



AUTOCAR

ELECTRIC NATION



The future of motoring, pioneered in the UK

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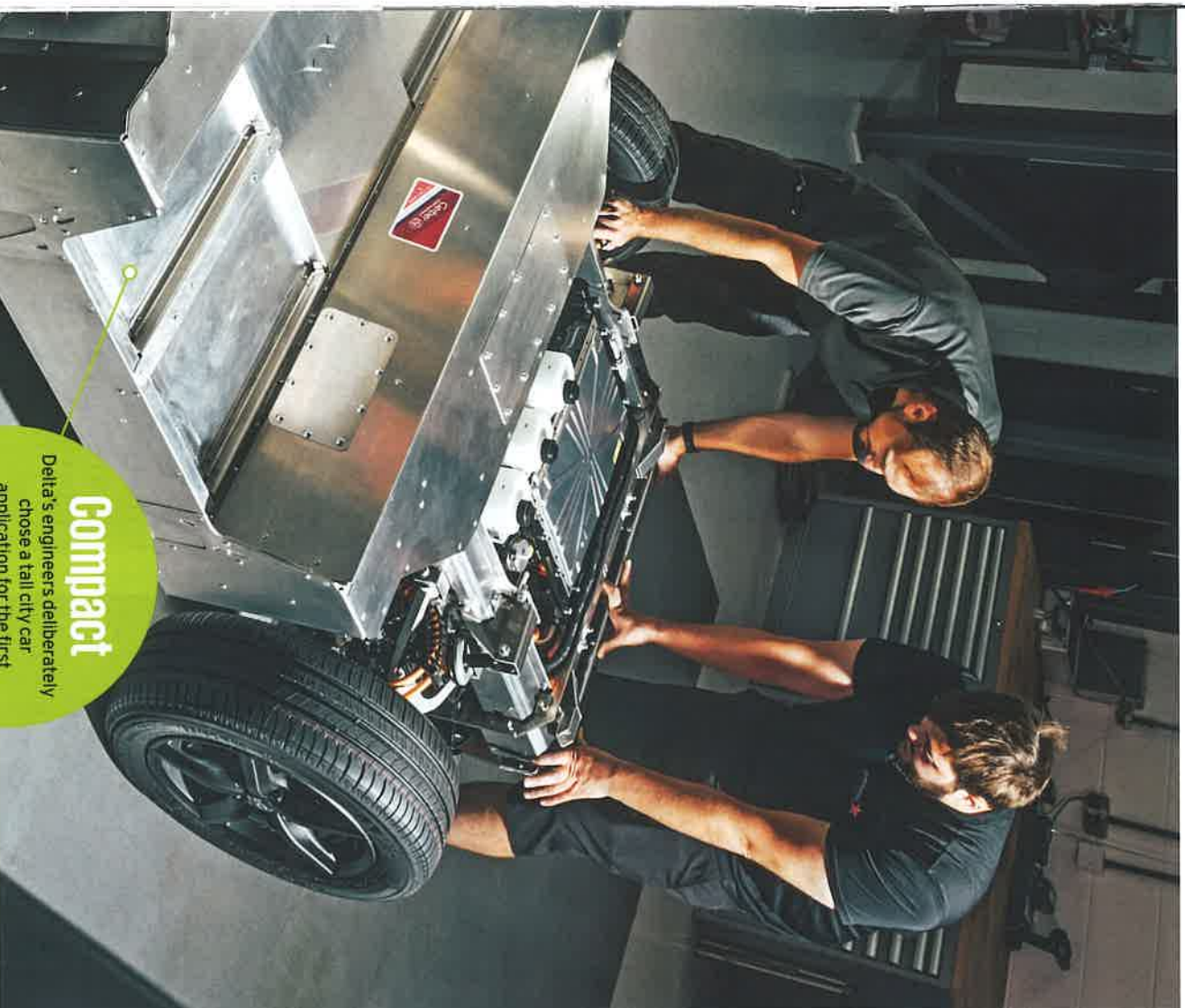




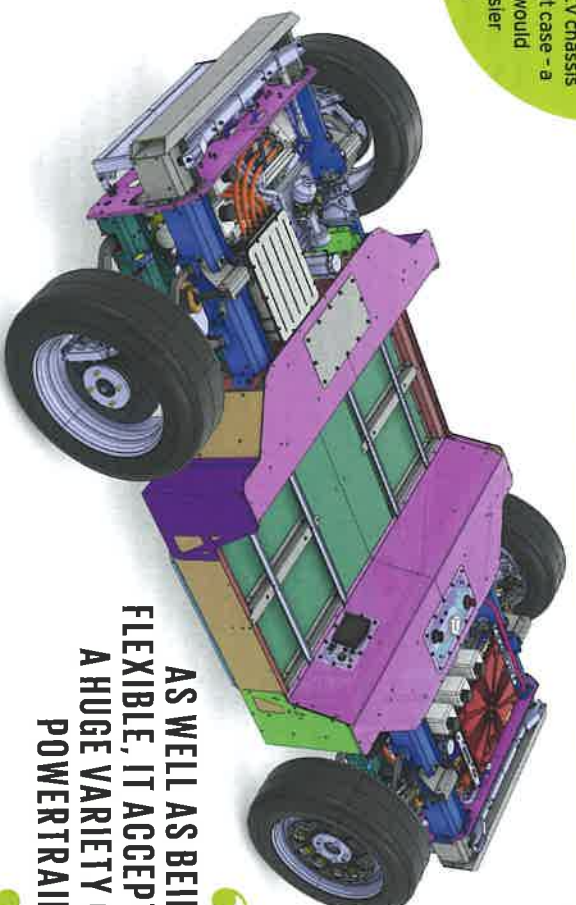
THE TEST MULE REINVENTED

A highly adaptable new chassis has been fast-tracked into existence to help explore our electric and autonomous future. By Steve Cropley

PHOTOGRAPHY MAX EDLESTON



Compact
Delta's engineers deliberately chose a tall city car application for the first version of the new EV chassis as the most difficult case – a longer version would have been easier to create.



AS WELL AS BEING FLEXIBLE, IT ACCEPTS A HUGE VARIETY OF POWERTRAINS

In the beginning – which is to say in September last year – Delta Motorsport's highly flexible new S2 autonomous and electric car chassis, one of the star exhibits of this year's LCV Show, was only going to appear as a notional prototype, born in a computer and destined to stay there forever.

Under the original plans, this all-aluminium, skateboard-style EV chassis design – which now sits proudly in three dimensions at the centre of a specially designed stand – wasn't even due to show its screen-based face until this time next year.

Then everything changed. In a remarkable last-minute turnaround, Delta's two founders – engineering director Nick Carpenter and operations director Simon Dowson – decided their S2 project would be more timely and have a far bigger impact if shown this year as a live concept. As project leaders they hurriedly consulted partners in this Innovate UK-backed project – Titan (by-wire steering), Alcon (by-wire brakes), Warwick Manufacturing Group, Potenza Technology (digital safety know-how), Cranfield University (limit handling studies) – and, with everyone's enthusiastic approval, and working alongside GCE (structure design) and Tecosim (CAE specialists), they set to work at top speed.

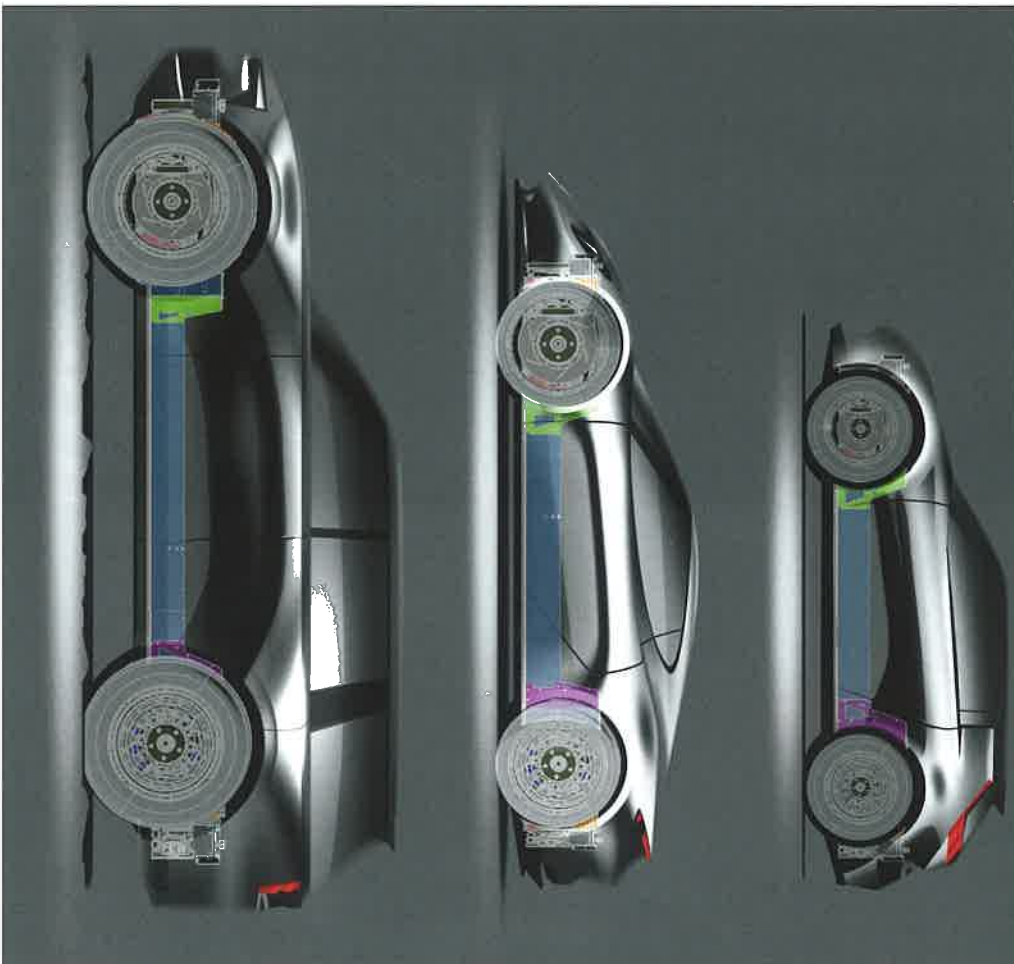
The chassis you see here was completed just days before the show opened. It was a true feat of execution, although Carpenter, Dowson and partners seem entirely unfazed by their achievement. It goes with the territory in their high-pressure world of technical creativity. "Being part of a small organisation with a limited budget is a really positive thing," Carpenter explains. "The bigger you are, the more prone you are to paralysis by analysis. There's huge pressure to find exact answers when there may not be any. In a small company, you just don't have time."

What's the reason for the S2 project's sudden change of pace and shape? Carpenter has a more eloquent explanation, but it boils down to the fact that there are currently platoons of promising researchers in the nooks and crannies of vehicle-focused autonomy and electrification, all with theories or processes that urgently need to take next steps. Trouble is, appropriately engineered test vehicles are expensive and in extremely short supply. S2 can do much to fill the void.

At the same time, Delta and its partners see →

WHERE DELTA'S PLATFORM COULD LEAD

The highly flexible new S2 platform is so easily configurable in different dimensions, and with different powertrains, that it could eventually be used for vehicles such as the three seen here, drawn by Autocar's resident car designer, Ben Summerell-Youde. Production cars aren't the priority, though. Delta's first clients will use the platform to further their own autonomy and electrification ideas.



← a golden opportunity to prove, progress and then earn from their own technical expertise – and their well-proven car-building capabilities – while greatly aiding others in parallel fields of automotive technology: sensor designers, for example, or creators of vehicle infrastructure and even start-ups working on new forms of ‘mobility as a service’.

“S2 is a flexible chassis system with a much broader capability than the production-based machines our industry usually has to make do with,” explains Carpenter. “When you ask colleagues with a promising project what they’re going to do for a test vehicle, they’ll often tell you they’ve bought a Ford Mondeo or a Chrysler Pacifica and are going to automate it to make a test mule. It isn’t the car they really want. It’s just what they can get.”

By contrast, S2 can be configured comparatively quickly and easily to handle a huge variety of tests and customer activities, says Carpenter, and practically every use furthers the causes of Titan, Alcon and the other partners. “Let’s say you’ve

developed a promising piece of process but it’ll cost £5 million and two years to convert a mule to take it further. You’re never going to do it. But if the cost is £200,000 and six months, you’ll probably give it a go.”

On the face of it, skateboard-style chassis aren’t particularly new. Plenty of players in the EV business have already employed the concept of locating motor, ancillaries and power electronics at the extremities of an electric car and connecting them with a low, rigid platform chassis that carries the traction battery-set below the cabin floor. It’s the logical way to do things.

What makes the skateboard revolutionary are the far greater levels of designed-in flexibility than those of previous offerings, to the extent that Delta is describing it to clients as ‘skateboard 2.0’, justifying the S2 name and deliberately built to take account of lessons thrown up by predecessors. It uses a self-supporting structure of fabricated aluminium, designed by GCE and Tecosim, and depends on compact box sections for its rigidity, with the double-wishbone independent

suspension systems carried on the chassis longitudinally at both ends.

As well as being almost infinitely flexible in wheelbase, track, overall length, overall width, bulkhead dimensions, crossmember positioning, seating positions and ride height, it can accept a huge variety of powertrains, both hybrid and pure EV. In theory, it could also handle hydrogen fuel cell applications, and even a petrol-only version should anyone ever ask. In fact, it’s so flexible that Carpenter is reluctant to say it has a back or a front, because components can be located in such a wide variety of locations. In Delta’s promo video (catch it on its website), there’s even a factory-based loader version with a single-seat operator’s cabin located outside the wheelbase.

In LCV Show form S2 is a pure EV, without a body and using the ultra-short wheelbase suitable for city-based pod use, the kind of thing you’d earmark for a car-sharing business. The Delta partners deliberately chose a short, high version to test their design in the worst case: high centre of gravity, least battery and ancillary space, poorest

Carpenter: “We decided we were as well placed as anyone to choose a destination for the project”



“S2 CAN BE CONFIGURED QUICKLY AND EASILY TO HANDLE A HUGE VARIETY OF TESTS AND CUSTOMER ACTIVITIES”

DELTA: MOTORSPORT AND MICRO-TURBINES

Simon Dowson and Nick Carpenter, the principals of Delta Motorsport, met as young engineers at Reynard, the race car manufacturer, in the mid-1990s and have been mostly working together ever since. They set up Delta in 2005 in a family-owned barn with Carpenter as technical director and Dowson as delivery specialist and supply chain manager, moving to Silverstone soon after.

They rapidly won a high reputation from working on a wide variety of motorsport-related projects (designing, testing, building and shipping 15 single-seater race cars in five months for GP Masters was an early one). They later played a big part in the planning and design of Jaguar's stillborn but highly praised C-X75 hybrid supercar. More recently, Delta has gravitated towards electrification and range-extender projects, seeing these as the future. Their five-vehicle E4 experimental car fleet won high

praise, and they have since produced an amazingly compact micro-turbine range extender.

Carpenter is a huge enthusiast of range-extender theory as the most practical, logical step we can currently make to shift decisively towards a low-CO₂ future. "Look at the money we currently spend on lightweighting," he argues vehemently. "The easiest way of lowering the weight of an EV is to use a smaller battery. That's what a range extender does and - as my own experience with a range extended BMW i3 shows - you still do over 95% of your driving on electric power."

"If our objective is to increase the total number of electric miles driven in Britain - a goal that's too little recognised - the priority isn't to have a few more Jaguar I-Paces and Tesla Model Ss on our roads. What we need are many more cars driven by small batteries."



The pair met while working at race car manufacturer Reynard

stability, requirement for a big passenger space. Larger versions can be lower and more spacious.

The show S2 is also configured for fore and aft seating for four, has no steering wheel and is powered by a single 80kW motor, driving the front wheels through a single-speed reduction gearbox, plus a pair of hub-mounted motors to power the rear wheels. The set-up shows how easily torque can be deployed to the wheels in varying amounts to aid traction and stability. It could just as easily have its motor locations reversed, to suit a client's requirements, or be equipped with a steering wheel, or have a range-extender powertrain.

(Among other accomplishments, Delta has already won awards for a unique turbine-based power generator design, ideal for a range-extender application.) "In simple terms," Carpenter explains, "the vehicle has three main parts: an end, a middle and another end. We've designed it with load paths running through the chassis sills to front and rear crash structures."

Despite the rush, Delta and its partners have especially enjoyed bringing the S2 concept towards

reality in just a few months. "It feels right," says Carpenter. "We've done a wide variety of work since we started the company in 2005, but we've moved more and more towards electrification and hybridisation. Last year we started thinking more directly about how to commercialise our knowledge, about generating revenue and, essentially, earning money when the lights are off, which is what Innovate UK is supporting us to do. That employs people, helps other inventors and brings wide benefits to UK plc, which we're passionate about."

"Without the right vehicle as a basis, many people involved in electrification and autonomy research can't ever be sure how their theories will pan out," Carpenter explains. "In the end, we decided it was best to just get on and make something, essentially to see what happened. There isn't a vast bank of know-how out there; you can't draw parallels with OEMs that have spent the past century building next iterations of existing models. We decided we were as well placed as anyone to choose a destination for the

project and a path to get there. We've already found it has taken us a long way, fast."

After S2's introduction at the LCV Show, Delta and its partners will get serious about development. Full-on dynamic tests will be under way before the end of this year. Potential clients are already showing interest in vehicles in "ones, twos, fives and 10s". Delta has also had a couple of approaches from organisations wanting to scale up to much bigger volumes. "We'll have to think carefully about that," says Carpenter, "because at those volumes flexibility is just about the last thing you need."

To the outside observer, the whole S2 project smacks of a pioneering spirit, of important work being done here and now whose significance will grow with the years. So I put a sentimental hack's question: do Dowson, Carpenter and Co feel a sense of destiny in what they're doing? Their surprise at the suggestion does them credit. "Well, not really," says Carpenter, after pausing to think. "You just see a series of problems that need to be solved. You know there has to be a way." ▀

BACK (AGAIN) TO THE FUTURE

A former glam rock record producer from Dorset has made his DeLorean into an EV. Colin Goodwin drives it

PHOTOGRAPHY LUC LACEY

An email arrived: 'Could you nip down to Dorset and check out some bloke who says he's an old rock and roller who's fitting an electric powertrain into an old car?'

Electric cars are here to stay and I'm happy to review them, but retrofitting classics with electric powertrains seems pointless. Yes, you could drive an electric E-Type in central London, but why would you want to drive in London anyway? But down in Poole, things are looking up. For starters, Phil Wainman really is rock and roll. He was a

session drummer in the 1960s and then went on to write and produce for glam rock bands such as Sweet, Mud and the Bay City Rollers.

Second, the car that's being electrified is a DeLorean. This seems entirely appropriate to me. A car that is best known today for its starring role in *Back to the Future* should probably have had an alternative powerplant anyway. Also, the car could only be improved by chucking out its hefty and ineffective original PRV V6 engine. But before we explore, and indeed drive, this electrified DeLorean, a question needs to be asked first: why?

"I've always been interested in electric cars," says Wainman. "In the early '80s, I almost imported an electric car kit based on a MG TD that was built in Minnesota. I joined the Electric Car Association in the 1990s. I'm member number 77. "Converting a DeLorean to electric drive just seemed like the perfect project. I bought this one for \$19,000 in the US and shipped it over. It was painted red and in a bit of a state."

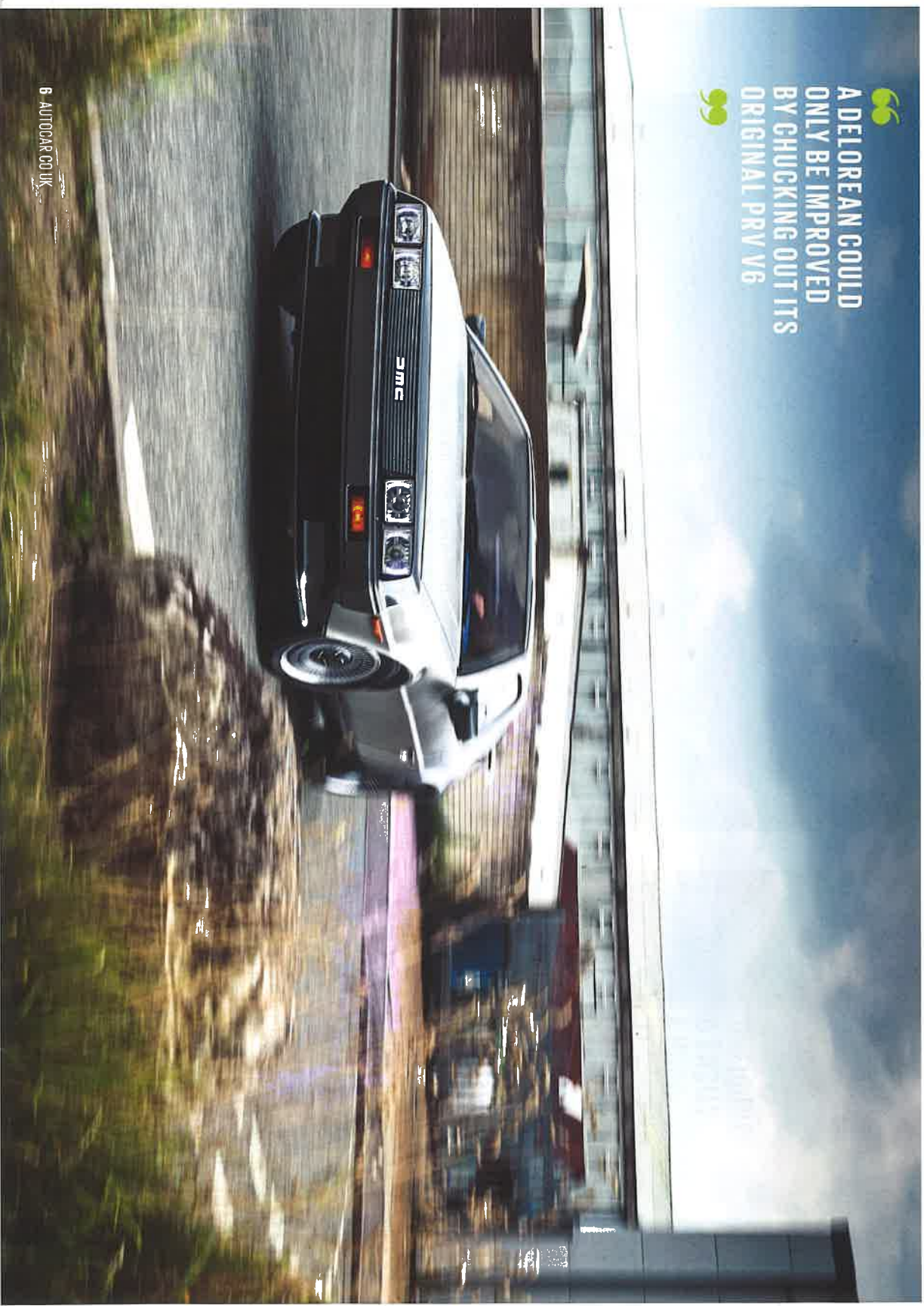
We're at the premises of Castleman Auto Repairs, whose managing director Clint Townsend has been responsible for the creation of the DeLorean EV. "At first, Clint wasn't too keen," says Wainman. "I persuaded him by pointing out that it was his future and he ought to learn about the technology."

Townsend is now a bit of a nerd on electric powertrains. He's also one heck of a good mechanic/fabricator. Not only has he transformed this once-knackered DeLorean into a virtually concours example, but he has also carried out this conversion to a stunning standard.

"The electrical components, including motor, battery and control systems, are all from Tesla," explains Townsend, "provided by a company in Bristol called Zero EV."

If you're not well up on DeLoreans, I'll just remind you that the car was engineered by Lotus and, like an Esprit, features a steel backbone chassis with a glassfibre monocoque attached to it. The DeLorean's famous stainless steel outer panels are bolted to the glassfibre monocoque.

“A DELOREAN COULD ONLY BE IMPROVED BY CHUCKING OUT ITS ORIGINAL PRV V6”



What's impressive is how neatly all the Tesla components have fitted. "The electric motor itself is what Tesla refers to as the 'small drive unit', and this particular one came from a P70D. It's actually the front motor," says Townsend.

He had to fabricate new mounts and various brackets, but it looks like the motor unit was designed for this chassis. The driveshafts are perfectly parallel, for example. Wainman (who's very much involved in the project) and Townsend have split the Tesla's batteries and fitted a batch in the rear of the DeLorean and another in the front, although they haven't managed to fit the entire complement of batteries from the P70D and are missing a couple of cells.

"One of the big challenges has been the cooling for the motor, inverter and other components," says Townsend. "We've fitted a pair of radiators in the car's nose but getting the right amount of cooling flow has been a matter of trial and error. That's been the case on a lot of the car, in fact."

Another example is the wiring. Getting 21st-century electronics to have a dialogue with late '70s and early '80s analogue systems is a mighty challenge. Townsend says: "We've had to design our own CAN bus [controller area network] to enable everything to work. We've also built our own digital instrument panel, but we're still working on that because it keeps overheating."

Time for my first ever drive in a DeLorean. The car has been fitted with electric power steering from a Toyota Auris and, according to Townsend,

it's a huge improvement: "We haven't had a weighing session yet but the original car had an automatic gearbox which, with the 180kg PRV6, weighed a lot. I won't be surprised if the electric conversion is no heavier."

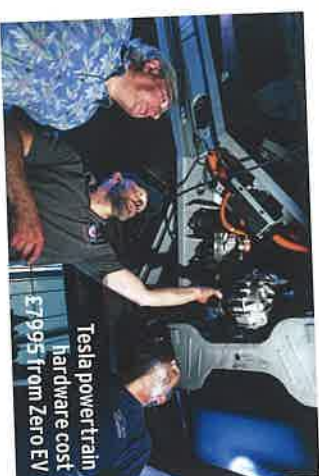
You activate the DeLorean by pressing a red start button, then by moving a lever to select D. The lever is a work of art, and was designed and built by Wainman. He says: "Some people think it's from a boat; others [including Goodwin] guess that it's from an aeroplane."

The DeLorean glides magically away from the kerb. No creaks or rattles. Part of the reason for the original car failing in the showroom was its feeble performance given the asking price. Townsend reckons the project is 80% there and that there's more performance to come with some software changes. This and the fact that Wainman has spent £200,000 of his own cash on the project prevent me from giving the DeLorean a more thorough foot full of, er, volts.

I'm very much looking forward to a promised proper go in the DeLorean EV when it's finished. Its energy comes from lithium ion; I'm not sure where 73-year-old Wainman gets his from. He's fantastic company, dynamic and hugely likeable.

The next project that he has lined up is electrifying an E-Type Jaguar that's sitting in pieces in Townsend's workshop. I spare him my views on electrified E-Types. You don't have a pop at a bloke who owns both a 1958 and 1965 Corvette and who wrote the Bay City Rollers' Bye Bye Baby. 

BOLT-ON BATTERY POWER



Tesla powertrain hardware cost £7995 from Zero EV

Bristol-based Zero EV was set up in March last year by young engineers Chris Hazell and Alex Dawood and specialises in supplying EV powertrains, hardware and software to those carrying out conversions. "We started because we were asked to build three electric stunt cars for a hotel in Macau. No one else wanted the job so we took it on. We've also built the first electric car for the world drifting championships." They'll sell you a complete Tesla small drive unit kit for £7995. More importantly, they'll provide helpful advice on how to incorporate it into a project.

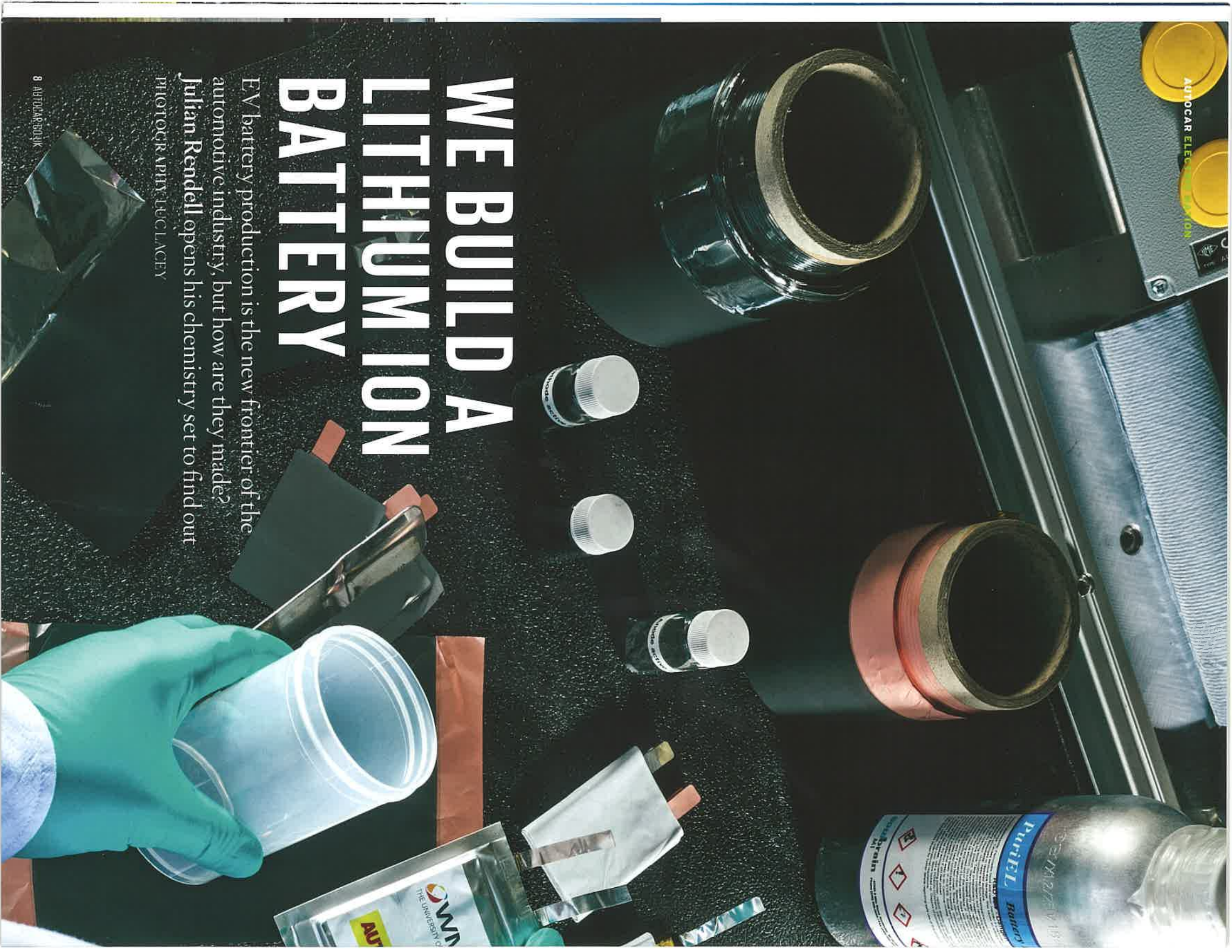
Thanks to Phil Wainman (phil.wainman@utopiaev.co.uk)

£6

Cost of a piece of nylon drain pipe which, along with machined nylon arms and a chrome arm, makes up the gear selector.

The conversion work is top notch and the car is now concurs standard





WE BUILD A LITHIUM ION BATTERY

EV battery production is the new frontier of the automotive industry, but how are they made?

Julian Rendell opens his chemistry set to find out

PHOTOGRAPHY: LUC LACEY



Opportunities like this one don't come around very often. Here, Autocar has the chance to build its own lithium ion electric car battery cell from scratch, to see the inner workings of a device that usually stays closed because its contents are flammable and to hear an expert 'how it works' explanation from the UK's foremost professor of EV batteries.

There are only a couple of places in the UK where batteries are built from raw materials and one of them is the prototype manufacturing plant at Warwick Manufacturing Group (WMG), a department of the illustrious University of Warwick. Our mentor for the day is Professor David Greenwood, a brilliant communicator of the intricate flows of electrons and lithium ions inside these anonymous-looking grey packages. So free your mind of the notion of crankshafts, valves and bearings and introduce to it instead the anodes, cathodes, separators and LiPF₆ electrolytes of our electrically driven future.

Our task is to make a small 3.5V A7-sized pouch cell – about the size of a credit card at 50mm by 70mm – using machinery on WMG's prototype production line. In a production car, like the Nissan Leaf or Jaguar I-Pace, dozens of these pouches are built up into modules before the modules are wired together to make the battery.

The internal parts and the principles of design and build are the same as for bigger pouch cells, like those fitted to the Leaf, but also the prismatic designs and cylinders used by Tesla. Tesla's 18650 cells may be a very different shape but they contain the same basic componentry, just rolled up inside a tube.

There are four main processes – make the anode, make the cathode, pack them into a pouch and fill with the liquid electrolyte that contains the vital lithium – but in total there are 11 manufacturing steps. Our session will take a couple of hours, but in a volume production plant, like Tesla's Gigafactory, 20 cells a second roll off the production lines. Time to don the protective green rubber gloves, white lab coat and go mix chemicals.

MAKING THE AUTOCAR BATTERY

1 MATERIAL WEIGHING FOR ANODE

The electrochemically active ingredient in the anode is graphite – it's the component that actually stores lithium ions. It comes as a fine powder, each particle of which is just 10 microns across – one fifth of a human hair. Here, the graphite is mixed in a water-based solvent with carbon black and a latex-based binder to make a slurry.

The carbon makes the graphite electrically conductive and the binder is an adhesive so it will stick to a copper backing plate in the next stage. A very similar process is used to make the cathode, but the very fine nickel particles can only be handled while wearing pressurised breathing masks, so aren't appropriate for our visit. →



It's a bit like making bread, but with more risk of an explosion



Anode slurry is applied to a length of copper sheet

▼ 2 ANODE MIXING

This key step is carried out with equipment designed for the food industry to mix bread and chocolate. Production-quality anode material is mixed in volumes of hundreds of litres. It needs hours of mixing to ensure the powders, solvent and binder are uniformly distributed in the slurry.

▼ 3 ANODE COATING

The slurry is attached to an electrical conductor to allow the lithium ions to flow in/out of the graphite, so it is spread thinly over a copper sheet, about half the thickness of a sheet of paper. Copper is used for the anode and aluminium for the cathode because the conditions in the cell would otherwise mean the cathode dissolving and the cell being destroyed.

In a production factory, the coating and drying machine that makes the anode can be up to 90 metres long. The material passes through it in just a minute to optimise the drying process that is critical to how efficiently the anode stores charge.

▼ 4 CALENDERING

This maximises the charge storage capacity of the graphite in the anode by gently crushing the coating to increase its density. The process originated as a finishing technique for textiles.

▼ 5 DRY ROOM

Lithium will react if exposed to moisture in the air and degrade the performance of the cell, so the final production processes are carried out in a dry room where relative humidity is just 0.5% – one tenth of the Atacama desert. Workers in here have to take frequent rehydration breaks.

▼ 6 DIE-CUTTING THE LAYERS

The ribbon of copper and its graphite coating are cut to the A7 shape to make individual layers. To achieve performance of 3.5V and 6Ah, our cell needs 15 layers – seven anodes and eight cathodes. Each cut is made by a precise die-cutter to ensure each sheet locates precisely between the separator/insulator and has no rough edges – otherwise the cell could short-circuit and possibly catch fire.

▼ 7 CELL ASSEMBLY

Each of the anode layers has to be interleaved with a separator and the cathode sheets. It's a fiddly process that's handled automatically by a Z-fold



Graphite-coated copper is precisely cut into shape

HOW DOES A LITHIUM ION CELL WORK?

Inside the cell are four main components – anode, cathode, separator and the lithium electrolyte – and each one has a specific job to do.

In its normal, uncharged state, the lithium atoms (supplied by the liquid electrolyte) are stored on the cathode. During charging, the voltage applied to the cell pushes the lithium atoms off the cathode for collection at the anode, at which point the atoms split up by losing an electron and the atom temporarily becomes a lithium ion.

The cunning bit is the separator. This porous polymer membrane between the anode and cathode only allows lithium ions to flow to the anode. As a result, electrons have to flow in the opposite direction, out of the cell and through the charger, ending up at the anode where they reform with the ions to recreate lithium atoms. When all the lithium atoms have collected on the anode, the cell is fully charged. The separator then prevents a backflow of the lithium atoms.



Connection tabs are ultrasonically welded in place

stacking machine. Our cell will end up with about one metre of separator between the 15 layers.

▼ 8 WELDING THE CURRENT COLLECTOR

Ultrasonic welding joins the layers of the anode together into a robust tab – the connection point through which electricity flows in/out of the cell.

▼ 9 PACKAGING THE CELL

The anode layers are housed inside an air-tight pouch made from aluminiumised polymer – a more



The pouch is sealed and must stay airtight for 15 years

robust version of the material used to package food such as coffee beans. In the cell, it has to remain airtight for 15 years; for coffee, it's just six months. The edges of the pouch are heat sealed but left oversized to allow room for a later process.

▼ 10 ADDING ELECTROLYTE

Just 2ml of liquid electrolyte containing lithium hexafluorophosphate (LiPF₆) is pumped into the cell and the pouch sealed in an ultra-dry vacuum to keep moisture away from the reactive and flammable lithium. With all the other parts needed to make the cell function, only 4% of our A7 cell's approximate 200g weight is actually lithium.

▼ 11 FORMATION AND AGEING

This is the Frankenstein moment, when the pouch becomes a functioning cell. A special rig repeatedly charges and discharges the cell while its behaviour is monitored for quality control. Initial reactions between the electrolyte and the anode create the solid electrolyte interface (SEI) – a protective layer – and in the process give off gas, which is why the pouch was left oversized earlier on. It will be purged and trimmed later. Amazingly, the cell takes days to form: typically the small cell in a Tesla might take three to four days, but some larger pouch cells can take an astonishing 28 days. Our smaller A7 cell will probably be one to two days in the making. 



Chemical process can take days before the cell is ready



Professor Greenwood (left) speaks fluently of electron flows

THE BEST OF THE REST...

The UK is a hotbed of behind-the-scenes innovation in future propulsion. Here are five more projects at the cutting edge of powertrain development

A STEP CLOSER TO ARIEL'S SUPER-EV



Hipercar will run in disguised mule form in a few months

Ariel's 1000bhp electric Hipercar, the super-performance four-wheel-drive concept unveiled at the 2017 LCV Show, is continuing to run flat out, with first signs of "something to see" likely to emerge early next year. Simon Saunders, boss and founder of Ariel, says styling is close to complete, along the lines already seen in sketches around 18 months ago. Details have been changed by CFD aerodynamic testing and practicalities such as the need to provide doors that open and shut.

The car, which has an electric motor to drive each wheel and whose batteries are replenished

by a revolutionary gas turbine range extender, has reached a Gen2 state, and some components, such as the powertrain, being dyno tested right now, are even further advanced. Disguised mules will be running in the next few months, says Saunders. The original partners in this Innovate-backed, collaborative project - Equipmake, Delta and Ariel - have been joined by several more, including industrial giants Johnson Matthey and GKN. For now, the project leaders are engaged in complex compliance work, but despite the lack of headlines, Saunders says things are progressing well.

START-UP TO MANUFACTURING SUCCESS



Equipmake, the Norfolk-based start-up that specialises in electric powertrains - and especially the unique, ultra-compact 'spoke' electric motor - is busy converting into a full-scale manufacturing business, says managing director Ian Foley. The workforce now numbers in excess of 40 and is

tipped to grow further, and a move to bigger premises is imminent - all enabled with the help of £3 million raised from investors.

Two big projects are under way: manufacturing motor inverters "in the low thousands" for supercar applications such as the Ariel Hipercar, and a five-year deal to produce complete electric powertrains - motors, inverters and battery packs - for a new bus project in Argentina, with the likelihood of the units being sold elsewhere for similar applications. Foley reckons his company is close to crossing "the great divide" between experimental operations and full-scale production and is generous in his praise for grant assistance from government-backed Innovate UK and the Advanced Propulsion Centre. "We're only doing what we're doing because of them," he says. "Their help has been invaluable."

SMALL IS BEAUTIFUL

Delivering "the most cost-effective, lightweight, compact and efficient electric powertrain on the market" is the tall order set for backers of the ACeDrive project, a partnership led by GKN Automotive, with Drive System Design and the University of Nottingham.

The £8 million project, backed by match-funding from the Advanced Propulsion Centre, is aiming its electric powertrain at the global mass market, along with an ability to be manufactured at plants around the world. The technology is expected to be production-ready by 2023.

ACeDrive - which stands for Advanced Cooling and Control of High Speed e-Drive - is described as a "groundbreaking concept in cooling and system integration, leading to a significant reduction in the number and size of components".

The system combines a downsized electric motor, a low-friction transmission and a high-frequency inverter within a single unit, enabling shared cooling and compact housing. This promises not only smaller size and reduced cost, but lower internal friction.

GKN says its aim is "to help the UK take the lead in electric powertrain design and manufacturing".

The target for reduction in both packaging size and cost of the powertrain, plus a 20% drop in weight and a 10% increase in efficiency compared with current equivalents.



THE PROJECT IS AIMING ITS ELECTRIC POWERTRAIN AT THE GLOBAL MASS MARKET

IT'S NOT ALL ABOUT THE BATTERIES



Ricardo's Magma xEV is targeting 15% CO₂ drop

RICARDO PREDICTS MORE THAN 70% OF CARS WILL STILL HAVE AN ICE IN 2030

There's life in the internal combustion engine (ICE) yet, says Ricardo Engineering, despite the worldwide push towards electrification. The Shoreham-based firm is finding new ways to breathe extra life into petrol power with a concept called Magma xEV, which is aimed at "achieving the next steps in engine efficiency for hybrid vehicles". Ricardo predicts more than 70% of cars will still have an ICE in 2030,

making the continued development of efficient ICE powertrains vital. Magma xEV has been specifically developed for "hybrid applications, optimised for high thermal efficiency with limited operating range" and promises improvements of more than 15% in CO₂ and economy compared with a "leading TGD engine". The concept is currently at the R&D stage, with production tipped for 2025.

Ricardo's Dr Richard Osborne explains Magma xEV uses a long piston stroke to enable a very high compression ratio, with a minimum surface area-to-volume ratio for the combustion system. Knock mitigation is provided by Miller cycle operation, with lean combustion and the option of water injection. The engine has low specific power and is cost-optimised with a fixed valve train and a single turbo.

TIN-TOPS EMBRACE HYBRID TECH

A huge part of the British Touring Car Championship's success is the stability of its rules. But those regulations risked the BTCC being left behind as electrification took hold, so bosses are taking careful steps towards the future, introducing a spec hybrid system from 2022 onwards.

Today's rules, which dictate the use of a 2.0-litre turbo engine, have existed since 2011, which in turn helps to control costs, gives teams stability to invest and keeps the racing close. From 2022, every car will be fitted with a Cosworth Electronics gearbox-mounted 60V hybrid system, and drivers will be able to use its extra power as 'boost' to attack or defend. The BTCC will use the hybrid boost to get rid of its success ballast system: drivers will be penalised for winning with a reduction in hybrid power.

It's a cautious first step into electrification for the BTCC, but it's a clever one, too: the system can be leased for £20,500 annually, a fraction of the cost to teams of having to develop full hybrid powertrains. But it ensures the championship maintains its much-vaunted rules stability, while taking a small step into the future.



New hybrid rules should maintain BTCC's appeal

SELF-DRIVEN TO SUCCEED

A British autonomous vehicle maker is already doing very well for itself, but you probably haven't heard of it. Jim Holder pays a visit

PHOTOGRAPHY MAX EDLESTON

Unit 11, Humber Avenue, Coventry. Doesn't sound extraordinary, does it? But wander in and you'll discover the home of what is, by some measure, the UK's most advanced autonomous vehicle manufacturer – so advanced, in fact, that it is already in the business of selling its four-seat electric self-driving pods to happy customers around the world at about £150,000 each.

This is not some outpost of Jaguar Land Rover or Nissan, however, but rather one part of the less well-known RDM Group, the parent company of Aurigo, its autonomous vehicle arm, which is perhaps best known for its ongoing test projects in Milton Keynes, where it has been running its pods safely and effectively in public environments for some time now.

Listen carefully and you'll soon get an idea of the depths of expertise in the room – partly from the number of big-brained qualifications being bandied about (think maths, computer science and electronics degrees) and partly from the variety of accents that give away the global pull of working at a cutting-edge firm. Dotted around the up-and-comers there are also familiar industry

faces among the 160-strong workforce: Jez Coates, ex-Caterham technical head; Richard Bartlam, former designer at MG Rover; and the Royal College of Art-trained Elliott Hawkins, now RDM's head of design. Also present is Miles Garner, ex-Philips and Sony sales and marketing lead.

Heading it up is the firm's CEO and co-owner, David Keene, who is – to emphasise the above point – also entitled to call himself Professor David Keene, BSc (electronics and electrical engineering), MEng, CEng and FRSA. “We’re on a journey with autonomy but I think our success to date is the result of being realistic and unrelenting,” says Keene, surveying the first, two-seat autonomous prototype the firm built – without even any suspension – six years ago.

“We aren’t looking to take on JLR or GM and get 50 million self-driving cars on the road, we’re looking to develop advanced systems that achieve enough to be sold to customers.”

So it is that the firm has trials running in Australia, moving old people around a gated community to give them mobility where otherwise they would struggle. There’s also a project at Heathrow’s Terminal 5, with an autonomous

baggage dolly taking luggage crates to and from planes. By operating in environments that are easily mapped and where the risks can be contained, the possibilities of using, rather than talking about, autonomous vehicles open up. It’s a popular formula – other projects are running in Canada, Finland, Singapore, the US and Vietnam.

“Our approach – backed and boosted by investment from various initiatives such as Innovate UK and CCACV – has always been to build our expertise in a modular way,” says Keene. “In the same way you don’t try to teach a one-year-

“WE’RE ON A JOURNEY, BUT OUR SUCCESS TO DATE IS THE RESULT OF BEING REALISTIC AND UNRELENTING”

RDM GROUP: A DIVERSE PORTFOLIO

David Keene set up the RDM Group with his brother, Graham, 26 years ago, and can still recall the shock of his parents when he announced, aged 29, that he was giving up a high-flying career as an electronics engineering manager at Rover to do so.

Today, the thriving company – coincidentally based on the site of the Humber car factory – has expanded in a scarcely believable number of ways. The carbonfibre facility, for instance, ticks over off the back of a deal to manufacture replica American footballs to sit atop trophies exported to the US, but it also makes parts for the upcoming Aston Valkyrie. The trim department can upholster cars to order but also makes leather bonnet corner edges for Morgan. A wiring facility sends out 500,000 looms a year.

Perhaps the biggest headlines belong to David's ownership of X-Part, supplier of parts for MGs and Rovers; Wood & Pickett, the once-upon-a-time makers of converted Minis for the likes of the Queen and The Beatles; Leacy Classics, supplier of classic car parts; and Revival Cars, which rents out classics including a Mini, MG RV8, Morgan 4/4 and Jaguar Mk2. "So long as I can see how it contributes to the core goals, I'm open to any ideas," says Keene. "If an off-beat contract can fund a piece of equipment that I can use elsewhere, and keep a team employed working on it, then I'm all for it."



RDM makes bonnet trim for Morgan and carbonfibre for Aston

old to run, we have always focused on building our understanding and applying it step by step according to the ways we can imagine our work being employed in the real world.

"The airport scenario is very interesting. If you look into the number of baggage trucks running around and the issues they have with lost bags, time management and even damage from hitting things, then we can provide a solution. Certainly airports and airlines are keen to talk to us, and we see a great business in that in a way that an OEM looking to sell hundreds of thousands of cars may not."

Keene lists other possible outlets, from university campuses, hospitals and theme parks to communities for injured ex-servicemen or old people. Another example of that is being assembled just around the corner along the way. Through

RDM, Keene has worked with manufacturers including Aston Martin, Bentley, JLR, Mazda, McLaren, Mitsubishi, Morgan and Volkswagen over the years and understands the need to keep some projects secret, but he's happy to show us – if not let us photograph – the next evolution of the firm's autonomous revolution: a 12-seat bus that is being assembled and which will initially run in protected busways around the UK.

"The idea is that we trial it in Cambridgeshire overnight – in a restricted bus lane and when there are fewer pedestrians, cyclists and hazards in the way – and build our understanding," he says. "I don't expect there to be fully autonomous cars on our roads in a major way in my lifetime, but what we've proved is that there are numerous situations where they can operate and make life better. Our goal is to make them a reality." ■



BA luggage pod nestles behind a restored Jaguar



Four-seater pods, here on a test track, have had real-world trials too (left)



BAC's Briggs points out the graphene-infused components



Making a lightweight supercar even lighter is challenging, but never more so than when the existing version already weighs only 580kg. The weight of BAC's 340bhp Mono R, unveiled at the Goodwood Festival of Speed in July, has been pared back by a further 25kg to a mere 555kg. The weight reduction has been achieved mainly by the addition of graphene to the resin used in the carbonfibre-reinforced plastic (CFRP) structures of the Mono R. The Mono R's body panels are all made from carbonfibre containing graphene, a world first for a production car.

Work started with a proof of concept project, part funded by the Advanced Propulsion Centre UK via the Niche Vehicle Network (NVN), in conjunction with advanced composite specialists Haydale and Pentaxia. That was in 2016, then last year the NVN provided further funding to take the project to production readiness. By introducing exactly the right amount of graphene into the resin, the amount of carbonfibre can be reduced, in turn cutting weight and cost, increasing toughness and improving thermal properties. BAC acted as a technological test bed – and the Mono R was born.

Neil Briggs, director of product development at BAC, explains: "Graphene is a 2D molecular structure made by breaking graphite down to a single molecular layer. You can add several layers together, so you can think of it as an A4 ring binder full of sheets of paper, except you need an electron microscope to see it. Graphene comes as a powder which is then added to the resin."

BAC uses 'pre-preg' carbonfibre, which consists of carbonfibre cloth impregnated with resin and supplied in rolls, much like clothes fabric. Components are made by cutting the pre-preg into the required patterns, laying it up in a mould and curing in an autoclave. "It's almost impossible to tell that the graphene is in there in terms of how the material is handled," says Briggs. "The tactile nature of the pre-preg containing graphene makes it easier to manipulate into the mould because of its additional stickiness."

The important thing is the difference graphene makes to the finished item. "Graphene enhances the structural properties of the carbonfibre and the resin," Briggs says. "It increases the strength of the part, so we can use less carbonfibre in the layup of a given panel which needs to withstand, say, a given aerodynamic load, or a body-engineering load, such as people getting in and out of the car."

"Traditionally there are three different layers of carbon in a carbonfibre layup. There's the face ply – because a lot of our carbon is visual – then you have a bulk ply and another face ply. A lot of our parts are two-sided, like the floor, which curves up round the side, so you don't just have an 'A' and a 'B' side, you have two 'A' sides."

The addition of graphene allows BAC to either take a layer of composite out (such as reducing the thickness of the bulk ply) or change the grade →

The new material
is more energy-
efficient to make



“THE WIDER BENEFIT IS
UNDERSTANDING WHAT
GRAPHENE COULD DO
IN HIGHER VOLUME

612bhp/
tonne

The staggering power-to-weight ratio of the 555kg Mono R, which uses a 2.5-litre, four-cylinder naturally aspirated engine.

wider implications for all uses of carbonfibre composite are more significant. In this sense,

the Mono R is a rolling laboratory for the innovation of lighter, more cost-effective materials.

Briggs is confident that the same technology is now ready to be adopted by the bigger niche car makers should they wish, but could it prompt increased use in mainstream cars? “I see the niche vehicle sector as an absolute catalyst for proving new technology at a proof-of-concept level and then taking it on to production readiness, which is exactly the two steps we have been through in this case,” he says. “I know what we’ve learned from this project and what the suppliers have learned. They already have major manufacturers as customers, so there’s already a potential customer base. For us, as a first mover in the automotive space, it helps showcase the fact that we are a design- and innovation-led business.”

WHAT'S NEXT FOR BAC?

Once the sold-out limited run of 30 BAC Mono Rs has been delivered to customers, the Briggs Automotive Company plans more of the same. “The technology in the Mono R will form the basis of future Monos. BAC won’t reveal any details now, but news is promised “in the not too far distant future”. Joint founder (with brother Ian) and a confirmed petrolhead, Neill Briggs has many years of experience in automotive engineering, including a period spent working with Richard Parry-Jones on the original Mondeo, being responsible for the unique control-blade rear suspension on the Ford Focus and working on the development of the first Ford Focus RS. BAC was founded by the brothers to innovate, and if the Mono R is anything to go by, the next moves will be worth watching.

← of the material while still achieving the structural target but saving weight and cost.

“We targeted four different parts initially because they all presented different challenges,” says Briggs. “First there’s the main body [the painted upper surface], a huge part, so in that respect there was a magnitude challenge. Then we looked at the rear diffuser, which is combined with the rear wheel arches. That gave us a geometric challenge, because it’s a complex part to mould. We also picked the side pod, which is close to the exhaust, so there was a thermal challenge, and also the core panel, which is one of the lower panels, because of the harshness of the environment, stone chipping and so on.”

It became clear early on that 10-20% weight savings would be possible on each component. “This project is of benefit to BAC, of course, but the wider benefit is understanding graphene and what it could do in higher volume in the automotive industry and across the other sectors,” says Briggs.

Graphene is also used in the carbonfibre tooling moulds in which the components are formed. Because it makes the carbonfibre a better conductor of heat, the tool can be heated more quickly and cooled more quickly for curing, reducing the cycle time and saving energy. “If we’re reducing the cycle time and using less material to make the mould and the component, the cost comes down,” explains Briggs. “This, together with the shorter running time of the autoclave, adds up to a saving in CO₂ emissions – the main point of the original project funding. The

Mono R’s graphene
tech will filter down
to other models



Much of the Mono’s
carbonfibre remains
exposed and in view

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