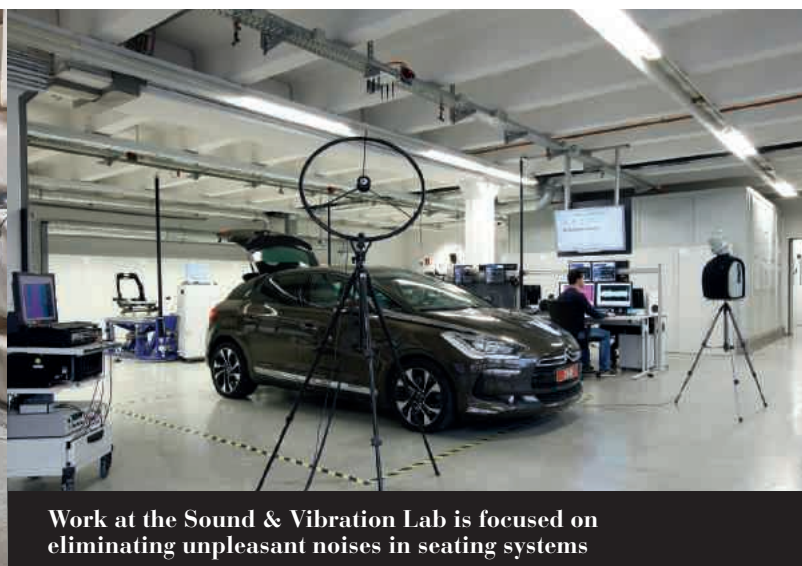
doors in premium vehicles have done for many years now.

“Lexus or Mercedes-Benz usually want a seat that is as silent as possible and they are less concerned about weight. Audi and BMW want a

Conscious buying decisions may seem rational enough, but they are created by emotional thinking. So it's no wonder some automakers are engineering brand characteristics into car seats.

Sound is one of the physical things that car manufacturers can use to ‘nudge’ the consumer experience to deliver the desired brand experience. While an R&D engineer may be tasked to make a seat more lightweight or recyclable, the brand owner needs to ensure that the overall experience isn't affected by an unintended consequence.

It's an example of how attention to detail in every aspect of product engineering is so important. Markets are full of good products, so the new



Work at the Sound & Vibration Lab is focused on eliminating unpleasant noises in seating systems

is too silent, the coupling action may be missed, which has the potential to hurt customer perception of product quality.”

Lingnau and his team are spending more and more of their time tuning sound to meet automaker requirements, in order to convey a brand-specific auditory experience, not unlike the manner in which car

mix. They want a seat that is lower weight, but which sounds as good as possible. Porsche want more of a low-frequency noise, because it fits the feeling of a sports car; it sounds powerful.”

While, in the field of hybrid and electric vehicles, “we know that customers want to get more noise into the interior, not less”, he adds.

battleground is to make the brand experience appropriate at every little touch point. It all matters. If something doesn't feel right, it gets noticed, even subconsciously, and has the potential to create a negative in the mind of the consumer.

At a time when all OEMs are fighting for sales, that is something not to be contemplated.

Augmented reality:

Nowhere more so than in modern cinema have the boundaries between reality and computerised imagery been merged into a seamless entity. As Ian Adcock discovers from Nvidia's Daniel M. Shapiro, that same technology is making the jump into the automotive sector

The camera pans round a silver Porsche 911, the sun's dying rays flecking its coach lines with orange hues. The driver's door opens and the camera zooms into the cabin and fascia, shadows fading and shifting with the camera angles.

It looks too good to be true and it is. This is a completely digitised image, using ray tracing to simulate how light reacts in the environment in which every pixel is tracing a beam of light from your eye into the screen and into the scene. The upshot is that you see an exact representation of how that light reflects off surfaces through glass, so that the viewer – me, in this case – receives a physically correct representation of the light.

"This screen is 2,560 x 1,800 pixels," explains Nvidia's Daniel M. Shapiro, before adding: "We can render to much larger systems, like a 4K projector that you might use for a power wall. You can also have a 3D model that can be scaled up to any dimension, right to life size – a lot of OEMs use our Quadro processors to drive those power walls."

POWERFUL EVOLUTION

Although automotive design and engineering is a growing business for the California-based company, it didn't start out that way, as Shapiro recalls. "The company started 20 years ago, making computer graphics cards for the gaming industry and from there has evolved quite a bit. We

have Quadro brand that's heavily used in automotive, and is the graphic accelerator that goes in the HP, Dell and TAG workstations, so design engineers and stylists all use Nvidia Quadro graphics in their workstations. The Tesla brand [not to be confused with the electric vehicle maker of the same name] uses graphics accelerator technology to carry out high performance computing or massive computations and parallel computing.

"About seven years ago, we recognised that computing was going in two different directions: the PC/workstation and mobile was beginning to take off. So we developed a way to take these large graphics cards and shrink them into a smaller form, which is Tegra, that's very energy efficient and incorporates different types of processors, called SOC or System On Chip."

What's particularly interesting about Nvidia's approach is the crossover between technologies that have been developed for one sector and that Shapiro sees having automotive applications. Take, for instance, last year's Olympics where maps of countries were overlaid on running tracks and the swimming lanes, merging graphics with live broadcasting. "You can imagine this form of augmented reality assisting the driver or delivering other information. For instance, we think that instead of your navigation map coming up, visuals would appear on the windshield, like a head up display,

painted on to the real road, with virtual street signs and all sorts of things like that."

Nvidia's high performance Tesla chips, with their hundreds of cores, the latest having 1536, are, says Shapiro, seeing traditional algorithm running times improved from "anywhere between five and 100 times", depending on the nature of the algorithm and how well it's suited for parallel processing. "If we're trying to push lots of data through that algorithm, the more cores you have, the more you can push through. It's the difference between having a single lane road and five-lane highway."

BROADER HORIZONS

The Graphics Processing Unit (GPU) has now broadened into areas Nvidia never imagined, including one client who is simulating what happens inside the engine, so it can make modifications to the cylinder size and oil viscosities etc.

But it's the ability to analyse video in real time that has truly exciting possibilities in automotive applications, as Shapiro enthusiastically explains: "It could be used to link into forward-facing camera to read the road ahead; it really comes down to software and algorithms that are interpreting that video."

"Driver assistance systems are what we're focusing on – taking video from front, rear, side cameras or other sensor data and being able to process that very efficiently and give the car a way in which to alert the

Visions of the future

driver to what's happening or intervene directly with the steering or brakes.

"We're talking about milliseconds; it depends on what the algorithm is doing, as some things are more complex than others. Because the car is moving around all the time, we can perform video stabilisation in just a fraction of a second. Currently, we're involved in a project with Mercedes-Benz on a front-facing camera carrying out object recognition, detection, tracking and then providing trajectory information for collision avoidance systems, so it knows when something is or isn't a problem. Essentially, it's real time. There's a split second delay, but it's happening as real-time analysis.

SYSTEM KNOWLEDGE

"Some of this borders on artificial intelligence to make certain assumptions. The system already knows a lot of things, where you are through the SatNav and speed, and you can get distance from video processing – although some companies are working with stereo cameras to do that – and, because you're moving, you can create a distance map. It's sensor fusion and, with different inputs, such as radar, it can build up a good 3D map around the vehicle. The great thing about these systems, too, is that ultimately they have better control than a human, because they know down to the split second the time to impact and can apply the proper braking force to stop every time or, at the very least, minimise the impact force.

"Computer vision is a big area of focus for us – the next wave is to use our processors to really power these advances," he states.



"Driver assistance systems are what we're focusing on – taking video from front, rear, side cameras or other sensor data and being able to process that very efficiently, and give the car a way in which to alert the driver to what's happening or intervene directly with the steering or brakes"

Daniel M. Shapiro

Hyundai's hydrogen future

“H yundai's first fuel cell research started in 1998. At that time, Hyundai's brand value was very low and most component providers wouldn't sell to us, so it was very difficult to even purchase fuel cell components. I joined in 2003.

“We made the first vehicle in 2000 and, until 2005, used bought-in stacks that were very good, but didn't match the vehicle technology, as they were used for stationary or other applications. In an automotive stack, they have to start up very quickly and it's very difficult to overcome this, so we decided to try to develop our own stack, matched to the vehicle application. The first we developed in 2006, using the older Tucson, and took part in Michelin challenge 2007. We weren't confident of our technology at the time, but we did have a result at Shanghai that year.

“For 2010 we said: ‘Okay, our technology isn't perfect, but it's time we have to act’ and decided to do series production. The first prototype, built in 2010, used stamped metal plates, instead of carbon, which was too expensive. But performance was only 80%, although they were the same size. There was corrosion in the plates and thousands of problems, but we overcame that with two years' development.

“The cost has reduced a lot; the plates are only one-tenth the original price. In the future, we can use cheaper materials. Maybe now we are over-designing or trying to have the best materials, but we have to develop low-cost materials and reduce size. There are many things on the vehicle that we're not confident of, but they will be improved part by part; we're modularising components as well.

“The system is still bigger than a normal engine. Our target for 2015 will be making the fuel cell system the size of a normal engine: about 100mm shorter.

“Initially, the first stack only lasted 300 hours and every three months I had to replace it. That was so expensive to do.

“On the test bench, we can go up to 5,000-6,000 hours, which is really our target, but in the car, on real road conditions, it depends. Right now, we're really near test bench data. Good engineering makes it closer to the bench testing data, because we have engineered the stack to run very near to the optimum situation.

“But 5,000 hours is still insufficient. I think we can double that. Like the internal combustion engine, we should have a lot more, because, if our stack and car are expensive, the durability has to be very long, so the whole-life cost of the car can be reduced. If I think of my learning curve, I believe that will happen quickly.”



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