Interview
Anders Eugensson is Volvo’s autonomous driving champion

Transformative technology
Ricardo’s Magma concept engine promises super-efficient gasoline power

Full-on mild
The 48-volt ADEPT project’s low-cost architecture matches hybrid economy

ENGINEERING
future security

Defence planners refocus on flexibility and sustainability – and Ricardo provides the know-how to maximise fleet readiness and performance
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

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Ricardo is continuing to push the boundaries of integrated vehicle solutions for our clients. 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 environmentally friendlier, cost-reducing advanced lead-acid battery technology, reduced component costs, mild hybridization at 48V, and high synergies in powertrain architecture.

The Advanced Diesel Electric Powertrain (ADEPT) project is a six-partner venture, bringing together scientific, research and development of ground-breaking technologies, we are positioned perfectly to collaborate on programmes – both from within Ricardo and other leading companies.

With autonomous cars at the centre of Volvo’s strategic safety programme, Tony Lewin hears how the Volvo approach differs from those of its competitors. With a broad spectrum of capabilities, a 2900-strong global team of specialists and a rich history in the motorcycle business, Ricardo is leading the 48-Volt ADEPT project to show how intelligent electrification can deliver fuel and CO₂ savings equivalent to full-hybrid capability. As Anthony Smith discovers, the concept’s low-cost mild hybrid architecture is adaptable for diesel, gasoline or alternative powertrains, too.

Ricardo engineers among leading companies. We aim to achieve this by presenting an up-to-date mix of news, profiles and interviews with top business leaders, as well as in-depth features on programmes – both from within Ricardo and other

• Ingenious engineering for super-efficient production-ready components with Ricardo's Magma concept engine blends technology and delivers fuel and CO₂ savings equivalent to high synergies in powertrain architecture.

• Reduced design complexities – Ricardo’s Magma concept engine architecture is adaptable for diesel, gasoline power.

• Lower cost of ownership – Ricardo’s Magma concept engine discovers, the concept’s low-cost mild hybrid full-hybrid capability. As Anthony Smith discovers, the concept’s low-cost mild hybrid architecture is adaptable for diesel, gasoline or alternative powertrains, too.

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The task of RQ is to highlight the latest thinking in global engineering and technology in the transportation and clean energy sectors and related industries. We aim to achieve this by presenting an up-to-date mix of news, profiles and interviews with top business leaders, as well as in-depth features on programmes – both from within Ricardo and other leading companies.

Client confidentiality is of the utmost importance to Ricardo, which means that we can only report on a small fraction of the work carried out by the company. So we are especially grateful to those Ricardo customers who have kindly agreed to co-operate with RQ and allow their programmes to be highlighted in print: without such help from customers it would not be possible to present such a fascinating insight into the development of new products, technologies and innovations.

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The MD of Ricardo Deutschland on flexibility and sustainability for their vehicle fleets rather than narrow combat roles. Anthony Smith hears how Ricardo is helping defence planners shape their vehicles for the future.
Time will tell whether or not Paris 2016 will come to be seen as a landmark motor show, but two of the highest-profile exhibitors certainly saw their innovations in suitably grandiose terms.

“The VW brand has started the greatest change process in history,” proclaimed Volkswagen director Herbert Diess in front of a screen displaying the Beetle, the original Golf, and the all-electric I.D. concept. The clear implication was that the I.D. would go on to make history and take over the mantles of its forebears as the best-selling car of their era.

Over at Mercedes-Benz, CEO Dieter Zetsche delivered much the same message: “The emission-free automobile is the future,” he said. “And our new EQ brand goes far beyond electric vehicles.”

Despite their differences in size and status, the EQ and I.D. concepts share some striking similarities. Both launch new corporate electric-car architectures destined to underpin a vast range of models both large and small; both promise electric ranges of over 500 km, and both preview interactive cockpit designs as a lead-up to increasing automation and, later, full autonomous capability. Both boast purely touch-based controls (“no switches, no sticks, just a screen,” bragged Diess) and both have illuminated brand mascots as well as visual welcome sequences to ram home the electric message.

Volkswagen’s MEB electric platform is rear wheel drive in its I.D iteration, allowing the finished car – barely longer than today’s Golf – to boast the interior space of the big Passat, while Mercedes mounts e-motors both front and rear for its AWD application. Mercedes also floats the idea of 300 kW charging to add 100 km of range in just five minutes. VW is even specific about pricing: the production I.D. will appear in 2020 and cost the same as a diesel Golf.

Significantly, two existing big-sellers in the European EV market get range improvements. The Renault Zoe gains an upgraded battery to give 400 km, while VW’s e-Golf is now capable of 300 km, widely seen as the minimum consumer-acceptable figure.

Mercedes-Benz EQ (left) and Volkswagen I.D. (below) both are ambassadors for all-new electric architectures. The VW, due in 2020, will offer 600 km range.

Electric with everything

With crossovers and coupé derivations of SUVs racing ahead in European sales charts, almost every new release finds itself billed as one of these styles. Respect, then, to BMW’s Concept X2, which shows an elegant new take on both aspects of the theme and which confines any aggression to its front mask. Less easy to read is the complex Lexus UX Concept, potentially an X2 competitor, and perhaps the harbinger of a more frantic urban style of design.

Elsewhere, the Peugeot 3008 and 5008, the new Audi Q5 and the Skoda Kodiaq all promise to add to the outpouring of crossovers, while Land Rover’s Discovery hits new heights for convenience: its seats can be folded remotely from a smartphone anywhere in the world.

Style and substance
Variable compression comeback

Infiniti, the premium nameplate of the Renault Nissan Alliance, is showing an innovative engine concept which revives the idea of a variable compression ratio in order to optimize thermal efficiency.

The two-litre turbocharged gasoline VC-T engine uses a system of actuators, links and auxiliary shafts to adjust the stroke of the pistons within their cylinders. The compression ratio can be altered between 8.1 for power and 14.3 for peak efficiency. Infiniti claims benefits which include not only ‘significantly reduced fuel consumption and emissions’ but also greatly reduced NVH as well as more compact packaging.

Towards the driverless farmyard

After autonomous cars, trucks and vans, now it is the turn of agricultural vehicles to dispense with the human driver. Case IH’s autonomous concept tractor, revealed at September’s Farm Progress Show in Iowa, is guided by GPS location and can operate independently of cables and other fixed systems. One farmer can supervise several such machines remotely via a computer screen or tablet, and the machines themselves take account not only of implement widths but also of weather and ground conditions to alter their operational itineraries. Should GPS contact be lost, the tractor will automatically stop.

EU targets carbon-free road transport by 2050

In a wide-ranging set of proposals announced in July, the European Commission is seeking to fully decarbonize road transport by 2050, with the interim target of a 40 percent CO2 reduction over 1990 levels already agreed by member states for 2030. Road vehicles currently account for 70 percent of EU CO2 emissions.

The Commission’s new Strategy for Low Emissions Mobility has been given a cautious welcome by environmental groups, though the lack of action on the fast-growing aviation and shipping sectors did come in for criticism. Notable features of the proposed strategy include tighter standards for passenger cars and vans in the run-up to 2030, as well as improved incentives encouraging zero and near-zero emission electric and hydrogen vehicles.

Also included are Europe’s first-ever truck CO2 standards, due to appear well before 2030. Further incentives to reduce truck CO2 emissions include road toll discounts for low-carbon models. No measures are included to revitalize rail transport, another point attracting criticism from green groups.

NEWS IN BRIEF

Highlighting the latest thinking in automotive engineering and technology worldwide

Downsizing taking hold

Paris show debuts provide the proof: the new and bigger Nissan Micra enters the market with a 0.9-litre engine, while Honda’s staple Civic seems to grow larger as fast as its engines become smaller – the tenth generation model, previewed at the show, is 4.5 metres long but is powered by a one-litre, three-cylinder engine.

Weight-watcher’s award

The price for the greatest reduction in kerb weight goes to Land Rover’s new Discovery. The fresh multifaceted seven-seater has shed a remarkable 480 kg in mass, the benefit of moving from a steel ladder chassis to a new aluminium platform.

Smart’s EV first

Smart is the first automaker to offer its whole range with a choice of combustion engines or battery power. Late 2016 sees the launch of electric editions of both the ForTwo and its four-seater counterpart, the ForFour.

Diesel fallout

Diesel cars are losing market share in the wake of the VW emissions scandal. In the first eight months of 2016 diesels suffered their worst reversal since 2012 in Germany, falling to under 47 percent share of overall sales.

Grand designs for Rio

Volkswagen Truck & Bus is launching an ambitious scheme to provide an operating system for the entire global supply chain. Cloud-based Rio will link shippers, dispatchers, carriers, drivers and recipients through a uniform information and application system which will be able to take into account weather, traffic and other factors in scheduling logistics movements.

Aircraft face emissions norms

Draft aircraft emission regulations could be in place as early as next year, according to the New York Times. As one of his last acts to stem climate change, President Obama is encouraging the EPA to put its tentative plans for aircraft standards into practice, despite resistance from the airline industry.

Key to survival

Knowing the habits of its Transit customers, Ford has developed a new generation of super-tough keys for the range. The new keys can be submerged underwater, dropped onto hard concrete, vibrated and surrounded by dust without giving up.

Transit key: survives 30 minutes underwater
Truck technology is catching up

September’s IAA Commercial Vehicles show in Hannover witnessed a series of significant advances in truck and bus technology, many of the innovations coming from the world’s leading truckmaker, Mercedes-Benz.

The Mercedes Urban e-Truck is an engineering study for a fully electric distribution truck with a 12.8 tonne payload. Powered by twin hub motors each rated at 125 kW and 500 Nm, the e-Truck promises a range of 200 km on a modular battery pack 212 kWh in capacity; eventual customers will be able to specify different battery module combinations to suit their required ranges.

The e-Truck claims to offer the performance of a diesel equivalent and is fully connected in its operation, being able to work out its own delivery scheduling to make best use of its battery capacity.

Mercedes also showed a further concept, the Vision Van, for the so-called “last mile” in the delivery process. With a 75 kW motor it has a range of between 80 and 270 km, depending on the battery capacity chosen; it is digitally connected to every level of the distribution chain, and if the end customer is not at home the vehicle is able to dispatch one of its two drones to make the final step of the delivery by air.

The Mercedes Future Bus, finally, is intended for urban rapid transport routes and is semi-automated in its operation using CityPilot programming, itself based on the company’s Highway Pilot for intercity trucks. For city use the system has significantly more sensors to ensure safe operation in a busy urban environment, and in semi-autonomous mode has an accuracy of between two and five cm. The cameras also enable precise positioning in tunnels where the bus is unable to receive signals from GPS satellites.

Vision Van is one of several Mercedes innovations, along with all-electric Urban e-Truck and semi-automated Future Bus.

Landmark year for solar

Within a matter of months, 2016 has seen a succession of milestone events that suggest this could prove to be a landmark year for solar energy.

Shortly after the Solar Impulse completed its epic round-the-globe flight using nothing but solar energy, a Spanish energy producer struck an all-time best price for solar power at just $29.10 per Megawatt hour, and research by Bloomberg New Energy Finance showed that eight percent of total energy generation in the G20 nations came from solar, wind and other ‘green’ sources, excluding hydropower.

Additionally, the Financial Times was prompted to suggest that, with energy consumption in Europe declining, China slowing down and the US flattening, the world could be approaching the point of peak energy demand, peak oil having been passed some years ago.

While the Solar Explorer relied entirely on solar panel generation for its epic 43,000 km, 550-hour circumnavigation, ground-based solar panel prospects continue to improve. Research into the microclimates around solar farms conducted by Lancaster University revealed potential benefits in terms of shading and protection of fragile crops in hot areas, as well as the use of condensing water in dry areas.

EV battle shapes up

General Motors’ long-awaited pure electric Bolt EV compact car has been announced with a range of 238 miles (384 km) and an on-sale date in the final quarter of this year. The five-door hatchback will be priced at $37,500 before incentives and will also be sold in Europe under the Opel Ampera-e badge.

The Bolt squares up to Tesla’s high-profile Model 3, which has built up a long waiting list ahead of its 2017 introduction, despite no one having been able to try the vehicle. The Model 3 will cost less than the Bolt EV in its simplest form, and offers a 215-mile range.

In Europe, meanwhile, VW brand director Herbert Diess has predicted the company will be selling a million EVs annually by 2025, although sales head Jürgen Stackmann believes EVs will only become attractive once they offer a 300 km range. Nissan UK expects electric car charging stations to outnumber gasoline and diesel filling stations by 2020.
The need for speed

Bonneville Salt Flats in Utah has been very busy in recent weeks, with a series of teams setting new world or class records. After a three-year wait for course conditions to improve, Monaco-based Venturi has at last beaten its own absolute record for electric vehicles: the VBB-3 posted a two-way average of 549 km/h, with a top speed of 576; a Honda R60 team managed to squeeze 422 km/h out of its S-Dream streamliner, powered by a 660 cc three-cylinder engine derived from the S660 road car. This makes it the fastest Honda ever, beating even the team’s Formula 1 cars.

Perhaps the most unusual record breaker has been the VW Beetle LSR, which hit 328 km/h thanks to its 2.0 litre TSI engine boosted to 550 hp. On two wheels, UK premium bike maker Triumph has been less successful: piloted by TT racer and TV presenter Guy Martin, the 1000 hp Triumph Infor Rocket broke a long-standing Triumph record at 442 km/h but was prevented by unfavourable course conditions from achieving its aim of reclaiming the world motorcycle speed record, which stands at 606 km/h.

Follow the money

Some surprising results from a CAR-Center Automotive Research analysis of the pre-tax profit figures delivered by volume automakers in Europe. Top scorer is Nissan, which earns an EBIT of €2008 per vehicle sold; it is followed by Toyota on €1589 and Skoda at €1358, with a resurgent Ford still some way behind at €973. That is still better than Peugeot Citroën and Renault, which earn €844 and €715 per vehicle respectively, while the VW brand languishes in ninth place at €395 and Opel is still struggling at barely €117 per unit.

Tidal flow brings promise

MeyGen, off the coast of Scotland, is expected to become the world’s largest tidal flow generating scheme when it begins operation later this year. The first proof of concept phase is a giant turbine, mounted 40 metres down on the sea bed, and this will quickly be followed by four more to bring the generating capacity to six MW.

Tidal flow water speeds of up to five m/sec guarantee a good rate of generation but have made the construction of the installations a challenging task: over 1000 tonnes of structure and ballast are required for each turbine, and work is often limited to neap time periods when the currents are weaker. By the early 2020s MeyGen intends to deploy up to 398 MW of offshore tidal stream turbines to supply clean and renewable electricity to the UK National Grid.

VIEWPOINT

We now have the critical mass to take on any challenge in motorcycles and personal mobility

Dr Robert Hentschel – managing director, Ricardo Deutschland GmbH

When I provided the welcoming address to the inaugural Ricardo Motorcycle conference in Milan in November 2014, just days following the announcement of the formation of our business dedicated to motorcycles and personal mobility, I was able to set out how we were able to address any challenge of this sector, anywhere in the world.

Ricardo had just completed the acquisition of UK motorcycle chassis, vehicle integration and prototype build specialist Vepra. This acquisition brought significant synergies with our existing motorcycle engineering team, not least in the highly complementary market profile brought in the US cruiser motorcycle market and in India, and its perfect fit with the extensive and long-standing Ricardo experience with leading German and Asian brands.

But there was one aspect of the vision for Ricardo Motorcycle that remained what might be termed ‘unfinished business’. Alongside the then new acquisition and our long-established engineering team, a third equally complementary element was represented by Exnovo – will be familiar to many within the motorcycle industry as likely as not to see them putting their considerable expertise in the design of exceptional urban mobility solutions, including small three- and four-wheeled vehicles as well as motorcycles.

I believe the Ricardo Motorcycle team... goes way beyond the capabilities offered by any other consultancy

These are engineers of exceptional talent, but, crucially in my view, they are enthusiasts for the product too. On the daily commute or at the weekend, you are as likely as not to see them putting their cherished collections of motorcycles – from classics to the latest performance models – through their paces.

I believe that the combined strengths and experience of the Ricardo Motorcycle team and its proven engineering leadership goes way beyond the capabilities offered by any other consultancy or in-house engineering team anywhere in the world.
You are at the centre of strategic safety planning at Volvo. What are you working on right now?
It’s a very exciting time: I’m working on autonomous cars, and this is the most exciting thing I’ve been involved in during my 32 years at Volvo. Crash safety is very interesting, but being part of this development for autonomous vehicles – that could change so much about how we transport ourselves in the future. The more you think about it, the more possibilities you find. It could involve everything we do, the way we connect with people, the way we approach mobility.

How does Volvo approach the issue of driverless cars?
When we sat down and looked at this from the beginning, we asked ourselves what modern people are lacking. What are we all craving? And the answer is time – we don’t have enough time to spend with our families and friends and people we want to be with. What if we can create time for people, save some of that frustration of sitting in traffic not being able to do things? It’s part of our mission to uncomplicate people’s lives, to make sure they are comfortable and less frustrated. What is the key to this? Autonomous vehicles is the way we see the future, for they would create that time and allow people to stay connected.

Several of your competitors have announced autonomous vehicle programmes. How does Volvo’s strategy differ?
At the moment we’re not working on A-to-B technology; instead, we’re working on taking over when it’s not fun for the driver – in traffic, on highways where there is traffic next to you and you wish you were somewhere else. And when it’s fun, you drive – so it’s not a case of the car taking over. That’s where we plan to start with our development. In addition, we’re looking at developing autonomous parking.

Why is parking so important?
If you live in a congested area and don’t have a parking space nearby, you can drive up to your front door, take out your groceries and ask the car to park itself – like a valet service. This could be very important for the future when we get into more car sharing and having cars on demand: with car sharing today
you have to go to the place to pick the car up, but now the car could come to you. This could be a real game changer.

How will your programme unfold?
It will be a gradual development. We’re already running a trial in Gothenburg on the ring road [in an environment] where there are no pedestrians and no cyclists; in a couple of years we will be building on more sensors and more intelligence. Then we will have a way of dealing with intersections, roundabouts and more complex city driving. The project in London will be step by step over the next four years, too, also with up to 100 cars. Some will be leased to normal Volvo customers and the rest will be used by Volvo engineers.

How do you choose the customers taking part in the trials?
A lot of people have been coming up to us and asking to join. In Sweden, we have several companies on the ring road – and people who use this road for their regular commute will be given the cars. A few cars will be given to families, and the media will be able to speak to them about their experience. There has been huge interest in the UK, too.

You said that between 90 and 95 percent of all crashes are caused by human error. Do you expect a 95 percent drop in casualties once autonomous cars are in circulation?
Almost. There will still be interactions with normal cars and normal road users. One of the challenges we have [at the moment] is that we can’t go into central London, say, because there are roundabouts, intersections, pedestrians and cyclists. With intersections, our car can anticipate when the lights are green: the problem comes if another car runs the red light and hits us – that’s a crash. So we may not go down the full 90 or 95 percent [in casualties]. And in areas where there are pedestrians we are very slow and cautious, but there may still be interactions.

Once everything is completely autonomous, there shouldn’t be any accidents. But what is the critical proportion of autonomous cars on the road before we will see the big breakthrough in terms of traffic flow and safety?
There is a tunnel in Gothenburg which has multiple approaches to it, and a study we did showed that if 30 percent of the cars going into the tunnel were autonomous, there would be a significant impact: traffic would merge more smoothly and there would be a real improvement in traffic flow.

How important is networking between vehicles? Can it, for instance, alert traffic to obstacles in the road?
We’re running a project right now in Sweden and Norway to alert drivers to icy roads. Our cars measure whether the road is slippery and send a signal to the cloud; that signal is sent back to other road users and also to the operators of salt trucks so they know exactly where to put the salt or the sand. The signals are also sent to the roads administration. Cars will be able to identify obstacles in the road and also warn about pollutants in the air. China is a good example, and areas could be closed [to traffic] if the pollutant levels are too high, or vehicles might have to switch to electric mode.

With what Tesla now offers, are we not already there with automated driving?
We have similar technologies, too. I don’t like to name any manufacturers, but I’d like to stress that what you describe is still driver supervision. It is very easy to think that that technology can deal with everything on the roadway. We like to make the distinction between supervised and unsupervised automation. There’s a tendency for people to think they can just pick up their laptop and start working, and that might be the case occasionally. But what this technology can’t do is deal with the unexpected. What we are doing in our project is making sure we can understand everything. If there is something the car can’t identify, it will ask the driver to take over control: if the driver doesn’t do this, the car will enter its ‘safe harbour’ mode and go to the side of the road and stop in a safe place designed

“If you live in a congested area and don’t have a parking space nearby, you can drive up to your front door, take out your groceries and ask the car to park itself – like a valet service”
government. The UK did not sign the Vienna convention, which states that the driver has to be in control at all times.

Won’t we lose the fun of driving?
Not really. I get that question all the time, by the way. I like to explain it like this: when I’m on a nice piece of road, like a coastal highway, I like to drive. But when I get into congested situations, I don’t mind [not driving]: there’s nothing that I enjoy, and I say that it’s fine for the car to take over. In the initial stages, at least, I see it as something that I would gladly give away to allow me to do other things and enjoy myself. But if you say ‘now I want to drive’ and you want that really fancy suspension setup that you had on, say, your 1964½ model year Mustang, we can probably recreate that in the future. A lot can be done with electronics.

You say that the driver can take over if he or she wants some fun. But isn’t that a formula for lots of accidents and liability questions?
If the driver wants to take back control, this is done with a transition time that will make it safe. First of all, the driver will get a clear indication of how long it will be before the transition back to [manual] control, then we will make sure everything is in place, the car is in lane and there is no conflict at the moment we hand over, and then there’s a countdown. But even when [the driver] is back in control there are still all the systems in place looking all around the vehicle, telling the driver if there is a crash risk, a pedestrian on the road, or other warnings. We’re still using all the power of the sensors to help the driver in that situation.

Will the US be the first adopter of autonomous vehicles, and how soon?
Yes, without a doubt. Unless there is a drastic change of mind by the [UN ECE legislators] in Geneva, it will be in the early 2020s in the US. Other markets can get a two-year exemption [from the Geneva regulations], so it could happen at the same time elsewhere too. The UK is doing a great job, and we’re really positive about the interactions we are having with the British government. The UK did not sign the Vienna convention, which states that the driver has to be in control at all times.

The five steps to autonomous travel

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<thead>
<tr>
<th>Level</th>
<th>Year</th>
<th>Description</th>
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<tbody>
<tr>
<td>Level 1</td>
<td>Jaguar XK, 1996</td>
<td>Autonomous cruise control gives ‘feet off’ capability on motorways</td>
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<tr>
<td>Level 2</td>
<td>Mercedes S-Class, 2013</td>
<td>Active lane keeping, brake and steering intervention; partial hands off</td>
</tr>
<tr>
<td>Level 3</td>
<td>Tesla, 2016 and Cadillac, 2017</td>
<td>‘Super cruise’ can take full control on highways. Hands and feet off</td>
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<tr>
<td>Level 4</td>
<td>Ford, Volvo, Nissan, BMW, 2021-3</td>
<td>Whole journeys potentially automated. ‘Eyes off’ potential</td>
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<tr>
<td>Level 5</td>
<td>Google pilot, 2014 on; various trials</td>
<td>Full automation, no conventional controls, no need for driver</td>
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Source: FT, with additions
have not been central to our present development of highly autonomous driving on highways with vehicles being in control and using advanced sensors, cloud connection and 3D maps. This type of application is not using DSRC and is based on other systems and with a different approach.

**What percentage of your R&D budget is going into the area of autonomous vehicles?**
I don’t want to give away numbers, but we are spending a lot of money developing these systems. But I’d like to stress that it is not purely autonomous – it’s also adding to the safety of all of the vehicles. All of this development is in parallel to making our cars completely safe: all those sensors will in the fullness of time appear on all our vehicles. The costs will come down and we will make it a standard package, with ways of switching the autonomy on or off. The knowledge we gain with autonomous vehicles is part of our Vision 2020 development for cars not crashing in the future.

**When Volvo launches its autonomous vehicles around 2020, will it be first?**
We haven’t decided on an exact date, and it depends on what you mean by first. We will be offering autonomy on certain parts of the roadway. There are other manufacturers looking at similar things, so we’re not sure if we are going to be first. But there is no other manufacturer who has launched a [field trial] project on the scale that we have. We’ve taken the stance of putting normal customers in a lot of cars to make sure we can do what is safest.

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**Anders Eugensson, director of government affairs, Volvo Car Group**
Eugensson gained his Masters in Civil Engineering from Chalmers University, Gothenburg and Imperial College, London, in 1978 and joined Volvo in 1984, to work on the structural crashworthiness of the 850. From 1998 he worked on strategic safety issues and government liaison, becoming director of government affairs in 2003. In 2013 he won NHTSA’s special appreciation award.
Throughout the 1990s and early 2000s, the development of light military vehicles was primarily focused upon the adaptation of existing commercial platforms. This provided benefits in terms of access to the latest automotive technologies as well as providing a very cost-efficient model of vehicle development. However, the combat missions in Afghanistan and Iraq presented the US, British and other participating NATO countries with an entirely new form of conflict: an asymmetric confrontation in which the need to project force flexibly, at the same time as defending against improvised explosive devices, became an urgent imperative.

The need to provide solutions delivering much higher standards of crew protection, in particular against improvised explosive devices (IEDs), led to a rapid change of focus in favour of bespoke solutions. Several new vehicle fleets were developed against these new threats and delivered for use in theatre at timescales that were

With their recent major combat missions completed, US, British and other NATO forces no longer require new vehicle types for immediate use in theatre. Now, the priorities have shifted to long-term maintenance and the development of existing fleets in readiness for potential future threats. **Anthony Smith** reports
in sharp contrast to the highly planned and evaluative procedures for defence procurement that would be expected in peacetime. A notable example of this was the British Army’s Foxhound light protected patrol vehicle, which Ricardo and its partners took from an initial sketch through to full scale production in just 26 months.

In parallel, with the return of the surviving vehicle fleets from theatre in recent years, the investment climate has also been profoundly affected by the squeeze on public sector finances as austerity policies swing into play in order to reduce national budget deficits. So how is this ‘new normal’ of constrained budgets and the requirement for post-conflict fleet management affecting the military vehicles sector?

Perspectives either side of the Atlantic

Chet Gryczan is president of Ricardo Defense Systems (RDS), a separate and wholly-owned limited liability company, formed in 2015 and structured under a Defense Security Service ‘Special Security Agreement’ that allows the business to work on US defence programmes without limit or restriction: “The US government’s tactical vehicle budgets have fallen significantly since the height of the Iraq and Afghanistan wars,” says Gryczan. “That said, the government is prioritizing investment in several notable new vehicle programmes including the Joint Light Tactical Vehicle, the Ground Mobility Vehicle and Mobile Protected Firepower. There is a real opportunity for the government to streamline procurement to bring cost-effective innovation to the field with these new programmes. In parallel, we are seeing a strong focus on sustainment.”

“The initial introduction of autonomous ground logistic vehicles may likely be tethered rather than remote operated or fully autonomous. Tethering a convoy with a manned vehicle presents a relatively low-cost, robust, low-tech way to reduce human life exposure to hostile situations”

Chet Gryczan, President, Ricardo Defense Systems
Case study: the UK Cougar fleet Post-Design Services contract

An example of a major post design service contract is that of the UK Cougar fleet, comprising vehicles known as Mastiff, Wolfhound, Ridgeback and Buffalo, which formed the backbone of the UK’s protected patrol fleet in the Afghanistan and Iraq theatres of operation.

Having performed exceptionally well in combat operations, as the Cougar fleet began to be returned to the UK the Ministry of Defence (MoD) took the strategic decision to transition the vehicles into the Army’s core fleet capability. This necessitated the creation of an effective support solution through to the fleet’s projected end of service life of 2035.

To this end, the MoD sought support from industry in the form of a Post-Design Services (PDS) contract covering current maintenance and future development. The role of the PDS contractor is to act as the design authority for the fleet on behalf of the MoD, providing expert knowledge, configuration management, safety case management, obsolescence management and change control.

A unique partnership

In participating in the competition and ultimately securing this strategically important PDS contract, Ricardo went into partnership with prime contractor Morgan Advanced Materials (formally NP Aerospace), together with fellow team member Ultra Electronics. Collectively this partnership offered an extremely compelling blend of skills and experience. Morgan designed, developed and integrated UK-specific, specialized armour protection and electronic systems into the entire Cougar family and also implemented and operated the spares support processes, including configuration management, stocking and supply chain management to keep the fleets running during combat operations. With its access to state-of-the-art automotive technologies and its extensive defence vehicles expertise in the development of Foxhound and RWMIK, Ricardo was clearly extremely well placed to take responsibility as the design authority for the Cougar fleet’s automotive systems.

Making up the partnership, Ultra Electronics was able to take responsibility for the electronic systems of the vehicle.

Key development projects

Under its core commitment to the Cougar PDS contract, Ricardo provides engineering support at the site of Morgan, where the project is co-ordinated. Work on the core programme includes support for system technical and safety reviews and participation in ongoing programme review meetings and providing ad-hoc technical advice. Crucially, the work also includes the scoping and costing of additional non-core tasks, such as significant vehicle upgrade initiatives.

The major focus of the non-core tasks to date has been on safety-related issues and improving the support solution. For example, one of the implications of transferring the vehicles to the UK was that they were non-compliant with UK road regulations. Whilst this is less of an issue in a theatre of operations, the consequential requirement to use low-loaders to transport the vehicles between UK bases and training grounds adds significant cost and time burdens.

Whilst the base vehicles were originally fitted to US highway-compliant standards, the addition of UK mission equipment such as bar armour both obscured the lights and in effect extended the extremities of the vehicles; as such, lighting systems were in the wrong position according to the legislation. Ricardo has therefore developed a UK/EU road-legal modular lighting system that can be fitted to all of the Cougar fleet. This system is based on modern LED lamp technology that saves energy while increasing reliability and reducing the need for multiple spares.

A further Ricardo task has been the engineering of a common axle and brake system across the UK Cougar fleet. As a result of the multiple ‘urgent operational requirement’ purchases over an evolving operational requirements specification, the MoD’s stores system was supporting no fewer than 23 different axle combinations for Cougar. The Ricardo project has rationalised this down to just three variants, which will both save cost in terms of peacetime maintenance operations, and also make the vehicles easier to sustain in any future theatre of operations. Moreover, through the supply of Ricardo upgrade kits – manufactured by the Performance Products division – many of the older, lower specification vehicles have been brought up to a common standard, thus increasing the overall capability of the fleet.
New vehicles: bespoke or commercial platforms?
While the primary focus of the moment appears to be upon the maintenance, life-extension and upgrades of existing fleets, what of new operational roles that require new vehicles? Here, the perspective of the North American and European markets differs slightly.

“I do not believe that there is an appetite for a return to commercial conversions in the more mature economies of Europe,” explains Ricardo’s John Stretton, “and this contrasts with some of the less affluent markets such as African nations. However, I believe that as the IED threat spreads – or becomes more widely appreciated – this demand will diminish even in these developing markets. Tactical flexibility becomes more important and platforms that can serve multiple missions types will start to dominate the landscape.”

In the US, however, Chet Gryczan views that the market may be open to the adaptation of commercial platforms: “We are beginning to hear a strong voice in the government in favour of modified commercial platform based solutions. This appears to be primarily based around reducing the initial cost of new vehicles and leveraging the commercial market’s investment in new, robust automotive technologies.”

He goes on to say that he believes there are clear opportunities for companies like Ricardo to develop and present these relatively low-cost, robust platforms as potential alternatives to a militarized vehicle system. “In certain cases, this makes sense. Certainly we would not expect a pickup truck to take direct fire or survive an IED, but likewise a costly bespoke military vehicle may not be optimal for transportation around a base or for clandestine operations.” And the advantages are not solely about cost or the acquisition of commercial technology: “The government is investigating concepts that depart from traditional heavy blast and ballistic protection towards better off-road mobility, which may ultimately provide equal or better crew protection at much lower weight and cost.”

Tried and trusted or new powertrain technologies?
So there is an appetite for the life extension and development of existing fleets as well as for the development of some new vehicle types, but what about some of the latest fuel-saving technologies? Will we see an increasing use of powertrain electrification, alternative fuels, or even fuel cells?

Here the views from the US and Europe seem to be more closely aligned. “Diesel

Case study: improving safety of the U.S. Army’s iconic HMMWV
The High Mobility Multipurpose Wheeled Vehicle (HMMWV) or ‘Humvee’, is a core element of the US Army’s vehicle fleet and one that is planned to remain in service well beyond the next decade. In order to improve the safety, serviceability and agility of this important military vehicle, Ricardo embarked on a project in 2014 to modify a fleet of ten HMMWVs belonging to the Michigan National Guard by installing a Ricardo-engineered ABS and ESC system that would significantly improve occupant safety.

The Ricardo system was developed, in part, in response to a National Highway Traffic Safety Administration (NHTSA) report conducted in 2014 that discovered a 74 percent reduction in vehicle rollovers since the 2011 mandate of ABS and ESC systems on all passenger vehicles in the US. The Ricardo system is the first of its kind to uniquely adapt the same commercial automotive components cited in the NHTSA report to improve HMMWV handling and vehicle stability at a low cost. Moreover, the system also provides shorter stopping distances, significant reduction in the wear of brake system components, as well as increased reliability and hence operational readiness.

The inclusion by Congress of the ‘HMMWV Rollover Mitigation program’ as a priority in the forthcoming defence budget validates the important contribution to vehicle safety that this Ricardo-engineered system offers.

The complete package developed and tested by Ricardo for the HMMWV includes anti-lock braking, electronic stability control, active rollover protection, traction control, and improved brake calipers, pads and rotors. The entire system leverages low-cost, proven components engineered by Ricardo specifically for the arduous requirements of service in the military environment. It was also designed for ease of upgrade to the existing fleet.
“The initial introduction of autonomous ground logistic vehicles may likely be tethered rather than remote operated or fully autonomous,” he says.

“Tethering a convoy with a manned vehicle presents a relatively low-cost, robust, low-tech way to reduce human life exposure to hostile situations, whereas fully-autonomous large vehicle solutions are likely to be cost-prohibitive in the near term and a tethered solution may fulfil the short-term need.” At the same time, Chet Gryczan believes that there is significant interest in fully-autonomous auxiliary kits which could be applied to their manned vehicle counterparts.

Case study: the UK ‘Challenger 2 Life Extension Project’

In June 2016 Ricardo signed an MoU with Belgian weapons systems designer, manufacturer and integrator CMI Defence to collaborate on a response to an invitation to tender issued by the British Ministry of Defence regarding its Challenger 2 Life Extension Project (LEP). This project will see the upgrade of the British Army’s main battle tank fleet.

CMI Defence provides an extensive history and knowledge of delivering heavy firepower gun-turret systems. Known under the brand name Cockerill®, CMI Defence weapons systems are battle proven, reliable and safe, and demonstrate a firepower capability rarely seen on the market. Thanks to this vast history and knowledge set, CMI Defence is thus perfectly positioned to integrate its systems capabilities into the Challenger 2.

Ricardo’s position as a leading authority on automotive platforms in the UK makes it CMI Defence’s ideal premium partner for the Challenger 2 LEP. Ricardo’s vast wealth of knowledge on Challenger 2 stems from its former successful contracts with DSTL and DE&S for powertrain studies, which provided demonstrable options for Platform Obsolescence Management and upgrade opportunities.

In my view, JP8- based fuels will in my view remain the norm for the foreseeable future,” explains John Stretton. “And until hybrid and electrical systems are deliverable at a much lower cost than at present, they are unlikely to feature very heavily in the military vehicle space.”

Likewise, we have not seen examples suggesting that alternative fuels and novel locomotion technologies are going to be adopted by the military in the near future,” agrees Chet Gryczan. “Having said that, the government does have an interest in staying abreast of these technologies, and Ricardo has been involved in the development of concept demonstrators and production-intent kits to address fuel economy needs.”

What about autonomous vehicles?

Interest in autonomous vehicles is strong in the US but, as Chet Gryczan explains, the extent of “autonomy” is debatable. “The initial introduction of autonomous ground logistic vehicles may likely be tethered rather than remote operated or fully autonomous,” he says.

“Tethering a convoy with a manned vehicle presents a relatively low-cost, robust, low-tech way to reduce human life exposure to hostile situations, whereas fully-autonomous large vehicle solutions are likely to be cost-prohibitive in the near term and a tethered solution may fulfil the short-term need.” At the same time, Chet Gryczan believes that there is significant interest in fully-autonomous auxiliary kits which could be applied to their manned vehicle counterparts.

Future requirements

With strong teams focused on both the US and UK and able to draw upon support from across the global organization, Ricardo offers unparalleled expertise in military vehicle design, engineering and support. The company’s independence is as valuable to defence customers as its unrivalled focus on automotive systems and technologies. Whereas the engineering teams of major defence contractors may, for example, see an engine and vehicle integration project just once in a decade, Ricardo’s team has access to specialists who are accustomed to dealing with this sort of challenge on a regular and ongoing basis.

While the highly arduous duty cycles of military vehicles are very different to those of on-highway vehicles, these same processes and skills can be applied. This not only saves cost but also delivers a better engineered, safer and more capable product for Ricardo’s military vehicle customers around the world.
The Ricardo-led 48-Volt ADEPT project shows how intelligent electrification can deliver fuel and CO₂ savings equivalent to full-hybrid capability. What is more, the concept’s low-cost mild hybrid architecture is adaptable for diesel, gasoline or alternative-fuelled powertrains, as Anthony Smith reports.

In the almost twenty years since the first mass-produced hybrid car – the first-generation Toyota Prius – rolled off the production line, the world has become used to the concept of electrification improving the fuel-efficiency of the combustion engine powertrain. In addition to such ‘full’ hybrids, consumers have also become accustomed to the so-called ‘mild’ hybrid products where a more modest amount of regenerative braking, energy storage and stop-start functionality is typically deployed.

In terms of the voltages employed in the non-plug-in vehicles developed...
over this period, there has been a broad distinction between at one extreme, full hybrids with electrical systems operating at up to 650 Volts and, at the lower end, the basic implementations of stop-start technology incorporated within the vehicle’s standard 12-volt architecture, sometimes referred to as micro-hybrids. Between these extremes, many mild hybrid products have traditionally been engineered with significantly higher voltages than the 12V baseline, resulting in a significant manufacturing cost premium over conventionally powered models.

The 48V cost advantage

For a fixed power rating, higher voltages bring some clear advantages in terms of electrical efficiency and reduced volume of copper in electrical machines and cables. Above 60 volts, however, safety considerations regarding shock protection require a much more expensive treatment of aspects such as electrical insulation. In addition, the integration of hybrid powertrain electrical architectures with existing on-board electrical systems – which are still generally restricted to 12 or 24 volts, even in full hybrid products – requires the deployment of multiple DC/DC converters, which add costs and bring incremental efficiency losses. The increasing popularity of 48-volt architectures stems both from the simplicity and cost saving they can bring to mild hybridization, and the significant improvements in the quality and performance of available low-voltage power electronics and ancillaries.

With the early consumer anxieties regarding the robustness and longevity of vehicle electrification systems, in particular of batteries, now largely a thing of the past, perhaps the most significant remaining obstacle to increasing the size of the hybrid vehicle fleet is the issue of cost. While it is almost universally accepted that improving fuel economy and reducing CO2 emissions is a good thing, few customers are likely to be willing to pay the significant premium. Yet, at the same time, regulation is forcing automakers in exactly this direction. With tightening rules for CO2 in Europe and fuel economy in the US, the fundamental objective is essentially the same: significantly increasing the efficiency with which fossil-based fuel is used.

In a nutshell, the automotive industry is facing the challenge of offering customers new vehicles that are able to deliver significantly improved fuel economy and reduced carbon dioxide emissions, while at the same time maintaining performance and affordability, and achieving the latest regulated emissions limits. While battery electric vehicles, plug-in hybrids and full hybrids will all undoubtedly play their part, the significant reduction of carbon dioxide emissions from the bulk of the vehicle fleet requires fresh thinking about cost-effective measures to improve fuel economy.

Intelligent electrification

Ricardo originally demonstrated its concept of ‘intelligent electrification’ in the form of the HyBoost project (see RQ Q3/2012). HyBoost demonstrated how a practical mix of proven or ready-for-market technologies could be applied across the whole engine system: its innovations were focused on more than the simple delivery of torque and the harvesting of energy through regenerative braking. Instead, it also investigated the use of electrically driven ancillaries, exhaust waste energy recovery through technologies such as turbo-compounding, and torque boosting – for example, to offset fuelling for a given level of torque demand or to enable aggressive engine downsizing. These were combined in a pragmatic manner to deliver extremely high levels of efficiency.

To demonstrate the potential of this concept as applied using the latest 48-volt systems, Ricardo teamed up in a research partnership with the Advanced Lead Acid Battery Consortium (ALABC), Controlled Power Technologies (CPT), Faurecia Emissions Control Technologies UK Ltd, Ford Motor Company and the University of Nottingham. In addition to the contributions of the partners, matched funding was provided by the UK Government’s Office for Low Emission Vehicles (OLEV) implemented through the UK innovation agency, Innovate UK.

Rather than apply the technology to a gasoline powertrain as with HyBoost, the ADEPT (advanced diesel-electric powertrain) project sought to demonstrate what could be achieved by applying the technology to a state-of-the-art diesel vehicle. As such, the baseline for the project was a Ford Focus ECOnetic with 1.5-litre TDCi diesel engine and six-speed manual transmission, homologated at a mere 88 g/km CO2.

“The ultimate goal of the ADEPT project,” explains Gareth Milton, Ricardo chief engineer for the ADEPT research project, “was to show that intelligent 48-volt mild hybrid electrification has the potential to deliver full hybrid economy and CO2 emissions – but at a significantly lower production cost. This was an extremely ambitious endeavour, as the start point was an already highly optimized vehicle in terms of its homologated CO₂ emissions.”

ADEPT powertrain architecture

Key features of the ADEPT demonstrator vehicle systems include CPT’s water-cooled SpeedStart switched reluctance belt-driven integrated starter generator (B-ISS), capable of delivering in excess of 12 kW of regenerative braking, as well as near-instantaneous and near-continuous torque assist levels of over 7 kW – sufficient to enable significant engine down-speeding in addition to a highly capable start-stop functionality. In most current manual transmission vehicles equipped with stop-start based
on a 12-volt electrical architecture, a ‘stop in neutral’ strategy is used. With engine restart triggered as the clutch is depressed and the gear selected, the 12-volt starter has sufficient warning to bring the engine to idle speed before its torque is required. For the baseline Ford Focus ECOncetic 1.5L TDCi, the time to idle speed is 600 milliseconds, but with the B-ISG implemented, which avoids the ‘stop in neutral’ strategy, the ADEPT vehicle achieves this in just 300 milliseconds.

“The benefit of this 50 percent reduction in the time from engine start to idle speed is to enable significantly increased opportunities to realize the fuel-saving benefits of stop/start,” explains Milton. “On the NEDC cycle this represents a full 65 percent increase from 190 to 315 seconds in engine-off time, and in real-world city-based driving, the benefit could be considerably greater.”

In addition to regenerative braking energy recovered through the B-ISG, further energy recovery is achieved from CPT’s exhaust-mounted 48V turbine-integrated exhaust gas energy recovery system known as TIGERS. Instead of connecting a turbine to a compressor, as in a turbocharger, the TIGERS unit integrates a turbine with an electrical generator. Rated at 2.4 kW, TIGERS is capable of capturing further power recuperated from the exhaust downstream of the turbocharger. A key aspect of the ADEPT control system in this respect is to determine when the thermal requirements of the diesel aftertreatment technology are such that this energy can be recovered without detriment to emissions control. This is achieved via two bespoke emissions control valves, which were developed by Faurecia Emissions Controls technologies for the ADEPT project.

Rather than adopting one of the more expensive battery cell chemistries typically employed in commercial full or mild-hybrid products for its energy storage capability, the ADEPT vehicle

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“The ultimate goal of the ADEPT project was to show that intelligent 48-Volt mild hybrid electrification has the potential to deliver full hybrid economy and CO₂ emissions – but at a significantly lower production cost”

Gareth Milton, Ricardo chief engineer

ADEPT powertrain installation

[Diagram of ADEPT powertrain installation]
uses an advanced 48V lead-carbon battery pack developed by Provector, a contractor to ALABC. “This incorporates ‘ultra battery’ modules, effectively a VRLA lead-acid battery with high rate partial-state-of-charge capability which, in addition to their competitive cost, reliability, robustness and end-of-life recyclability, incorporate an ultra-capacitive effect within their lead-carbon electrodes,” continues Milton. “This enables additional short-duration, higher-power performance, which is particularly useful in torque assistance to the vehicle.”

The ADEPT powertrain includes a range of electrical ancillaries powered from the 48V system rather than directly from the engine, including, for example, the vehicle air conditioning compressor. This enables the energy demands of these systems to be managed, avoiding the inefficiencies of direct permanent coupling to engine speed and also allowing loads to be managed for maximum benefit in terms of torque boosting and fuel economy. In the ADEPT vehicle the 12-volt alternator is no longer required due to the presence of the B-ISG, which can provide all lower voltage requirements through a DC-DC convertor. The mechanical air conditioning pump is replaced by a 48V electric compressor, and a packaging and efficiency study was carried out for similar replacement of the mechanical water pump.

The control strategies deployed have been developed based on extensive vehicle systems simulation work. This has enabled the core powertrain and aftertreatment system, as well as the 48V BSG, ancillaries, battery pack and exhaust energy recovery system, to be operated in a seamless manner, while also providing a valuable computer-aided engineering (CAE) capability to explore further potential avenues of development and optimization opened up through intelligent 48V electrification.

**Test and simulation**

The ADEPT concept includes a range of technologies that were applied to the demonstrator vehicle as well as a number of further enhancements for which there was insufficient time or resource within the scope of the project, but where simulation could be carried out to determine their likely fuel economy and CO2 benefit. Following extensive testing and simulation by the project partners, the key achievements of the ADEPT project are impressive. Starting from an already highly fuel-efficient state-of-the-art diesel powertrain homologated at just 88 g/km CO2, it has been shown that the integration of hybrid and emissions control systems in the manner envisaged by the project can deliver a Euro 6b-compliant package offering significant fuel and CO2 savings.

To provide some insight into the individual contributions of each of the technologies that the ADEPT concept comprises, and also to demonstrate their effectiveness under the new WLTC drive cycle, the results are presented in the form of the CO2 ‘walk’ shown above/ left. Starting from the baseline vehicle, the addition of regenerative braking provides a full 2.4 percent reduction in CO2 by supplying the full requirement for the vehicle’s 12-volt systems. The torque assist and engine down-speeding provide respectively a further 2.5 and 1.4 percent saving, with just 0.3 percent arising from extended engine-off time – arguably less than might be expected in real-world urban driving. In total this provides a measured 6.6 percent CO2 reduction over the WLTC cycle. Beyond this, simulation of the e-water pump and associated micro-circuit improvements gives computed further savings of 0.7 and 0.5 percent respectively, while the University of Nottingham’s study of advanced lubrication systems projected a further one percent CO2 saving.

In total the ADEPT technology demonstrator vehicle has been shown to deliver a CO2 reduction of 6.6 percent under the new WLTC drive cycle, which is equivalent to 11 percent under the old
NEDC drive cycle. In addition, if the electric water pump and advanced lubrication innovations were also to be implemented, the fuel savings are projected to rise to 8.8 percent (WLTC) and 14-15 percent (NEDC) respectively. Beyond this, however, in real-world driving the potential, and in particular for the extended engine-off functionality in urban or city-based driving, could also be considerable.

**Cost advantages confirmed**
Production implementation costs are extremely encouraging, too. According to an analysis conducted independently by Ricardo of the potential cost of production of an ADEPT concept such as that demonstrated, the system would represent an incremental cost of in the region of €60 per gram/km of CO2 reduction. This is a result that makes the ADEPT powertrain architecture very competitive with other fuel economy solutions such as full hybridization, where costs of implementation can be significantly higher.

**Applicability to gasoline and alternative fuelled powertrains**
While the focus of ADEPT was the application of intelligent electrification to an already very fuel-efficient diesel, the basic architecture could be applied very successfully – albeit with application-specific fine-tuning – to a gasoline or alternative-fuel powertrain. In many respects, the advantages with a gasoline application may be even greater. Rather than being obliged to switch off the TIGERS exhaust energy recovery system when required to preserve the operation of downstream diesel NOx and PM aftertreatment, on a gasoline vehicle the TIGERS unit might be positioned downstream of the catalyst and thus be usable across a much greater extent of the duty cycle.

Similarly, the torque-boosting capability of the B-ISG could provide low-speed launch assistance that would enable a far greater level of aggressive engine downsizing than might otherwise be possible. For customers, too, perceptions are likely to be enhanced by the potential for improved acceleration and NVH through engine downsizing and down-speeding, through stop-start, and in more extreme implementations, through silent pure-electric take-off.

**An expanding market for intelligent electrification**
The potential of 48-volt intelligent electrification to significantly expand the market for mild hybridization is clear. “The ADEPT vehicle is a research demonstrator that includes just some of the 48V technologies that could be deployed, and applies them in conjunction with an already highly optimized diesel,” explains Milton. “It is possible that you will see automakers already developing products that include some of the concepts demonstrated in ADEPT. In this project we were focusing on delivering the lowest possible CO2 emissions without compromising the driveability of the baseline vehicle. But intelligent low voltage electrification is a flexible toolbox for the automaker to calibrate the vehicle for economy or performance depending on the application. I believe that we should expect to see many more examples of 48V technology on the market within the next two to three years.”

Beyond this, as he predicted in the Viewpoint column in the last issue of RQ, Ricardo hybrid & electronic systems product group head Steve Doyle believes the widespread attractiveness and low cost of this form of electrification could be considerable. In his article, Doyle argued that this approach may well contribute more to overall CO2 emissions reduction in the next five to 15 years than all plug-in vehicles combined.

This does not imply a reduction in the market demand for full hybrids, plug-in hybrids or battery electric vehicles. There remain compelling environmental and operational benefits to all of these technologies for different applications, market segments and consumers. But for the high-volume mid-market segments where the costs of hybridization might otherwise be prohibitive, 48-volt intelligent electrification could just prove to be the perfectly positioned technology that allows automakers to come that crucial step closer towards their future European fleet average CO2 and US Federal fuel economy targets.

“I believe that we should expect to see many more examples of 48V technology on the market within the next two to three years”
Gareth Milton, Ricardo chief engineer
With 80 percent of the world light vehicle market using gasoline as a fuel, improvements in this technology stand to deliver the biggest global reductions in emissions – especially if those enhancements are low in cost and easy to implement in production vehicles.

Ricardo has a strong track record in delivering engineering advances that bring step changes in efficiency and low emissions. Now it is the turn of the Magma concept, which distils the thinking of many previous projects and goes a vital step further in offering a sizeable jump in economy.

Magma: the Ricardo approach to efficiency

As always, the Ricardo approach is to achieve potential maximum benefit across as wide a market as possible and as quickly as possible. This means employing – or extending – known technologies and using existing components wherever possible.

That is why the basic architecture of Magma is that of the familiar four-stroke gasoline engine, complete with four valves per cylinder and the now-obligatory boosting system. The secret comes in how these commonplace components are exploited in order to extract the absolute maximum from each drop of fuel.

By employing an extreme version of the Miller Cycle [see panel] as opposed to the baseline Otto Cycle, the Magma engine is able to achieve higher thermodynamic efficiency through increased knock resistance and an extended power stroke. This helps it draw out every last ounce of energy from the expanding gases. Pumping losses on the induction stroke are reduced, too, particularly at unboosted conditions, which we reduce to a significant improvement in fuel economy over a broad range of operating conditions.

Trevor Downes, chief engineer, engines, at Ricardo Innovations, has been one of the leading lights behind the Magma project. “The good thing about this technology,” he says, “is that we are not swapping any components out for something that is not yet production ready (TRL9) in its own right. There is no additional component which isn’t proven in production already.”

Magma: the essential ingredients

In keeping with its Miller Cycle operating principle, the Magma engine closes its inlet valve much earlier than in normal engines. Under most conditions the valve is closed at least 30 degrees before bottom dead centre (BDC): the gases drawn in are expanded – and thus cooled – as the piston descends, before being re-compressed as the piston rises again. In comparison with conventional engines, the compressed gases are...
lower in temperature as the spark plug fires, helping reduce dangerous knocking and potentially allowing more advanced ignition timing for better efficiency.

This advantage is compounded by the fact that the expansion ratio enjoyed by the burning gases on the exhaust stroke is much higher than the effective compression ratio faced by the trapped pre-combustion gases on their compression stroke. The gases can expand for longer, giving extra power to the crankshaft and extracting more energy from the fuel that has combusted. There is also less work expended during the pre-combustion compression stroke.

Conventional engines are limited to compression – and, by implication, expansion – ratios of around 10:1. Magma’s radical valve timing, with its early inlet valve closure, allows the geometric compression ratio to be pushed up to 13:1 but keeps the effective compression ratio to around 9.5:1. All this benefits fundamental thermodynamic efficiency, the core precondition for true fuel economy.

High-pressure boosting

A major challenge with Miller Cycle engines is that the early closure of the inlet valves gives a much shorter time window for the charge to enter the cylinder. It follows that a boosted inlet system is essential for effective cylinder filling. Magma goes a step further by employing not only a supercharger and a turbocharger but also two stages of intercooling to ensure the charge air is as cold and dense as possible as it enters the cylinder.

“The temperature rise through the compression event is a power relationship based on the compression ratio,” explains Downes. “The key thing about the Magma configuration is that it compounds the pressure ratios across both boosting devices all the way across the full-load speed range and in the steady state, allowing for effective inter-stage cooling.”

This cooling is doubly important as Magma runs on higher boost pressures than have been the norm, as Ricardo global technical expert for gasoline combustion Richard Osborne reveals: “We get up to about five bar absolute, which is quite significant compared with the base engine.”

A second strategy for high loads

The principal drawbacks of high boost levels are the energy absorbed by the supercharger and the high underbonnet cooling requirement imposed by the two stages of external compression. These issues can be especially significant at higher loads and high power.

Both are addressed by a possible extension to the Magma engine’s operating strategy, which closes the inlet valve late (LIVC), rather than early under certain conditions. The effect is to reduce the boosting demand placed on the supercharger, thus reducing the intercooling requirement, while within the engine the incoming charge is partially re-expelled past the late-closing inlet valve, again helping to reduce pumping losses.

Downes and Osborne are reluctant to divulge too many strategic details at this sensitive stage, but from published papers it appears that the LIVC option would be deployed at certain points in the part-load phase of engine operation.

The next steps

Rapid progress is being made towards confirming the absolute level of benefit from the Magma technology. Early results from the test cells point towards a significant reduction in specific fuel consumption compared with the baseline engine. Given that this is a concept specifically designed with an uncompromising focus on minimum fuel consumption, this represents quite an achievement.

The Magma engine represents a more extreme application of Miller Cycle thinking than designs already on the market such as the Audi EA888 and Nissan Micra, and the difference shows in the BMEP efficiency figures achieved. Whereas Audi and Volkswagen are operating engines at around 20 bar BMEP and Nissan is down at 14 or 15, Magma is targeting 24 or even 25 – a sizeable gain in efficiency whilst still using off-the-shelf componentry.

The project continues forward, and full validation needs to be completed before definitive data on this potentially transformative project can be released. But the early signs are highly promising and in an upcoming issue of RQ we will return to Magma in greater technical detail as soon as the results come through.

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The Miller Cycle

Working in the 1950s, engineer Ralph Miller developed the idea of improving the thermodynamic efficiency of a gasoline engine by reducing the effective compression ratio while retaining the full expansion ratio.

Miller made many suggestions as to how this could be achieved, but at today’s levels of engine technology a Miller Cycle engine is most clearly defined as one which employs managed valve events to obtain a difference between compression and expansion ratios.

This compression-expansion ratio difference is the key to the greater thermodynamic efficiency of the Miller cycle and its related Atkinson counterpart, and is used to good effect in highly economical hybrids such as the Toyota Prius.
Ricardo is working with UK-based Recycling Technologies to characterize the use of fuel created from residual mixed plastic waste that is not amenable to direct recycling and which would otherwise go to landfill. In this work, the application of this highly innovative fuel will be investigated as a low-sulphur substitute for fossil-based heavy fuel oil (HFO) and diesel in applications such as power generation and marine propulsion. Recycling Technologies has called the new feedstock Plaxx™.

Current approaches only allow a small fraction of plastic wastes to be processed for recycling; the remainder is directed to incineration or contributes to the ever-expanding problem of landfill. In addition to the loss of its material value, the carbon cost of processing this mixed waste is considerable, not least in terms of transportation, as many regions and states export their mixed plastic waste due to a lack of localised processing facilities. To help address this global issue, Recycling Technologies has developed a machine (RT7000) and is industrialising a process to convert residual plastic waste into Plaxx™.

This can be used as a petrochemical feedstock, a manufacturing commodity such as paraffin wax, or as a clean and more sustainable fuel substitute for fossil-based HFO, which also displaces imported oil.

Ricardo is currently working with Recycling Technologies to assess the relative performance of Plaxx™, HFO and diesel when used in an engine of the type and scale typical of power generation or marine propulsion applications. The Ricardo Atlas II research engine is being used for this work: this advanced test engine is capable of efficiently evaluating the performance of fuels in large, multi-cylinder engine designs ranging from 150-200 mm bore and representing engines in the class 0.5 to five MW, in a single power cylinder. Working with the Atlas II can result in a reduction exceeding 90 percent of the test fuel consumed in a typical research or development project.

In the early stages of the Recycling Technologies project, a thorough review of the properties of Plaxx™ as a combustion engine fuel is being carried out in order that a comprehensive test plan can be developed. Back-to-back testing of Plaxx™ against diesel and HFO will then be undertaken over a range of loads using the Atlas II engine. Combustion characterization will also be trialled, based on the measured in-cylinder pressure, power, specific fuel consumption and exhaust emissions. This will help to fully understand the behaviour of Plaxx™ in this type of engine and enable the further refinement of engine and fuel settings for maximum efficiency and low emissions.

Chinese collaborations

Ricardo continues to build upon its extensive collaborations in the Chinese market with two new agreements announced in the summer of 2016.

The first, a strategic co-operation agreement with SAIC-GM-Wuling Automobile Co. Ltd (SGMW), covers joint working on new product programmes, as well as training and technology transfer. Specific aspects of support that can be provided under the agreement include the adaptation of Ricardo’s product development process in order to enable the Chinese automaker to achieve global standards for its new vehicle products, and to reduce the required time to market.

The partners envisage that Ricardo will assist with the upgrade of SGMW’s existing engine and transmission product range through the joint development of new, more fuel-efficient products including hybrid powertrains. The agreement also covers support provided by Ricardo in the areas of powertrain integration, and the engineering of vehicle NVH performance in a manner that will most effectively appeal to customers by promoting SGMW’s brand character.

The second agreement is with one of China’s largest diesel engine makers, Anhui Quanchai Engine Co Ltd (“Quanchai”), to support the development of a new-generation common rail diesel engine platform for commercial applications. Under the terms of this agreement, Ricardo will support Quanchai – which is based in Quanjiao, Anhui province – in the design and development and calibration of a new diesel engine family, with sizes ranging from 2.5 to 3 litres and to be deployed in both on- and off-highway applications.
UKAS accreditation unlocks key new rail opportunities

Ricardo's Certification business has achieved formal accreditation by the United Kingdom Accreditation Service (UKAS) to provide independent assurance services for the international rail sector.

This development means that Ricardo Certification, which operates as a separate and entirely independent business within the Ricardo group, can perform ‘Notified Body’, 'Designated Body' and 'Assessment Body' roles on any rail project that is required to comply with relevant international and national technical rules. The accreditation also covers Railway Product Certification services.

The accreditation follows the successful completion of a rigorous 12-month global assessment process by UKAS and other European accreditation bodies, and was marked by the formal presentation ceremony at UKAS head offices in Staines-upon-Thames on 19 July.

The achievement of this accreditation means that Ricardo Certification has become the first independent assurance provider in the rail market to offer a UKAS-accredited independent Safety Assessment service. All its processes and structures were assessed against BS EN ISO/IEC 17020 Type A.

This accreditation was voluntarily requested by Ricardo Certification and underlines the company’s commitment to upholding the highest levels of competence, independence and consistency in its activities.

Ricardo and E4tech collaborate on "urgently needed" UK automotive strategy report

The UK automotive industry needs to define its post-Brexit strategy to make the best of low-carbon propulsion technologies – and the recent publication of a report for the Automotive Council outlining the key opportunities available to the UK provides a clear direction. The report, “Low Carbon Automotive Propulsion Technologies: The UK’s capability to capitalise upon future technology-led research-to-manufacture supply chain opportunities”, was published by the Advanced Propulsion Centre UK. It represents the culmination of six months of research carried out in a collaboration with Ricardo and E4tech.

The drive for further significant emissions reductions, as well as the trend towards the increasing electrification of vehicle powertrains, is already disrupting incumbent supply chains. This is providing opportunities for those automakers and suppliers embracing the challenge of technological change, who can benefit from international first-mover advantage. The report identifies a range of strategic opportunities that align with strong capabilities and latent potential within the UK automotive sector. These provide the potential for the UK to build a strong future supply chain position – given suitable investment in key areas. The identified UK capabilities, needs and opportunities are organised into five technology themes: engines; transmissions, driveline and kinetic energy recovery systems; traction electric machines and power electronics; traction batteries and fuel cells; and lightweighting technologies.

Ricardo achieves FTSE4Good Index status

Ricardo has been included in the FTSE4Good Index – the pioneering global responsible investment index, designed to identify companies that demonstrate strong environmental, social and governance (ESG) practices. The globally recognised FTSE4Good Index Series has been running for 15 years and is a benchmark for companies meeting global corporate responsibility standards. Transparent management and the clearly-defined ESG criteria – which Ricardo demonstrably meets through its inclusion – have made the index a valuable tool for investors in assessing responsible investment products, and especially as a means of identifying environmentally and socially responsible companies.

"Ricardo’s inclusion in the FTSE4Good Index is a real achievement,” commented Ricardo CEO Dave Shemmings. "It bears testament to the strides we have taken as a global concern in developing and applying the very highest standards in environmental, social and governance practices.”
Ricardo engineers amongst Autocar’s ‘100 most influential British women’

Ricardo engineers Angela Johnson and Yvonne Paige-Stimson are featured in Autocar’s list of the ‘100 most influential British women in the car industry’. This list is part of an initiative led by Autocar magazine – the UK’s oldest and most respected weekly motoring title – to encourage more women into the automotive industry, and to address the challenges they face both in entering and progressing within it. The initiative is backed by the Society of Motor Manufacturers and Traders (SMMT), Direct Line Group, Ford and Jaguar Land Rover, with additional support from Gaia Innovation. Autocar unveiled its ‘top 100’ list at an event hosted at the London headquarters of the Society of Motor Manufacturers & Traders (SMMT) on 8 July.

The Ricardo engineers included on the list – Angela Johnson, chief engineer, advanced technology development, and Yvonne Paige-Stimson, senior programme manager – both hold important positions, respectively in the development, dissemination and application of new automotive technologies and in the delivery of major new vehicle and powertrain programmes.

“Ricardo is extremely pleased that two of our top women engineers have been recognized on the inaugural Autocar list of the ‘100 most influential British women in the car industry,’” commented Ricardo head of organisational development Oonagh McPhillips. “Ricardo believes passionately in encouraging the very best of scientific and engineering talent regardless of gender or ethnicity. At the same time, we recognize that women are under-represented at all levels within the industry. We therefore applaud the Autocar Great British Women in the Car Industry initiative, while also congratulating Angela and Yvonne on this very well-deserved recognition.”

First-ever fuel economy survey of US auto suppliers

Major automotive suppliers see national US fuel economy standards as important for long-term planning and investment and don’t want to see these rules altered by policymakers. These are among the findings of a first-of-its-kind industry survey commissioned by CALSTART from Ricardo Energy & Environment.

“This survey underscores the degree to which deploying new fuel-efficient technology is already baked into companies’ businesses plans,” commented John Boesel, president and CEO of CALSTART. “Companies are clearly ready to innovate and see the upside in the standards.”

CALSTART commissioned Ricardo Energy & Environment to conduct the survey over the summer of 2016. The firm polled and interviewed 23 suppliers, almost all of them global Tier 1 suppliers that sell parts directly to automakers.

According to the survey:
• 70 percent of suppliers said policymakers should not adjust the programme’s goals.
• 65 percent agreed with the decision to set new miles-per-gallon standards for 2025, with 30 percent saying they strongly agreed with the decision.
• Among those who agreed, all but one named regulatory certainty as critical for the industry and half said the standards spark innovation.
• 59 percent said that fuel-economy standards help spur job growth.
• Suppliers identified a wide range of conventional and electric technology that could be used to meet the standards.
• Three quarters agreed that setting targets beyond 2025 is also important for long-term planning.

When presented with a list of technologies that might be used to meet fuel-efficiency standards, suppliers picked turbocharging and engine downsizing, along with higher multiple-ratio automatic transmissions, as the most critical. Hybrid technology was also viewed as important, along with variable valve timing, gasoline direct injection, and weight reduction. Suppliers were split on whether or not meeting the standards would ultimately require more electric vehicles than are already slated to hit the roads under state zero-emissions vehicle requirements.

“US fuel economy standards spark innovation.”

The full survey report is available for download from the CALSTART website: www.calstart.org.

Ricardo’s ‘Smart Factory’ shortlisted for award

The Ricardo high-performance engine assembly facility has been shortlisted in the prestigious MX Awards 2016, hosted by The Manufacturer magazine in association with the Institution of Mechanical Engineers. This state-of-the-art engine assembly plant was nominated in the ‘Smart Factory’ category alongside facilities of CCP Gransden, Forterra Building Products Plc, Hayward Tyler Group Ltd, Lander Automotive Ltd and Siemens Plc.

The Ricardo engine assembly factory, at Shoreham, UK, has been a true success story for advanced design, engineering and innovative manufacturing. Originally opened in 2011, the facility was recently expanded, doubling its capacity and incorporating a range of new laboratories and workshops capable of supporting prototype engine builds and advanced technology. The expanded facility also includes a second dynamometer, capable of simulating real-world load conditions and testing engines across the full range of power outputs.

The MX Awards Ceremony and Gala Dinner will be held on Wednesday 2nd November at The Vox, Birmingham.
Significantly predating new European legislation, Ricardo’s clients have benefited from our real-driving emissions (RDE) testing capabilities for more than three years.

Our Portable Emissions Measurement System (PEMS) represents tested and refined technology in the hands of experienced technicians and analytics experts.

**Key features**

- Results robustness-testing in state-of-the-art vehicle emissions research centre
- UK-Vehicle-Certification-Agency-witnessed testing of key emissions for light-duty diesel and gasoline vehicles on validated RDE test route
- Four matched PEMS systems available, featuring heated-flame ionization detector for total hydrocarbon analysis and fully compliant particle number measurement
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Ricardo’s advantage is clear

The technology behind a winning Formula 1 partnership

Formula 1 is unrivalled in every aspect of high-performance motorsport – the speed of its cars, the demands of its tracks, the quality of its drivers and the secrecy surrounding its customers and technologies.

Ricardo can’t tell you about the specifics of its 20 year history supplying the very best teams in Formula 1 with the most successful transmission technologies.

We definitely can’t tell you about the components and transmissions we supply, or the teams we supply them to, or the numerous drivers and teams we’ve supported to victory. We can’t tell you about the breakthrough materials and advanced machining equipment we use to deliver products for these extreme-sport applications, either. We can’t even tell you who, within our unrivalled team of UK engineers, works tirelessly to ensure every design is optimized to deliver unmatched performance, over the shortest lead times in the market.

What we can tell you, however, is that our capabilities will deliver you a clear advantage across key components in the covert world of Formula 1.

Find out how our experts can help you.

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