Unplugging the electric vehicle
Latest-generation wireless systems take the hassle out of recharging

3D printing of tooling
A new model for automotive manufacturing

Signal of intent
Ricardo helps Denmark’s rail network with Europe’s largest signalling replacement programme
Ricardo continuing to **push the boundaries** of cost-effective hybridization and vehicle electrification

Ricardo is a leading force in hybrid system design, powertrain engineering and vehicle electronics

With a broad spectrum of capabilities, a 2900-strong global team of specialists and a rich history in the research and development of ground-breaking technologies, we are positioned perfectly to collaborate on the first-time application of ‘intelligent electrification’ in diesel vehicles.

The Advanced Diesel Electric Powertrain (ADEPT) project is a six-partner venture, bringing together scientific, engineering and vehicle technology expertise to develop next-generation technology for a low-cost, low-carbon diesel-electric hybrid passenger car, without compromising performance or driveability.

Through extensive experience of hybrid systems and joined-up knowledge across engines, transmissions, power electronics and e-machines, batteries and controls, we deliver on our promise to develop truly integrated vehicle solutions for our clients.

- Reduced component costs
- High synergies in powertrain efficiency
- Mild hybridization at 48V
- Reduced design complexities
- Cost-reducing advanced lead-carbon battery technology
- Environmentally friendlier switched reluctance motor-generator technology

Find out more about ADEPT
[www.ricardo.com/adept](http://www.ricardo.com/adept)

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Cost-effective hybridization and vehicle electrification continue to push the boundaries.

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Ricardo’s hybrid specialist says 48V hybrids will save more CO2 than plug-ins.

Ricardo oversees truck platooning project; Ricardo’s hybrid specialist says 48V hybrids will save more CO2 than plug-ins; Forbes Best Autonomy winners; energy storage advances boost renewables; electric vehicle charging technology such as Qualcomm Halo\textsuperscript{TM}, the inconvenience and hassle of using power cables to connect to charging points could soon be a thing of the past, says Anthony Smith.

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Ricardo news. Ricardo overseas truck platooning project.

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FEATURES

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NEWS

Industry news. Super-diesels for premium cars as smaller models turn to gasoline; Engine of the Year winners; energy storage advances boost renewables; electric truck takes Tesla approach; battery price prospects; Volvo’s new architecture.

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CONTESTS

Ricardo Quarterly Review • Q2 2016

08

07

04

08

08

07

07
A new generation of super-diesels is emerging, their mission to restore the credibility of diesel power in the wake of the emissions scandals that have engulfed several automakers in Europe and Asia.

The first wave of new engines are large, complex and powerful and will appear on top premium models, where their efficiency advantage is greatest and where high prices allow the most sophisticated emission control equipment to be built into the specification.

The first to reach the showrooms is the Audi SQ7 SUV, claimed to be the most powerful diesel on the market and powered by a new 4.0 litre V8 with the world’s first use of an electrically powered compressor working in tandem with twin sequential turbochargers to eliminate turbo lag and boost acceleration from rest. The new TDI also has a valvelift system that controls gas flow to each of the turbos to maintain optimum flow; the injection operates at 2500 bar, and peak outputs are 435 hp and 900 Nm torque. The SQ7 also breaks new ground with its high-power 48V electrical sub-system, which feeds a maximum of 7 kW to the e-compressor and also powers the electromechanical active roll stabilization system.

The SQ7 uses a NOx-oxidating catalytic converter and a downstream SCR converter integrated into the diesel particulate filter to reduce oxides of nitrogen. CO2 emissions are 177 g/km and 100 km/h is reached in a claimed 4.8 seconds.

Not to be outdone, BMW too has developed an all-new luxury diesel engine. The 3.0 litre straight six in the upcoming 750d is the most powerful in the company’s history and features no fewer than four turbochargers. These, in BMW’s words, are “precisely co-ordinated in their function to ensure an early onset of pulling power that continues right up into high engine speed ranges.”

The BMW unit offers 400 hp and 760 Nm and, in its 750d launch application, gives CO2 emissions of 149 g/km and 0-100 km/h acceleration in 4.6 seconds. The piezo injection system runs at over 2500 bar and the aftertreatment comprises a diesel particulate filter and NOx-storage catalyst, close-coupled with the engine, and an SCR system. Compared with the outgoing engine, power is up by 5 percent and consumption down by 11 percent.

Mercedes-Benz, meanwhile, is investing an additional €3 billion in new engine technology, including a new OM 654 family of modular diesels that include stepped combustion chambers and the EGR system placed directly on the engine to make performance largely independent of ambient temperatures. The OM 654 already complies with 2017 European emissions standards and the initial version, a four cylinder of 2.0 litres, is fitted to the new E220d sedan and station wagon where it gives 195 hp and 102 g/km CO2 emissions.

In what could be the first concrete signs of a transition away from diesel power, the PSA Group is investing to double its production of three-cylinder gasoline engines and is developing plug-in hybrid and electric powertrains for its new dedicated e-CMP architecture for battery vehicles. Gasoline engine capacity at the group’s Trnava plant in Slovakia will also be expanded. The Douvrin plant in France will manufacture electric drivetrains in-house.

PSA was one of the primary players in popularizing diesel engines over the past two decades, especially in small and medium-sized vehicles. It was the first to launch a diesel hybrid, too. Though the Group’s new ‘Push to Pass’ strategic plan does call for continued diesel development, the main focus is on gasoline and hybrids. The announced launch programme includes seven plug-in-hybrids between 2019 and 2021 on the medium EMP platform, as well as four EV models from 2021 onwards, built on the CMP city car platform and each offering a range of 450 km.

Volkswagen presented the first of a new generation of small gasoline engines at the Vienna Motor Symposium in April. The 1.5 litre EA211 TSI evo operates on the Miller cycle with a high compression ratio of 12.5:1 and employs a variable geometry turbocharger; with selective cylinder deactivation and the common rail injecting the fuel at 350 bar through new 6 mm injectors, it gives between 130 and 148 hp. Fuel consumption is claimed to be 10 percent lower than that of the outgoing 1.4 litre TSI.
Energy storage boosts renewables

A concentrated solar power (CSP) plant in South Africa has produced an uninterrupted supply of electricity around the clock for almost six days, thanks to its molten salt energy storage facility. The Bokpoort CSP plant in Northern Cape Province, built by SENER, Acciona and TSK, supplied up to 50 MW of power for a continuous period of 161 hours, the 9.3 hours of energy storage allowing it to maintain a 24-hour supply.

A combined wind and water power station now being built in Baden-Württemberg in Germany will use the foundations of its four large turbines to store some 70,000 kWh of energy in the form of pumped water. The wind turbines are expected to each generate up to 11 GWh per year at an average wind speed of 6.2 m/sec; the stored water falls some 200 m to a reservoir in the valley below, and the process is claimed by its builders to be 80 percent efficient.

Norwegian gas and oil producer Statoil has been diversifying into wind energy and is developing an offshore wind platform with a built-in battery system to buffer the peaks and troughs of power generation.

Turbo clean sweep

 Forced-induction engines triumphed in ten out of the twelve categories in the 2016 International Engine of the Year awards. Only the over 4 litres class – where large displacement multi-cylinder supercar power units tend to dominate – saw a normally aspirated winner, in the shape of Ferrari’s 6.3 litre V12. Tesla took the Green Engine award for the all-electric powertrain of the Model S and Model X.

Reflecting a widespread industry trend, all but four of the 40-plus finalists in the seven smaller-capacity classes were turbocharged designs, the only exceptions being BMW’s twin-cylinder range extender for the i3 EV, the 1.8 litre Toyota-Lexus hybrid, Jaguar’s supercharged V6 and Porsche’s last remaining non-turbo flat sixes in the 911 Carrera. Only four diesels figured in the list, the smallest being BMW’s 2.0 turbo.

Smooth ride for Citroëns

For many years the brand signature of Citroën was standard-setting ride comfort thanks to technically complex suspension systems; recently, however, platform standardization has made it hard to retain such systems in the portfolio of engineering modules.

Now the company has decided to return to its smooth-riding roots, and the Citroën Advanced Comfort Programme is a holistic approach addressing suspension, damping, acoustics and seating. So-called hydraulic cushions replace conventional bump stops on the suspension, allowing softer spring rates with no fear of an abrupt stop during significant compression; subframe mounts and acoustic shims help minimize noise and vibration transmission, and the body’s structural elements are bonded, again to reduce vibration.

The seats, finally, are multi-layer designs with stratified foam densities that reflect the advances made in memory-foam mattresses. Citroën plans to roll out the comfort programme across its complete range, regardless of price point.

NEWS IN BRIEF

Highlighted the latest thinking in automotive engineering and technology worldwide

Racing improves the breed

Eighteen years of endurance racing and 13 wins at the Le Mans 24-hour classic have improved Audi’s performance dramatically: the V6 hybrid diesels in this year’s race post quicker lap times than the first diesel winner in 2006 but use 46 percent less fuel than the original 5.5 litre V12 cars.

Loudspeakers go digital

Digitalization has reached almost every corner of the automobile and the systems used to control and operate it – except for the furthest reaches of the audio system. Now Clarion has developed Full Digital Sound, which puts an end to digital-to-analogue conversion by digitizing the last link in the audio chain, the loudspeakers. The result, says Clarion, is akin to a full surround sound experience but without the multitude of loudspeakers, processors and additional amplification required to achieve it.

Concert hall on wheels

So quiet are the electric buses on route 55 in Gothenburg, Sweden, that the bus operator is collaborating with the city’s symphony orchestra to present classical music performances on the move with musicians from El Sistema, an international music school holding a music camp in the city this summer.

Fuel shortages spark EV interest

France’s wave of strikes may have caused misery for fuel-starved drivers of gasoline and diesel cars, but it has proved a boon for the country’s growing community of electric-car users. Leading EV manufacturer Renault has reported a 50 percent spike in enquiries for its Zoe hatchback, and EV drivers have delighted in offering lifts and car-sharing services to stranded ICE-vehicle owners.

Carbon wheels boost dynamics

Ford’s soon-to-be-launched GT supercar will offer buyers the option of carbon-fibre wheels, the first time they have appeared on a Ford. The 20-inch carbon wheels offer a weight saving of 1 kg per corner, reducing unsprung mass compared with the standard forged aluminium wheels and benefiting not only steering and handling but also NVH, ride comfort and fuel efficiency.

BMW and Toyota sports car

The sports car being jointly developed by BMW and Toyota will be manufactured by Magna Steyr in Austria, according to media reports. BMW’s version, which will replace the long-serving Z4, will be cma-pumped and appear in 2018, while Toyota’s coupé model will follow to replace the Supra.

Hyundai’s premium catch-up

Korea’s Hyundai-Kia combine has outlined ambitious plans for its new Genesis premium brand. The challenger will field six products by 2020 and, says ex-Lamborghini brand director Manfred Fitzgerald, the range will include “alternative propulsion systems”. Hyundai has already shown the mainstream i40iNG range, to be available with standard, hybrid or pure battery power, and it sells the fuel cell powered iX35/Tucson in several markets.

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In a close parallel with Tesla’s shake-up of the luxury car market with its all-electric Model S, Salt Lake City start-up Nikola Motor Company is presenting a radical truck that aims to rewrite the rules and the business model for heavy commercial vehicles.

The Nikola One is a hybrid Class 8 truck capable of hauling 80,000 lb [36 tonnes] and travelling 1200 miles (1930 km) before needing to refuel: its fuelling costs are claimed to be half those of a diesel truck, and its emissions – whether on the highway or when parked up – are significantly lower. The truck is also claimed to have horsepower, torque, acceleration, pulling power and stopping superior to that of any current Class 8 truck.

The truck’s driveline comprises a liquid-cooled lithium ion battery pack of 320 kWh feeding power to six wheel motors, each rated at 335 hp and driving the wheels through reduction gears; the aggregate torque at the wheels is over 115,000 Nm. The suspension is fully independent using Meritor componentry, and the world’s first 6x6 torque vectoring system controls each wheel individually; additionally, the low placement of the heavy components means a lower centre of mass and improved handling, steering and braking.

The battery is recharged by a multi-fuel turbine rated at 400 kW: this says Nikola, is sufficient to allow the truck to climb a 6 percent grade at a steady 65 mph [105 km/h], while diesel equivalents can manage little more than half that speed.

As an incentive to kick-start sales of the new model, Nikola is offering the first 5000 customers the offer of free fuel for a million miles – enough to offset the full purchase price of the vehicle. The fuel will come from Nikola’s own gas wells, bringing a further fresh dimension to the company’s business model.

On a smaller scale, the UK’s Tewa Motors range extender electric powertrain has been extensively evaluated in service, including by package delivery service UPS.

Germany switches on to EVs

Conscious of its target to have a million electric vehicles on its roads by the end of the decade, the German government has finally agreed to an incentive programme to promote the uptake of EVs.

The €1.2 billion cost of the programme will be split between the government and the German auto industry. Pure-battery EVs will attract a subsidy of €4000, while for plug-in hybrids the figure will be €3000. Vehicles with list prices over €60,000 will not be eligible. The German government has set the objective of at least 30 percent electric vehicles within its national fleets.

Deutsche Post, the country’s postal service, is to phase in electric vans and recently took over the StreetScooter start-up which built the 50 prototype battery vans already being field trialed. Some 2000 will be built this year and the aim is to have the entire 30,000 fleet battery powered.

Volkswagen, for one, strongly emphasized electric vehicles in its Beijing Moor Show announcements, promising not only a premium all-wheel drive plug-in hybrid SUV but also seven additional EVs and PHEVs by 2020. Built on the VW group’s new MEB modular platform for electric vehicles, they will offer driving ranges of up to 533 km.

The hysteria surrounding the launch of the Tesla Model 3 earlier this year has refocused attention on the cost of battery packs. Industry commentators estimate the pack in the larger Model S to cost around $190 per kwh; this compares to the $147 per kWh reported as GM’s cell cost for its Bolt EV, set to debut later this year.

Many factors point to a continued downward trajectory for battery costs. A study by Carnegie Mellon University suggests costs will be relatively unaffected by fluctuations in the price of raw lithium, and economies of scale will increase with the growth of the domestic energy storage market, the opening of Tesla’s Gigafactory in July, and Daimler’s entry into the field with its own Deutsche Accumotive battery-making subsidiary. French oil major Total has entered the market, too, with its purchase of battery maker SAFT.
Modular strategy electifies Volvo

Volvo has given an insight into the thinking behind its new modular small- and medium-car architecture, CMA. In contrast to the larger Scalable Product Architecture already seen on the new XC90 series, CMA is entirely front-drive based.

Two body-style concepts were shown at a recent presentation in Sweden: the rugged 40.1 crossover and the 40.2, with a more coupé-like silhouette but retaining the same high build. The first versions are set to debut in 2017.

On a technical level the new T5 Twin Engine drivetrain will combine a three-cylinder gasoline engine with an electric machine and a new seven-speed dual clutch transmission for plug-in hybrid variants. The same basic architecture will also cater for pure battery EV versions as well as conventionally powered models. Volvo says this approach will make the range more affordable than the large SPA T8 models, which place an electric axle at the rear for hybrid versions.

Volvo’s target is to have sold one million electric cars by 2025, and to that end there will be electric and plug-in hybrid versions of all its product lines, with a pure electric large car scheduled for release by 2019.

Automakers keen to share the ride

Competition is intensifying between automaking groups eager to grab a share of what are expected to be lucrative future revenue streams: sharing cars between users, and controlling taxi-like services such as Uber.

Daimler and BMW already have car-share fleets in many major cities, with China posting spectacular growth for Daimler’s Car2Go – one of its vehicles is rented every 1.7 minutes. Volkswagen has taken a $300 million stake in Israeli taxi app Gett, while Toyota has partnered with Uber. Earlier in the year, General Motors bought a stake in the US ride-hailing service Lyft and the partnership has announced plans to develop self-driving taxis.

VIEWPOINT

Saving CO2: 48V hybrids versus plug-ins

Steve Doyle – Ricardo product group head, hybrid & electronic systems

The growth of the plug-in hybrid and battery electric vehicle (PHEV and EV) market can rightly in my view be seen as a resounding success over recent years. According to the Society of Motor Manufacturers and Traders, a total of 28,188 cars were eligible for the UK Plug-in Car Grant scheme in 2015, compared with just 14,532 in the previous year.

However, this rapid market growth should be seen in the context of a very low base, in the case of the UK just 1.2 percent of the market in 2015, and some significant obstacles to growth remain. Range anxiety, safety concerns, the ready availability of charging stations and the time taken to recharge are all significant battery-related issues that impede the growth of the plug-in vehicle market. Perhaps more intractable than any of these, however, is battery cost.

Or at least, that’s how things stand at the moment. Looking ahead, a common goal in the R&D efforts of the major industrialized nations is to push battery costs to below $100/kwh, as this is widely believed to be the tipping point at which EVs can compete head-to-head with gasoline or diesel cars.

With much effort being focused on the development of new higher power and lower cost cell chemistries, Ricardo believes that the market will be dominated to at least the end of the current decade by developments of today’s lithium-based technologies. In the 2025-2030 timeframe, however, it may well be that the current problems preventing the commercialization of lithium-air will be resolved, offering at today’s prices a sub-$100/kWh technology capable of energy densities in excess of 0.7 kWh/kg.

48V hybrids: a new competitor

But if this tipping point at which battery electric vehicles become genuinely commercially attractive against diesel or gasoline cars is still some way off, what can be done in the medium term to deliver the further significant reductions in carbon dioxide emissions that governments and regulators are demanding in the US, the EU and elsewhere?

A potential innovation that many automakers are exploring is the 48V hybrid. At the heart of the system is a 48V battery enabling the application of a motor-generator capable of torque assist, ancillary electrification and, eventually, radical engine downsizing and down-speeding when combined with an e-supercharger. With batteries currently being developed to absorb regen energy and deliver in excess of 34kW, there is already further demand for units to deliver 25kW to support increased electrification.

A key attraction for this powertrain architecture is its performance in the new WLTC drive cycle, which includes more aggressive accelerations and decelerations than its NEDC predecessor. The new cycle – which is intended to be more representative of real-world driving – will suit the energy regeneration, sailing and torque boost functions that 48V hybrids can provide. Work by Ricardo has shown that 48V mild hybrid powertrains can deliver CO2 savings of 10-15 percent over the NEDC and 15-20 percent over the WLTC. In addition, these powertrains can also offer improved acceleration and NVH through engine downsizing and down-speeding, as well as silent pure-electric take-off, and stop-start. As such, they can offer most of the benefits of full hybridization but at a fraction of the cost.

With the market demand that it is currently experiencing, Ricardo believes that the 48V mild hybrid technology may well contribute more to emissions reduction in the next five to 15 years than all plug-in vehicles combined.

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RQ • Q2 • 2016
What was the impetus behind DRIVE PX 2? Did it come from within the automotive sector or elsewhere, and was then picked up by the automakers?

The response to our original DRIVE PX that we introduced at the Consumer Electronics Show (CES) in 2015 was very positive. Basically the desire was to bring as much computing power as we could for advanced driver-assistance systems (ADAS) and autonomous functionality, but still focus on leveraging our Tegra system on chip (SOC) design. The feedback from automakers, Tier One suppliers and university researchers was great, as they didn’t want four or five PCs in the car’s trunk. That original system was capable of 2.3 teraflops (2.3 trillion floating point math operations per second), but our clients still wanted more horsepower. So, we basically enhanced it by including the ability to have two additional high-performance graphics processor units (GPUs). Right now it’s a system that can scale from one to four processors and integrates our newest generation GPU. The result is that DRIVE PX 2 is capable of 24 trillion deep learning operations a second.

That seems to turn Moore’s law on its head, given the short time it has been in development?

It’s a combination of new hardware architecture for deep learning and additional computational horsepower. In just one year we increased the performance by a factor of 10 – a whole order of magnitude, something which is virtually unheard of in that timeframe. Basically Moore’s law [which suggests the number of transistors will double every two years] has run out of steam when new additions are giving only a 10-20 percent performance gain: this is a true 10-fold performance improvement over one year, and we did it based on direct feedback from our customers.

How big a step forward is this in enabling autonomous driving?

This is a huge step towards autonomous driving: there’s no possible way to write software that can handle the infinite number of things that can happen while driving. Instead of traditional computer vision algorithms that are a set of rules, artificial intelligence is the way forward. There’s no way that an ECU from an ADAS system can have code written for it to deliver an autonomous vehicle. We believe that it will be a combination of a supercomputer in the car, a centralized resource - as opposed to distributed computing at each sensor - plus the ability to train an artificial intelligence network, that will be required to achieve autonomous driving.

And does that training process incorporate deep learning?

Yes, we now have our GPUs being used for deep learning in two phases; one is the training which happens in the data centre, where you feed it massive volumes of information and it learns how to interpret that data, and secondly, there’s what’s called ‘inferencing’ where it senses/sees/interprets the data in real time based on that previous training. NVIDIA has exactly the same architecture throughout its product line: the GPUs in the data centre can run the same code and process the same data streams as in the car or in a mobile device, depending on what the application is. I am not aware of any other company that has a supercomputer built specifically for the car and has an end-to-end deep learning training and implementation.

Does the deep learning process mean that the more experience the system has, the more knowledge it gains for itself to understand and interpret what is happening in the world around it?

That’s true from one perspective, but we’re not saying the more you drive your car the smarter it gets, compared to the car of someone who doesn’t drive it very often. The research from the automakers and the information they collect in the cloud from other vehicles will be aggregated by data scientists. New data training will be inputted, validated and certified, and then the updates will be delivered to the fleet over-the-air to improve performance. The car won’t just learn directly from a particular driver; if a teenager takes a car out, for example, and drives it poorly, we don’t want that car to learn how to drive like that.

Does it mean that other components within the autonomous driving system, such as sensors and cameras, have to be similarly improved to take full advantage of DRIVE PX 2?

We are sensor-agnostic: we actually prefer to get raw data rather than have it pre-processed. We fuse the data together with multiple data types because radar and lidar can see things
the camera can’t see. But the camera sees colours that other sensors can’t see: just like a human, you have better perception with all the different sensory inputs. Having cameras with higher resolution lenses is a benefit, but not as great as you think – not like when you go to the movies and you want that higher quality. Algorithms have the ability to detect even at low resolutions, even on black and white images.

So, the most important thing is fusing the sensing technology rather than the finite resolution or feedback you get? Yes, that’s the advantage of DRIVE PX 2 as it’s an open platform for the automotive industry to build upon. We have over 80 different engagements with OEMs and Tier Ones, and each has the flexibility to design their vehicle around this centralized supercomputer, combining different blends of sensors. Our partners are doing research and experimenting; they are free to do development and fine tuning that they can’t do with a black box.

What implications or applications does deep learning have beyond autonomous driving?
We’re just scratching the surface of how this can be used: we see every industry from financial markets to industrial design to medicine to energy exploration leveraging deep learning. We’re doing research and brainstorming with smart cities for vehicle-to-infrastructure communications, working to solve big problems with traffic congestion. Instead of trying to figure out the timings of lights, we can use deep learning and the system would, in real time, be able to learn how to optimize the signal timings to reduce congestion and re-route traffic without having to hard code programme it.

Another aspect is simulation: you basically build the deep neural net that’s going to analyse and process data – what are the inputs and outputs? It can optimize and come up with better ways of designing things. For instance, it could create models simulating different engine and combustion strategies and, by using deep learning, be able to come up with more efficient engine designs.

Another example is cyber security: people are very concerned about vehicles being hacked. By using deep learning to detect hackers or cyber security breaches the system could monitor network traffic and detect anomalies. A lot of what deep learning is about is analysing data streams (video, speech, network traffic) and using pattern recognition to understand and interpret data. In the car you could constantly monitor the network traffic and detect anomalies, and if there’s a breach it will be able to shut it down – so deep learning can have vehicle security applications as well.

What is deep learning?

The MIT Technology Review, in its current list of the 10 most important breakthrough technologies, describes deep learning as follows:
“Deep-learning software attempts to mimic the activity in layers of neurons in the neocortex, the wrinkly 80 percent of the brain where thinking occurs. The software learns, in a very real sense, to recognize patterns in digital representations of sounds, images, and other data.

The basic idea — that software can simulate the neocortex’s large array of neurons in an artificial ‘neural network’ — is decades old, and it has led to as many disappointments as breakthroughs. But because of improvements in mathematical formulas and increasingly powerful computers, computer scientists can now model many more layers of virtual neurons than ever before.”

“There’s no possible way to write software that can handle the infinite number of things that can happen whilst driving. Instead of traditional algorithms that are a set of rules, artificial intelligence is the way forward.”

Danny Shapiro, Senior Director of Automotive, NVIDIA

Danny Shapiro is Senior Director of NVIDIA’s Automotive Business Unit. He holds a BSE in Electrical Engineering and Computer Science from Princeton University and an MBA from the Hass School of Business at UC Berkeley. He also serves on the Advisory Boards for the LA Auto Show, the Connected Car Council and the NVIDIA Foundation, which focuses on computational solutions for cancer research.
It is self-evident that today’s vehicles are spectacularly better built than those produced fifty years ago. The mechanical properties, the formability and the durability of the materials and finishes used, together with the efficiency of the manufacturing operation itself, have improved beyond all recognition. Design, in terms of safety, emissions, handling and functionality, has been totally transformed too. But despite these and many other improvements, the fundamental make-up of the automobile has remained largely unchanged for half a century: cars are still based on a unibody fabricated from a number of complex structural sheet steel pressings forming the body-in-white structure and its closures. While the ongoing refinement of this production system has been responsible for today’s high levels of manufacturing efficiency, this high-volume process brings some very significant drawbacks: the embedded capital costs of production for the major steel pressings are extremely high. The cost of a die-set can vary from a few thousand to over a million US dollars depending on the die’s size and complexity, and its durability and desired life.

These limitations mean that major auto manufacturers have to produce very similar, if not virtually identical, vehicles at very large volumes. This in turn limits the scope for variation and acts as a barrier to entry, preventing new companies or new production techniques from gaining a foothold in the market and denying these innovations the opportunity to achieve economies of scale. The low-volume demand for aftermarket parts,
A new model for automotive manufacturing.
“Stamping or drawing dies for high-volume production are comparatively expensive as they are machined from hard material such as tool steel and undergo heat treatment for surface hardening and polishing to achieve a sufficiently high-quality surface finish”

Piyush Bubna, Consultant, Ricardo Strategic Consulting

traditionally fulfilled by both automakers and their supply chain through manufacture-for-stock at the end of the main production run, also suffers from similar challenges. As we demonstrated in the last issue of RQ [see Aftermarket game-changer, RQ Q1 2016], this is a problem that will only get worse as the average operating lifespan of vehicles increases.

Removing the barriers to innovative technologies

The Advanced Research Projects Agency-Energy (ARPA-E) is the United States government agency focused on accelerating market readiness for transformational technologies. In early 2015 the agency awarded a grant to Ricardo Strategic Consulting to investigate automotive capital expenditure barriers in detail and to explore how novel manufacturing methods could reduce these challenges. The project, in which Ricardo collaborated with the United Technologies Research Center (UTRC), was entitled Reducing Automotive Entry Barriers through Design, Manufacturing and Materials.

In the first part of the study, Ricardo developed a manufacturing cost model and database to enable the estimation of the production costs and required investments for a large variety of components at different production volumes.

Piyush Bubna, consultant at Ricardo Strategic Consulting, led the company’s involvement with the ARPA-E project.

“The cost model we developed is comprehensive in its applicability to the major vehicle systems, including the structural components and closures of the vehicle body-in-white,” he explains. “The model determines bottom-up costs for the formation of individual parts and their assembly into components. It also includes the ability to analyse key business drivers such as tooling investment, equipment cost, process time, materials, scrap, automation, labour, supply chain impacts, and factory overheads.”

The model is supported by an extensive database of information on a wide range of materials, manufacturing processes, equipment and a common set of factory operating parameters, thus allowing the comparison of traditional techniques and emerging designs or processes – for example, to achieve light-weighting goals. This Ricardo toolset and approach has been developed and validated in consultation with industry experts representing automakers, suppliers, academia, consultants and national laboratories.

Cost comparators

To provide a basis for comparison of current methods and processes of automotive production with alternative and potentially disruptive technologies, the project group selected the Toyota Corolla as being representative of an existing high-volume passenger car. The Ricardo team then selected ten subassemblies of the vehicle structure for analysis using the manufacturing cost model. These subassemblies included the floorpan centre section, door trim, B-pillar and HVAC system assemblies, as well as the differential and clutch housings, as well as the door and cross-member/k-frames, an engine mount, and a headlight. For comparison with lower-volume products, the team also studied the Audi A8 and BMW i3, representing vehicles with body and closures predominantly manufactured from aluminium and carbon fibre respectively. This also enabled the analysis of the light-weighting/manufacturing cost trade-offs that had been adopted for these vehicles.

“Our cost analysis for the Toyota Corolla showed that for all the analysed components, the [per-unit] production cost starts to become prohibitive below an annual volume of 50,000 units,” explains Bubna. “The problem is the capital investment required for dies, fixtures and other tooling. This is one of the reasons why automakers try to find economies of scale by sharing platforms for different vehicle models and using common components wherever possible.”

“Give me the job and I’ll finish the tools”

While additive manufacturing or 3D printing technologies have gained a high profile for their potential to enable mass customization through direct, tool-free product manufacture, such an approach would clearly not be cost effective today for larger automotive structures and assemblies, particularly for high-volume products. Instead, as Bubna explains, the real potential here lies in the 3D manufacture of the tooling rather than the component: “Stamping or drawing dies for high-volume production are comparatively expensive as they are machined from hard material such as tool steel and undergo heat treatment for surface hardening and polishing to achieve a sufficiently high-quality surface finish. One option to reduce capital investment and bring down production costs could be to adopt less durable softer tooling and to reduce the automation in the process line. But such
tools also have certain limitations when it comes to dimensional accuracy and surface finish.”

Ricardo and UTRC collaborated in the next stage of the project to explore the economic feasibility of 3D printing, demonstrating that these new technologies have the potential to manufacture certain parts affordably, as well as creating dies to lower the capital expenditure requirements of existing production methods.

Alternative 3D printing techniques reviewed

There are many additive manufacturing techniques capable of producing hard tooling, but the selection of these typically involves a trade-off between deposition rate and dimensional accuracy. Laser- and electron-beam-based 3D printing processes that utilize powder feedstock tend to have the best geometric accuracy. Conversely, welding-based processes can rapidly deposit material but do so with more limited geometric accuracy. These processes are also cheaper than laser- or electron-beam-based techniques and provide the added advantage of comparatively lower investment costs. Stamping dies that do not require fine features may thus be an attractive candidate for welding processes, followed by some level of post-machining to achieve the desired finish. This approach can cut both lead times and production cost.

Wire Arc Additive Manufacturing (WAAM) is a welding-based 3D printing technique that builds a geometry layer by layer by depositing molten metal. The process uses six-axis robots in conjunction with a specialized Cold Metal Transfer (CMT) welding system to build up a fully dense deposit of material quickly. Heating is well controlled in this process and cooling is very rapid, a combination that can offer robust parts with limited warping.

The raw material costs are competitive with powder-based 3D printing, thanks to the lower energy requirement in wire drawing. This contrasts with the high-energy atomization of material at a tightly controlled particle size required in conventional 3D printing. WAAM also enables the use of a simple shield gas around the wire, rather than the highly controlled oxygen-scrubbed environments required when using high surface area powders.

Use of preforms

While geometrical flexibility is a key feature of 3D printing technologies, it is often most cost effective to start a workpiece from a preform plate and to superimpose the required features using an additive technique. This approach can save significant time and money compared to 3D printing a die from scratch. The starting plates need a larger cross section than the 3D printing area in order to handle the stresses at the edge of the die during stamping, and they also require sufficient thickness to handle the forces across the part.

To enable required manufacturing tolerances to be met for a die-set created with WAAM, it is necessary to deposit an excess of material and to then finish-machine this excess away with a highly accurate machining technique such as milling. The project team calculated the total costs for the 3D printing of dies inclusive of this post-process machining as well as any required surface heat treatment and manual polishing.

High volume stamping die cost to manufacture (USD)

Cost comparison: conventional versus 3D-printed stamping dies

To provide a detailed picture of cost savings for 3D printing of dies for high-volume manufacture, three Toyota Corolla parts were selected for study: a B-pillar panel, the outer skin panel of a door, and the floorpan centre section. Manufacturing these parts requires die-sets for blanking, drawing and a trim/pierce operation. For simplicity, the project’s cost comparison was focused on a draw die-set for each of these components.

The B-pillar panel is the smallest part and also has the smallest depth of draw during the forming process. Conversely, the floorpan centre section is the largest part, both in cross section and in depth of draw, whereas the outer door skin is intermediate in cross section and depth of draw in comparison to the other two die-sets.

The results of this part of the research are illustrated below, detailing the cost breakdown for the three die-sets. The cost benefit of 3D printing the draw die is clearly seen to be influenced by the part size and depth of draw. The draw die for a B-pillar panel requires less material deposition due to the small part size and shallow depth of draw, and is thus cheaper to manufacture. However, as the depth of draw increases, as is the case with the floorpan, the cost savings achieved by using additive manufacturing are no longer realized. This is due to...
By applying the principles and processes examined and refined in this project, we can help customers deploy the most appropriate technologies and processes to help ensure long-term success and profitability” Piyush Bubna, Consultant, Ricardo Strategic Consulting

the relatively slow deposition rate of additive manufacturing relative to the fast material removal rate that can be achieved via rough machining of the dies for this component.

A common trend visible in the cost estimates is that finish-machining and polishing account for the majority of the manufacturing cost. This points to the conclusion that tooling can be made cheaper with WAAM 3D printing of parts that do not require high levels of surface finish.

Other applications
The benefits of WAAM 3D printing can clearly extend beyond the automotive sector to include any industry where metal forming is required. WAAM can be an economical technique and bring capital cost reduction benefits when producing die-sets for parts with shallow depth of draw. But as the part shapes get more complicated, Bubna argues that in many cases it may be advantageous to use a powder-bed additive 3D printing process:

“While the slow deposition rate and high investment cost of a powder-bed system can be prohibitive, the better geometric accuracy can enable the placement of cooling channels within the dies. These can improve temperature distribution along the part surface and also substantially enhance cooling. This is a particularly advantageous attribute for processes like hot stamping, high-pressure die casting and injection moulding, where faster cooling can reduce cycle times and enhance factory throughput.”

Overall results for steel, aluminium and composites
Based on an analysis of the full set of ten conventional stamped and injection-moulded components and systems examined on the Toyota Corolla, the project team estimated a current tooling capital expenditure requirement of approximately $26 million. While not all components were as open to cost reduction using currently available technologies, there are clear opportunities.

For the 3D-printing technologies considered, WAAM in particular offered the prospect of up to 80 percent tooling cost reduction for some components, whereas the powder-bed-based selective layer melting offers greater dimensional accuracy but with a less competitive cost advantage. Overall, the cost benefit is expected to increase in the near future as deposition rates and raw material costs improve. Moreover, these 3D printing techniques offer other benefits such as improved cooling channel design and multi-material deposition – enhancements that may further improve manufacturing efficiency or offer opportunities for more innovative product design.

Investigation of the Audi A8 and BMW i3 vehicles showed many examples where design and material choice could lead to reduced tooling costs. The Audi A8 B-pillar was found to be lower in cost than the Corolla’s for all volumes, thanks to a 36 percent lower tooling cost. The BMW i3 floor and door designs enable lower tooling costs and lighter weight structures; the floor, however, was found to be expensive today compared to the Corolla’s an account of the cost of the carbon-fibre-reinforced polymer fabric.

For other components, the project team believes that additive production of door trims could become cost competitive in near future. For consumer visible parts such as these, 3D printing can enable the customization of design at lower volumes, an innovation that is likely to impact in luxury vehicles first which are less price sensitive, before the technology matures to a level at which it becomes viable in more mainstream vehicles.

Similarly, the production of low-volume K-frames also had some merit and could also offer light-weighting benefits. The team felt that 3D printing had the potential to produce complex light-weight designs that would otherwise not be possible using traditional techniques. In particular, multi-material deposition is a possibility where high strength material can be added at certain critical points, while the rest of the component can be made of lower strength, lower cost material.

Conversely, incremental sheet forming was not found to be cost-effective unless used for very low volume applications such as for prototype vehicles or extremely niche high-value applications.

Future services
The meticulous approach taken by Bubna and the project team on this project has enabled Ricardo Strategic Consulting to refine and improve its range of services in the areas of product commercialization, cost reduction, light-weighting, and the evaluation of emerging production techniques. “This project,” concludes Bubna, “has been extremely valuable to Ricardo, UTRC and the automotive industry generally in highlighting the opportunities that are available through the use of 3D printing technologies. This applies both in the creation of parts and, perhaps even more significantly, in the creation of volume-appropriate production tooling.”

“There is no technology, design innovation or manufacturing process that represents a panacea for any of the key systems of an automobile,” he concedes. “But without a thorough analysis of the product, its market and applications, and the manufacturing system that will make it, there is the risk of missing opportunities for cost and mass reduction, and for improving fuel economy and manufacturing efficiency.”

By applying the principles and processes examined and refined in this project, Bubna explains, “we can help customers deploy the most appropriate technologies and processes to help ensure long-term success and profitability.”
Unplugging the EV

Thanks to the latest generation of wireless electric vehicle charging technologies such as Qualcomm Halo™, the inconvenience and hassle of using power cables to connect to charging points could soon be a thing of the past for EV and PHEV drivers. Anthony Smith reports.

Plugging in for a recharge has to be the least glamorous aspect of driving an electric vehicle (EV) or plug-in hybrid (PHEV). Whereas most drivers of conventional diesel or gasoline fuelled vehicles might typically need to visit the service station to refill their tank once every week or two, plug-in vehicles should ideally be recharged rather more frequently, requiring them to be parked close to a charging point. However, recharging cables can be cumbersome and they collect dirt from repeatedly being run along the ground in different locations. Small wonder, therefore, that many PHEV owners do not bother with...
public charging points and instead rely on their combustion engine until they get home; drivers of pure EVs have no option but to find a charge point and plug in.

The most attractive alternative to plug-in charging is something we are familiar with from electric toothbrushes and the latest generation of smartphones: contactless or wireless charging. This technology enables such devices to charge automatically, without the need to plug in. The technology uses resonant magnetic induction to transfer energy wirelessly from a base pad to a pad integrated into the device.

Yet those domestic devices are small and comparatively low powered, with a tiny fraction of the energy storage requirements of a modern EV or PHEV. Wireless electric vehicle charging (WEVC) is based on the same principle: energy is transferred wirelessly from a ground-based pad, on or beneath the road surface or parking bay, to a pad integrated into the vehicle. Moreover, for WEVC to work on a practical basis, it needs to be able to do so over a comparatively large air gap between the vehicle pad and the ground pad. It also needs to be implemented in conformity with international standards for safety that ensure robust systems for critical functions such as living object protection (LOP) and foreign object detection (FOD) as well as providing for effective interoperability with other systems and technologies.

Unlike some other inductive charging solutions that need pads to be closely aligned or almost touching, Qualcomm Halo™ delivers high energy transfer over a large air gap up to and including that which might be necessary for the high ground clearance of SUVs. The advanced multi-coil design of the system is also capable of impressively high power transfer rates – 3.7 kW and 7.4 kW in current commercial installations; luxury and performance vehicle applications have already been demonstrated at up to 22 kW capacities, and the transmission efficiencies are close to those of wired connections, particularly at higher power levels.

**Formula E safety cars**

One of the most widely visible demonstrations of the Qualcomm Halo™ technology can be seen in the official Qualcomm Safety Cars used in the current eleven-race season of the FIA’s Formula E Championship; this season’s championship started in Beijing in October 2015 and concludes in London in July 2016. This year’s safety car is based on a version of the BMW i8 equipped for recharging wirelessly with an advanced Qualcomm Halo™ 7.4 kW wireless charging system.

With the increasing focus on hybrid and electric vehicles from automakers seeking to reduce tailpipe emissions, Ricardo sees the simplified charging process offered by WEVC as an important enabling technology for the mass adoption of EVs and PHEVs. “The increasing electrification of transportation is important in enabling society to reduce its reliance upon CO₂-emitting fossil fuels and also improve the quality of air in our towns and cities,” says Ricardo CEO Dave Shemmans. “Wireless charging is a potentially very promising enabler for more widespread adoption of pure electric and plug-in hybrid vehicles, with consequent environmental benefits.”

**Technology licence agreement**

Ricardo regards Qualcomm Halo™ technology as an advanced WEVC solution that has the potential to meet automakers’ and drivers’ desires for simple and convenient EV charging. For this reason, Ricardo and Qualcomm Incorporated have entered into a WEVC technology licence agreement, allowing Ricardo to commercialize WEVC systems for vehicles based on Qualcomm Halo™ technology. Under the terms of the agreement, Qualcomm has granted to Ricardo a royalty-bearing technology licence to develop, make and supply WEVC systems for automobile manufacturers. Qualcomm subsidiaries

“Ricardo brings a wealth of automotive engineering expertise and a real focus on performance, advanced engineering solutions, and a deep understanding of the direction the automobile industry is headed”

**Steve Pazol**, Vice President & General Manager, Wireless Charging, Qualcomm Incorporated
will provide technical expertise and engineering support.

Working with Qualcomm will enable Ricardo to design and build WEVC systems that meet automakers’ requirements for wireless charging today and in the future, in the anticipation of increased demand for higher power, faster charging, different deployment methods such as buried charging pads, and for WEVC systems which charge SUVs, taxis and autonomous vehicles.

“Ricardo brings a wealth of automotive engineering expertise and a real focus on performance, advanced engineering solutions, and a deep understanding of the direction the automobile industry is headed,” says Steve Pazol, vice president & general manager, wireless charging, Qualcomm Incorporated. “We are pleased to be working with Ricardo. This collaboration further strengthens the Qualcomm Halo™ automotive supply chain, providing options for WEVC both to the traditional automakers and the burgeoning EV entrants.”

Ricardo will benefit from comprehensive engineering support provided by Qualcomm subsidiaries. This support aims to enhance Ricardo’s ability to develop commercially viable and technically advanced wireless charging systems and will inform the future design of evolving WEVC systems. Qualcomm Halo™ WEVC technology has been developed with a focus on cost and package optimization, power, interoperability, and co-existence with vehicle systems. An advanced technology pipeline will deliver ongoing improvements, supporting standardized and interoperable WEVC technology suitable for stationary and, eventually, dynamic charging.

With the popularity of EVs and PHEVs increasing in many international markets, the ability to roll out robust and practical wireless charging solutions integrated into new plug-in vehicle models could act as a significant spur to the market. New vehicle purchasers will finally be freed from the hassle and drudge of plugging in via cables. Instead, users will be able to recharge their vehicles simply by parking in a space equipped with a charging pad; charging will be as easy and straightforward as parking the car.

This means that, thanks to the Qualcomm Halo™ technology and the collaboration with Ricardo, drivers of the next generation of EVs and other so-called plug-in vehicles may never need to plug in again.

For more information on Qualcomm Halo™ technology, visit www.qualcommhalo.com.

Official Qualcomm Safety Cars are in action in the current eleven-race season of the FIA’s Formula E Championship; this year’s safety car is based on a version of the BMW i8 equipped for recharging wirelessly with an advanced Qualcomm Halo™ 7.4 kW system

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Few seasoned rail commuters are forgiving of signalling technology. To those kept waiting on platforms for late-running services, ‘signal failures’ is often all they are offered by way of an explanation. Why is it, passengers might reasonably ask, that signalling systems remain the cause of so much disruption? And why is nothing ever done about it?

Their frustrations are understandable, but it is more a case of perception clouding reality. Far from being the scourge of journey plans everywhere, signalling, as the main safety-critical system of a railway, is in fact its most dependable asset. Out of sight of the travelling public, however, the signalling world is undergoing one of the biggest transformations in its near 200-year history, a change that is redefining the entire role of signalling.

Denmark’s rail network is undergoing the largest signalling replacement programme Europe has ever seen. Why, asks Andrew Foulkes, have so few territories attempted it before?

Signal of intent
within the rail system. But such are the historical, technical and political challenges involved that wholesale change will take decades to come to fruition. To demonstrate why this is such a complex change we will turn to Denmark, which has embarked on the most extensive re-signalling programme ever seen in Europe. First of all, however, we perhaps require an explanation of how the industry got to where it is now.

**At the first sign of trouble**

Since its earliest days, the railway has depended upon the presence of a system of signalling to safely regulate the flow of traffic across the network. Originally, signalling was an entirely manual system. In the 1830s flag-bearing ‘policemen’ would be stationed along the line to communicate directly with oncoming drivers about known traffic ahead. Their role was to impose a fairly rudimentary time-based model of train separation, ensuring five or ten minute intervals between each vehicle. As speeds and traffic levels grew, policemen were replaced by mechanical lever-armed semaphore signals, which in turn gave way to the system of coloured lights (known as ‘aspects’) seen today.

Meanwhile the ‘time-interval’ approach was supplanted by the ‘block’ approach – the principle of dividing the track into sections known as blocks, and ensuring only one train is permitted into any one block at any one time. And this basic principle of signalling – first established in the 19th century – has remained at the heart of every system designed since. With signals placed at the entrance of each block, drivers are told whether they have permission to enter the next block, or if they must wait for the preceding train to clear it. The one-train-per-block rule is so inviolable that the position of every signal is set to red (‘danger’) by default, with the system designed to ‘fail safe’ in the event of any doubt. This means signals can ‘fail’ for any number of reasons unrelated to the equipment...
Signalling: ERTMS or CBTC?

Though they apply to different types of railway, both ERTMS and CBTC are helping to revolutionize the traditional role of signalling. Where the design has previously been seen as a means of keeping trains apart, these fresh technologies show how the future of signalling will be about keeping higher volumes of traffic closer together, while retaining complete safety.

ERTMS (European Rail Traffic Management System) is backed by the EU as the single Europe-wide standard for train control and command systems on mainline, heavy rail routes. CBTC (Communications Based Train Control), by contrast, is optimized for the stop-start nature of urban metros, safely managing the high throughput of trains and the short distances between stops.

However, projects such as London’s Crossrail – to be known as the Elizabeth Line – are already challenging the distinction. Crossrail will run metro-style frequencies in the central section that lies beneath London, but services will travel onwards along existing heavy rail regional lines that stretch out to the suburbs to the east and west.

For this reason, the project will apply a mix of both the systems, and its rolling stock will be specially developed with this in mind. Nevertheless, Crossrail shows how even modern signalling systems can struggle to meet every requirement of the real world.

“Banedanmark took the decision that the network would already have to commit to an expensive programme of ongoing repairs and renewal. However, they concluded that a full replacement would achieve economy of scale through the planning and procurement stages, and enable them to streamline the complex safety approvals and authorisations process” Thomas Rasch, Ricardo Rail business manager in Copenhagen
along its route. For example, a train connecting Paris, Brussels, Cologne and Amsterdam would have to interface with up to seven different system borders. Apart from the technical complexities, the limited space within the train cab creates considerable design challenges for rolling stock manufacturers.

A further consequence of this fragmented approach was the stalling of an efficient global supply chain for signalling technology. Bespoke components consequently became expensive and difficult to replace. And with a full system-wide replacement considered way beyond the budgets of most countries, piecemeal repair and renewal programmes became the only way to keep up with ageing equipment.

**Denmark’s bold move**

By the turn of the millennium, Denmark’s equipment had aged to a point where the systems in use were past their service life, and the network was experiencing issues familiar to most mature networks – technical incompatibilities; problems sourcing spare parts; rolling maintenance programmes; and a general decline in network performance.

In 2006 Banedanmark – the state-owned company under the Danish Ministry of Transport with responsibility for the maintenance and traffic control for much of the national network – put forward a compelling case to the national government showing how the optimum long-term solution was not the traditional ‘patch-up and fix’ approach, but the replacement of the entire system in one programme.

According to Thomas Rasch, Ricardo Rail business manager in Copenhagen, the proposal was an honest reflection of the situation: “Banedanmark took the decision that the network would already have to commit to an expensive programme of ongoing repairs and renewal. However, they concluded that a full replacement would achieve economy of scale through the planning and procurement stages, and enable them to streamline the complex safety approvals and authorisations process.”

Government approval was given in 2008, and by 2021 more than 2000 km of existing lineside signalling technology across Denmark will have been replaced by a system called ERTMS (Level 2).

**ERTMS in overview**

ERTMS (European Rail Traffic Management System) is a system based on direct radio communications between in-cab driver displays and a central traffic control centre. It is a standard backed by the European Union so that the industry could begin to harmonize systems and practices across EU mainline routes, and ultimately establish a ‘single’, open European rail network.

A key differential between ERTMS and traditional systems is that by using control centres to monitor and instruct the movements of individual trains, it allows for the removal of some of the trackside signalling equipment that is a major cause of maintenance costs and operational delays. This means trains will be able to operate across borders without the array of on-board train protection systems, radios and signalling equipment required today. By incorporating technology similar to GPS, ERTMS will begin to enable control centres to monitor with pinpoint accuracy each train’s location, thus allowing more trains to run closer together – and even bi-directionally along certain routes – thus increasing capacity.

All new mainline projects in the EU must now apply ERTMS signalling, but Denmark is the first member state that has committed to ERTMS on a national scale in a single programme. This is a decision which offers a number of advantages. Firstly, it provides a wider choice, and thus increased competition, between signalling technology suppliers all working to the same technical specifications. Equipment and interface problems between components are also likely to be reduced, because a single supplier can be required to deliver a full signalling package. Costs will be further reduced, too, as only a single safety approval is necessary per contract. Finally, design and development costs will represent a comparatively low proportion of the investment. The operational benefits will be a network that can offer increased line speeds, improved safety, better reliability and higher traffic levels on key routes.

And the Danes are going further still. By 2018 a concurrent project will see the signalling system on Copenhagen’s suburban network replaced by Communications-Based Train Control (CBTC), a technology standard designed for the stop-start nature of urban metro systems. Again, the result will be a substantial increase in network capacity, with services able to operate at greater speeds and increased frequencies, and with reduced energy costs.

**Safety-critical assurance**

Since the outset of the Danish programme, the Copenhagen-based team of Ricardo Certification – a subsidiary formed in parallel with Ricardo Rail to provide a growing range of accredited assurance services for clients within the rail market – has been performing a number of important assurance roles on both the national and suburban programmes. This team has been heavily involved throughout the planning and design stages to ensure project-specific and regulatory requirements will be met.

“To remain on schedule and ensure the new systems can be safely put...
Automaton: don’t run before you can walk

The adoption of digital-led signalling technologies such as CBTC and ERTMS has been opening up an important debate over the extent to which the rail industry should allow automation to take hold in an area where there is so much safety-critical concern.

Automation has been central to most recent advances in train control technology, from supporting basic functions – such as warning indications of detected failures – to fully-fledged automated systems, such as driverless trains.

Whether in the control centre or on the station concourse, automation offers some tantalising opportunities for a railway: operational decisions taken free from emotion or distraction, staff released from routine tasks, and workloads kept at safe levels. However, there is growing concern within the industry about the potential drawbacks should the industry get the ‘level’ of automation wrong.

In 2014, Ricardo’s Professional Head of Signalling for the UK, Daniel Woodland, led a team conducting new research into the human factors implications of increased automation in train control technologies. “During the course of our review we found a number of concerns relating to our ability to implement effective automation within the industry,” he commented. “No-one doubts the benefits, but there is a debate to be had about how to avoid inappropriate automation, or an over-reliance on automation systems, something that could actually disrupt the smooth operation of services and, in the worst cases, lead to unsafe conditions.”

The range of issues raised during the research included incidents of incorrect system response and the general loss of experienced supervisory staff who would be deemed superfluous in the digital age. Other concerns related to doubts over longer-term system stability and security risks.

The research also uncovered the potential for a gradual erosion of competencies within the control centres. This raises a further question: as systems become more automated but also more complex, what is being done to ensure the human operator is not left behind?

“There are two significant limitations within our current technology and application know-how,” explains Woodland. “As an industry, we don’t yet fully understand every dynamic of the railway, meaning we cannot comprehensively specify automation solutions for every possible situation. Secondly, we are still learning about integration of automation and humans within a system, and still developing methods to implement solutions that enable knowledge sharing and mutual support. This is a limitation within current technology itself that restricts our ability to provide effective automation.

“Automation can assist in achieving the efficiency and safety that we aspire to, but we shouldn’t run before we can walk. The industry must consider the ‘art of the possible’ and not let an eagerness to achieve objectives jump ahead of our ability to deliver.”

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The research also uncovered the potential for a gradual erosion of competencies within the control centres. This raises a further question: as systems become more automated but also more complex, what is being done to ensure the human operator is not left behind?

“There are two significant limitations within our current technology and application know-how,” explains Woodland. “As an industry, we don’t yet fully understand every dynamic of the railway, meaning we cannot comprehensively specify automation solutions for every possible situation. Secondly, we are still learning about integration of automation and humans within a system, and still developing methods to implement solutions that enable knowledge sharing and mutual support. This is a limitation within current technology itself that restricts our ability to provide effective automation.

“Automation can assist in achieving the efficiency and safety that we aspire to, but we shouldn’t run before we can walk. The industry must consider the ‘art of the possible’ and not let an eagerness to achieve objectives jump ahead of our ability to deliver.”

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looking to ensure that suitable training and support will be in place throughout the migration.

**Evolution not revolution**
Since Denmark’s landmark decision, Austria, Belgium, Norway, the Netherlands, and Switzerland (for its standard gauge lines) have each declared their intention to migrate their networks to ERTMS, albeit over the course of longer-term renewals. And major mainline routes in Europe, particularly new-builds and through-traffic routes, will also begin to adopt ERTMS. And this is not just a European exercise: almost half of all ERTMS investment to date has been from outside Europe in countries such as Turkey, Saudi Arabia and China.

However, widespread change is still some distance off. For Europe as a whole – where the development of ERTMS began more than two decades ago – critical mass is still some 10 to 15 years away. Some countries are wary of the upheaval and risks involved in replacing deeply-ingrained national rules and practices. For others, financing is the key challenge.

Nevertheless, the industry is slowly restructuring; supply chains are becoming more global and railways across the world share the common pressure to support ever-higher traffic volumes from existing infrastructure. It is becoming clear that the general direction of travel is inevitably towards digitally-based, centralized control systems such as ERTMS and CBTC (see box on page 20).

And this is precisely why the team in Copenhagen is confident that the experience and knowledge already amassed will continue to help the project as it progresses, and prove valuable long into the future.

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Ricardo has been given the key responsibility of ensuring safety standards compliance for the EcoTwin consortium as it took part in the European Truck Platooning Challenge. Ricardo was also in charge of overall project management.

Platooning – achieved wirelessly – enables truck combinations to drive very close to each other, which offers benefits in terms of fuel consumption and therefore CO2 emissions; platooning also benefits safety and the flow of traffic.

An initiative of the Netherlands’ European Union Presidency, the objective of the Truck Platooning Challenge – which started in April from Westerlo, Belgium – is to demonstrate practical feasibility, and thereby obtain permission for further pan-European testing of platoons on public highways. The project vision is that truck platooning could soon become a reality in Europe.

Ricardo participated in the EcoTwin programme alongside DAF, TNO and NXP. With national and harmonized legislation for autonomous transport still being developed, Ricardo drew on existing automotive safety standards, and also on the safety standards expertise of its Utrecht-based Ricardo Rail business; the synergies between rail and autonomous road transportation are clear to see. Thus equipped, Ricardo outlined and supported the safety approach for the project, analysed the risks and failure modes and compiled the evidence of the safe application of driverless solutions. A white paper on this work is available on request.

Subsequently, Ricardo provided support in meetings and discussions with RDW, the Netherlands Vehicle Authority, in the mobility chain as well as with ERTICO, a platform for the co-operation of all relevant stakeholders to develop and deploy intelligent transportation systems standards in Europe.

In addition to its functional safety responsibilities, Ricardo performed the complete project management of the EcoTwin project on behalf of TNO. This included teambuilding with all four partners, and co-ordination of the planning and progress as well as communications. “Close co-operation of all parties involved was the main success factor in this exceptional project,” said Lizet Elshof, Ricardo project manager of EcoTwin, “and everyone acknowledged the relevance of each other’s contributions.”

Forbes has named Ricardo as one of America’s best management consulting firms for the automotive sector.

The Forbes America’s Best Management Consulting Firms 2016 report identifies which management consultancies are providing business sectors with the best guidance. To compile its list, Forbes collaborated with online statistics provider Statista, using data from both colleagues and clients. Ricardo has a disproportionately high number of client recommendations. “We’re honoured to be recognized for our ability to support our clients,” said Markus Doerr, global managing director of Ricardo Strategic Consulting. “The Forbes America’s Best Management Consulting Firms 2016 list allows us to recognize and thank our specialized teams of management and engineering consultants, scientists and technology specialists.”
A new version of the award-winning eight-speed automatic Shengrui 8AT transmission is to be co-developed with Ricardo. The new transmission will add stop-start functionality to the capabilities of this highly innovative and compact design, which is the result of an existing collaboration with Ricardo. Already being manufactured at volumes in excess of 8000 units per month, the 8AT provides excellent shift quality and is proving to be a highly successful product in the Chinese automotive market.

Under the new contract, Ricardo will support Shengrui on the development and first vehicle application of the new stop-start capable version of the 8AT. Ricardo will review the modifications to the transmission’s control software necessary to facilitate stop-start operation, and will assist in calibrating the unit to the vehicle to ensure that the required in-use performance is delivered.

“Our longstanding collaboration with Ricardo on the development of the 8AT transmission has been extremely successful in delivering an advanced-technology transmission with real benefits for our customers,” commented Mr. Zhou Liting, vice general manager of Shengrui Transmission Corporate Limited.

Ricardo has joined REWARD, a European project which is aiming to develop the know-how and technical capabilities to produce cost-effective, cleaner and more efficient passenger car and LCV diesel powertrains that go beyond Euro 6 limits under real driving conditions. The work anticipates the Euro 6d regulations due to come into force from 2017. Part-funded under the European Union’s Horizon2020 Framework, REWARD (REWal Advanced technologies foR Diesel engines) is a research collaboration between 16 partners in 10 different European countries. Ricardo’s participation is focused upon the development of advanced aftertreatment technologies through system simulation, evaluating new catalyst formulations, and the simulation and testing of exhaust thermal management strategies.

Ricardo has completed the acquisition of Lloyd’s Register Rail, originally a joint venture of Lloyd’s Register Group and CCS in China.

The acquisition marks the continued extension of Ricardo Rail’s international footprint into China; thanks to huge network growth over the last 15 years, China now accounts for half of the high-speed rail travel in the world. “We are now well placed to maximize our position in this fast-growing and increasingly important rail market,” commented Ricardo plc CEO Dave Shemmans.

“In China, almost 20,000 kilometres of new high-speed lines carry 800 million passengers per year,” added Ricardo Rail managing director Paul Seller. “A key focus for the rail sector now is on urban transit systems, with approvals or construction already started in over 80 cities. The export market, particularly across South East Asia, will also become increasingly important to its domestic equipment manufacturers.”
Ricardo to assist development of mild hybrid technology

A consortium has been formed to develop 48V through-the-road hybrid vehicle technology – a technology that offers the prospect of fuel and emissions savings comparable to high voltage hybrid architectures, but with significant savings on manufacturing cost.

The Forty-Eight Volt Electrified Rear-axle (FEVER) project, part-funded by Innovate UK, will be led by Control Power Technologies (CPT) in partnership with Ricardo, Tata Motors European Technical Centre and Provector. The project will apply CPT’s SpeedTorq technology to an ultra-lightweight rear axle module to significantly improve the fuel economy of a B-segment city car, and thus promote the further adoption of advanced mild hybrid functionality in mainstream vehicles.

Ricardo’s key responsibilities within FEVER will be the design and analysis of the highly innovative integrated 48V rear axle module, development of the supervisory vehicle control system, sub-system testing and project management support. This builds on Ricardo’s previous work on the ADEPT and ULTRAN projects.

The objective of the two-year project is to achieve a CO2 reduction of up to 15 percent over the regulatory cycle, using two through-the-road hybrid demonstrator vehicles. Integrating the electric motor within the rear axle will enable features such as low speed electric driving or ‘e-creep’, as well as electrically-assisted all-wheel drive, which will deliver additional significant savings over a typical city drive cycle. This technology will allow a carmaker to reduce the in-use carbon dioxide emissions of such vehicles by approximately 25g/km.

“The mass roll-out of electrification within the urban transportation fleet will require new and innovative power architectures that provide a performance, value and emissions trade-off that will be attractive to potential customers,” commented Stephen Doyle, Ricardo hybrid and electronic systems product group head. “Ricardo believes that a 48V electrified rear axle offering through-the-road hybrid performance – including significant ‘engine-off’ operation – will be highly attractive for many market segments but particularly for those that predominate in urban transportation.”

Modelon partnership expands IGNITE capability

A new partnership has delivered immediate benefits to users of Ricardo Software’s IGNITE complete vehicle system simulation product.

As of the recent 2016 product release, IGNITE users have instant access to Modelon’s advanced OPTIMICA Compiler Toolkit, a Modelica and Functional Mock-up Interface (FMI)-based computational platform for system design. This integration will advance IGNITE’s simulation speeds and capability – and offers the opportunity for future significant enhancements too.

The result of this partnership will bring together the best of IGNITE’s comprehensive ground vehicle performance and fuel economy simulation capability with Modelon’s state-of-the-art modelling and computational technology.

“We’re confident that improving IGNITE’s speed and agility will strengthen its position as a technology leader in the model-based-design space, further enabling our users to achieve faster and more advanced dynamic simulation results, and to create more fuel-efficient vehicles and better product designs,” commented David Higbie, Ricardo Software managing director.

NOx compliance in urban driving is possible – at a price

A range of viable aftertreatment options are available to automakers seeking to comply with the impending EU Real Driving Emissions (RDE) regulations, according to the results of recent Ricardo research.

Ricardo’s report, presented at the SIA Powertrain international conference and exhibition in Rouen, France, covers the use of an RDE simulation environment to explore the challenge and capability of LNT (Lean NOx trap)-based solutions to achieve full compliance. Solutions were also tested on an engine dyno, providing steady-state test results to help understand the mechanisms involved, and to provide input data for the simulation.

The research shows that RDE legislation represents a significant challenge for light duty diesel manufacturers, and will require large steps in the application of existing technologies. While known technologies were shown to be capable of appropriate NOx control when applied in a combination and manner appropriate to the needs of the vehicle, they each come with downsides to other product attributes – notably cost, reductant fill frequency (where applicable), and, ultimately, fuel consumption.

“The introduction of RDE regulations in Europe represents a very significant challenge, particularly for those automakers offering light duty diesel products,” commented Ian Penny, managing director – engines, Ricardo. “However, as the results of this research demonstrates, this is a challenge that can be met in a cost-effective manner through the application of a combination of aftertreatment technologies appropriate to each vehicle type.”
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- Efficient, cost-effective niche manufacture

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Find out more about Ricardo’s comprehensive battery solutions

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