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How technology is reshaping the world of competitive sport _{P20}

Roundtable report

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f all the non-industry sectors in which engineers play a significant role, the world of sport is perhaps one of the most fascinating.

From the exacting technological improvements that spell the difference between victory and defeat on the race track, to the sensing and monitoring techniques that remove human error from refereeing decisions, and the broadcasting innovations that enrich the viewing experience, engineers continue to have a profound impact on the shape of many of today's competitive sports.

And it's a relationship that has important consequences for the world outside sport. As we've reported before, the pressures of competition and the investment available to drive sporting success often conspire to create a fertile climate for rapid and bold innovation; and spur developments, breakthroughs and nimble approaches to problem solving that have applications in other areas.

The lightweighting expertise of the UK's motorsport sector – which is now drawn on heavily by the wider automotive industry, as well as other sectors such as defence and aerospace - is perhaps one of the most notable examples of this (it's a point that's expanded on in this issue's defence roundtable report, p24).

'Pressures of competition in driving sporting success often create a fertile climate for bold innovation"

In this issue's cover story (p20) we take a look at how the relationship between engineering and sport might evolve in the future and, specifically, how developments in autonomy and robotics are leading to the emergence of entirely new competitive sports, pursuits that just a few years ago belonged only to science fiction.

For those wedded to the roar of a petrol engine, or who prefer the crack of leather on willow to the hornet-like buzz of a 100mph quadcopter, autonomous sports cars and racing drones may not be a particularly appealing concept.

But with the Formula E electric racing competition already blazing a trail and demonstrating technology's ability to conjure up an engaged new audience, there seems every possibility that this pioneering new breed of competitions will find an enthusiastic fan base. And when this happens it will be largely thanks to engineers.

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ISSN 0013-7758. Printed by Headley Brothers Ltd, Ashford TN24 8HH Visit www.theengineer.co.uk for constantly updated news, products and jobs and to sign up for our FREE weekly email newsletter and tailored job alerts



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ROBOTICS

Going through the surgical motions

Sensors on exoskeleton pick up movement of a surgeon's hands and fingers Helen KNIGHT REPORTS



urgeons could soon be operating on patients by moving their hands through the air, using a wearable robotic system for minimally

invasive procedures.

The system, which is being developed by a team led by Prof Sanja Dogramadzi at Bristol Robotics Laboratory and the University of West England (UWE Bristol), is based on a sensor-equipped exoskeleton that picks up the movement of a surgeon's hands and fingers.

This information is then transmitted to flexible surgical instruments capable of mimicking this movement, while virtual-reality glasses give the surgeon a 3D view inside the patient.

Minimally invasive procedures offer benefits to patients and robotassisted surgery has increased the number of procedures that can be performed that way. Until now, however, the technology's use has been limited by the rigid instruments associated with it, according to Dogramadzi. The €4m research project, which has been funded by the European Commission under the Horizon 2020 scheme, will develop more flexible instruments, with greater levels of articulation, said Dogramadzi.

"We are developing instrumentation that will give surgeons better access," she said. "They will have more degrees of freedom, and more flexibility to move around inside the body, so that they can get to areas that they can't get to with rigid instruments."

The project, which also includes the North Bristol NHS Trust, the Bristol Urological Institute and the Translational Biomedical Research Centre (TBRC) at Bristol University, has been designed to expand the potential for the technology to be used in more complex procedures in urological, cardiovascular and orthopaedic surgery.

The instruments will be based on a new surgical gripper, which mimics the thumb and two fingers of the hand. Sensors on the exoskeleton detect the motion of the surgeon's fingers, and the thumb and fingers move in the same way, said Dogramadzi. "The instruments inside the body have the same degrees of freedom as the surgeon's hands, and at the moment their movement is being mapped one to one, although this may change, depending on the application," she said.

By using the surgeon's own hand movements to perform the procedure, rather than a console or joystick, it reduces the overall cognitive and training demand upon them.

The instrument will also provide haptic feedback to the surgeon, allowing them to 'feel' the tissues and organs inside the body, in the same way as conventional surgery.

"The instruments do not have any force feedback, so surgeons lack a sense of the force they are using when they are manipulating the soft tissue, and obviously we are talking about sensitive tissue," said Dogramadzi.

The researchers are planning to develop different versions of the instrument, depending on the requirements of the procedures.

They will also develop smart glasses that will enable surgeons to view live images of what is happening inside the body. This offers the surgeon greater freedom, as they no longer need to be plugged into a screen, said Dogramadzi.

"The virtual-reality glasses allow the surgeon to position themselves anywhere within the operating theatre," she said. "The glasses can either be transparent, to allow the surgeon to talk to other members of the team, or they can project images from inside the body, as well as other information the team needs," she added. ® **Read**moreonline

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ROBOTICS

Graphene has the balance of power

Robotic and prosthetic limbs get power through solar cells Helen KNIGHT REPORTS



Dr Ravinder Dahiya

esearchers at Glasgow University have developed a new way of generating solar power for robotic and prosthetic

limbs using graphene.

The researchers have previously used graphene to build a pressuresensitive electronic skin for prosthetic hands. Now, in a paper published in *Advanced Functional Materials*, they demonstrate that another of graphene's properties – its optical transparency – can also be harnessed for electricity generation. Around 98 per cent of the light that hits the material's surface passes straight through it, according to Dr Ravinder Dahiya.

So by placing solar cells directly underneath the layer of graphene, electricity can be generated to power the synthetic skin, he said.

"If we fabricate a solar cell and transfer the skin on top of that, then the entire structure will be able to generate power, because light can enter through the skin, and it will also be touch sensitive," said Dahiya. The skin, which needs 20nW of power per square centimetre, is capable of making very sensitive pressure measurements, allowing it to perform tasks such as judging the correct strength to grip soft materials.

Existing prosthetic limbs do not typically have this tactile feedback, so research groups around the world are attempting to develop synthetic skin.

"If you were to put your hand into an ice block for a few seconds and then try to grab an object, very likely you wouldn't be able to do it," said Dahiya. "Without tactile feedback it is extremely difficult to grab or manipulate an object."

The technology could also allow industrial robots to feel when a person has entered their work area, and stop moving before they injure them.

Although energy generated by the skin's photovoltaic cells cannot be stored at the moment, the team is investigating the possibility of adding a separate layer of graphene, to act as a supercapacitor. This could be placed under the solar cells, to store excess electricity for use when needed.

The graphene supercapacitor would be flexible, thin, and should be capable of storing enough charge to power the touch-sensitive skin and the prosthetic limb's motors, said Dahiya.

This could ultimately lead to a completely self-powered prosthetic.

What's more, the supercapacitor would not add significant weight to the prosthetic, which can reduce an amputee's sense that it is their "own" limb, said Dahiya.

"If you put a battery on a prosthetic limb, the amputee will never feel it is part of their own body, and ownership is important if you want to make it as close to a human hand as possible, for example." (a)

ENERGY

Wood Group is set for merger with AMEC FW

Firm will provide services to oil and gas industry

STUART NATHAN REPORTS

Aberdeen-based Wood Group is to merge with AMEC Foster Wheeler in a deal that effectively sees AMEC FW taken over by the larger contractor. The deal creates a £5bn company that will provide services to the oil and gas, other energy, chemicals, and mining industries.

The board of AMEC FW recommended the merger to shareholders after a troubled period for the company. Formed three years ago in the merger of UK firm AMEC with US contractor Foster Wheeler, it has £1bn of debt and has announced falls in revenues and profits owing to weakness in the oil and gas market.

The merger is an all-shares deal, with no cash changing hands. AMEC FW will comprise 44 per cent of the new company, with Wood Group's chairman and chief executive, lan Marchant and Robin Watson, remaining in their respective roles. AMEC FW has announced the suspension of a planned stock offer to raise £500m. The companies plan to cut £110m per year from the costs of the merged group.

"The combination extends the scale of our services, deepens our existing customer relationships, facilitates further development of our technologyenabled solutions and broadens our end market, geographic and customer exposure," said Marchant.

Prior to the recent merger announcement, AMEC FW reported it has secured a deal to provide engineering support to EDF Energy Nuclear Generation in the UK. The agreement is a five-year extension of a long-standing relationship. (1)

Newsinbrief

Big improvement Connected and autonomous

vehicles (CAVs) are expected to transform the lives of six out of every 10 people in the UK, according to new research from the SMMT. The views of over 3,600 respondents were gathered, with 71 per cent of those aged 17 to 24 believing their lives would be improved by CAVs. A CAV's ability to reduce driving-related stress was identified as attractive to respondents.

R&D footprint

Dyson hopes to create more high-skilled jobs and advance its R&D activities with the construction of a second technology campus in the Cotswolds. Located close to the company's headquarters in Malmesbury, the new facility will represent a tenfold increase in Dyson's UK footprint. The company has committed £2.5bn to future technologies.

Hydrogen take-up

The government has announced a £23m fund to accelerate the take-up of hydrogen vehicles and to roll out associated infrastructure. Hydrogen fuel providers will be able to bid for funding in partnership with organisations that produce hydrogen vehicles to help build high-tech infrastructure, including fuel stations.

Deal or no deal

EEF has warned that loss of access to the EU single market and the customs union would plunge the manufacturing sector into an unfavourable Brexit. The manufacturers' organisation adds that a 'no deal is better than a bad deal' stance will be detrimental to an industry that accounts for 45 per cent of all UK exports. EEF is urging the government to clarify its position on customs arrangements.

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ADDITIVE MANUFACTURING

Nuclear plants in the 3D spotlight

Researchers use nano-additive techniques for structural testing Helen KNIGHT REPORTS

> anoscale 3D-printing developed to build optical devices such as those found in quantum computing could be used to test materials for

nuclear power plants.

In an EPSRC-funded project, researchers led by Dr Anton Shterenlikht at Bristol University are investigating the use of nano-additive manufacturing techniques to build tiny irradiated structures, known as micromechanical coupons, for structural and behavioural testing,

Interest in the use of additive manufacturing for building advanced Generation IV and fusion nuclear systems is growing, thanks to its ability to produce components in shapes not possible with traditional methods.

But the new materials must be tested under high temperature and radiation conditions before being used in the nuclear industry, and health and safety requirements prevent laboratory tests of macro-scale components.

Instead, researchers use micromechanical coupons to test the effects of irradiation on the materials, and then use modelling to extrapolate the results to the macro-scale.

These coupons are typically fabricated using gallium- or helium-

focused ion-beam micro-milling, in which charged ions are fired at the sample to create the desired shape. However, this method is

not representative of additive manufacturing techniques, and can leave damage such as helium bubbles or gallium implantation in the components.

So, in a feasibility study, the researchers are investigating the use of techniques developed in photonics to fabricate the coupons without this damage, said Shterenlikht.

For example, the researchers will be investigating the use of electronbeam-induced deposition to deposit materials such as tungsten, iron or carbon onto a polymer scaffold. They will then remove the polymer, and fill out the scaffold using techniques such as chemical vapour deposition to deposit individual atoms of metal or carbon, said Shterenlikht.

"The material is heated to a very high temperature until it melts and evaporates, and the vaporised atoms are deposited on the substrate."

The researchers will use modelling to create virtual cracks with a range of different topologies, which will then be manufactured into the coupons for testing. They plan to investigate the fracture behaviour of nanometre-sized cracks, using X-ray tomography. (9)



Materials must be tested under high temperatures for the nuclear industry

RAIL

Tracks and trials

Train is run on electricity from a hydrogen fuel cell

Alstom has run the first tests of its Coradia iLint passenger train, claimed to be the first in the world to be run on electricity from a hydrogen fuel cell.

The test, which took place at the company's test track in Lower Saxony, Germany, saw the train running at 80km/h.

The test was the beginning of four weeks of trials of the iLint, which will check the stability of the energy supply system and the interface between pneumatic and electric brakes. Alstom has claimed that the train uses innovative technologies such as clean energy conversion, flexible battery storage,

MARINE

Autonomy gets set for a trip on the high seas Rolls-Royce investigates use of Al in shipping

Rolls-Royce is increasing its investment in technologies for remote and autonomous shipping, after receiving a grant for a research centre in Finland.

It has secured the grant from Tekes, a Finnish funding agency for innovation, which it plans to invest in an R&D centre in Turku, Finland.

Engineers at the site will carry out development projects focusing on land-based control centres and the use of artificial intelligence (AI) in remote and autonomous shipping.



The Coradia iLint passenger train

and smart management of traction power and available electricity. While for its tests the train is running on hydrogen produced as a byproduct of industrial processes, Alstom envisages train services running on hydrogen produced by wind power.

Tests are also underway in Velim, Czech Republic, during which the train will run at its full-service speed of 140km/h. **SN**

There is still very little AI or machine learning used in the maritime industry, according to Sauli Eloranta, head of innovation and technology at Rolls-Royce Marine.

The initial applications for the technology are likely to be in condition monitoring of machinery, he said.

"Vessels are complex systems, and they are quite difficult to master in their entirety, so machine learning is useful when you want to optimise a very complex system."

The technology could also be used to offer the crews of manned ships better awareness of their surroundings, said Eloranta. But, ultimately, it will allow vessels to make decisions for themselves from information received from sensors, such as deciding when to make an evasive manoeuvre.

"We will be doing the engineering and R&D work [at the centre], but also piloting and demonstrating the technology on board full-sized vessels," said Eloranta.

Rolls-Royce believes it can secure up to £200m of investment to develop its ship intelligence technology. (9)



The technology could allow vessels to make decisions for themselves

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ELECTRONICS

Gauging the state of the battery cell

Chip collects, processes and stores real-time data directly from cell Helen KNIGHT REPORTS

wireless chip that can be embedded into individual lithium-ion battery cells to monitor their health and state of charge

is a step closer to launch, after its UK developer secured £2m in funding.

Edinburgh-based Dukosi is developing wireless technology that collects, processes and stores real-time data directly from the cell itself, and then transmits this information to allow the battery to be analysed and managed externally.

The technology could enable developers to improve the design, use and management of batteries for electric vehicles, industrial and grid energy storage applications,

"You can use the data to calculate what power the battery can deliver"

Joel Sylvester, Dukosi

according to Joel Sylvester, chief technology officer at Dukosi.

"It gives you a continuous review of what the state of that cell is: what its state of charge is; what its state of health is, and you can use that to calculate what kind of power it can deliver," said Sylvester. Each chip can be attached to, or embedded within, a lithium-ion cell. It has no additional wires or connectors, and uses radio frequency (RF) technology to communicate with chips in other cells.

The removal of the wiring harness reduces the weight of the pack, as well as materials and assembly costs, said Sylvester. "It will also improve reliability, since every connection is a potential failure, and we could be removing thousands per pack," he added. The chip improves the accuracy of measurements, and provides a history of each cell – including the voltage across the cell terminals, the temperature of the cell, and the current going into and out of the cell – from its original manufacture to the end of its useful life.

"It doesn't matter how the cell is configured, what size or shape the battery pack has been configured in, or even if it is just sitting by itself in a box on a shelf, that chip is always live," said Sylvester.

The technology could also allow data from thousands of individual cells, including those being used for different applications, to be directly compared. This could enable developers to spot patterns in battery usage, and how this impacts on their health.

The latest investment, which will enable the company to ready the chip for commercialisation, was made by IP Group, Scottish Investment Bank, and members of Par Equity.



The chip can be embedded into individual lithium-ion battery cells

AUTOMOTIVE

Electric moves in Leamington Spa

Joint venture agreement means volume production of all-electric sports car will begin

Volume production of a new, all-electric sports car is set to take place at Detroit Electric's Learnington Spa facilities after the signing of a joint venture (JV) agreement.

The deal with China's Far East Smarter Energy Group has helped secure a \$1.8bn investment for production of electric vehicles over the next three years. The JV will invest \$370m into Detroit Electric's European operations over the next four years with initial funds directed at completing the final homologation phase of its two-seater SP:01 sports car and the start of volume production at Learnington Spa.

According to Detroit Electric, this will include the creation of 120 new engineering jobs and 100 new manufacturing jobs. Series production of the SP:01 is planned to start later this year.

The JV will establish a research and development, testing and production facility focused on creating a range of Detroit Electric vehicles for future launches. **JF**

AUTOMOTIVE

Toyota seeks to streamline its production

Derbyshire facility is all set for major upgrade

JASON FORD REPORTS

Toyota is set to invest £240m into its Burnaston, Derbyshire, plant.

Starting this year, the Burnaston facility will be upgraded with new equipment, technologies and systems to enable the production of vehicles on the Toyota New Global Architecture (TNGA) platform.

TNGA was announced by Toyota in September 2015 as a way to streamline the way the company designs, engineers and manufactures vehicles by standardising the size and position of key components within standard new vehicle platforms.

According to Toyota, the long-term benefits are predicted to be smaller, flexible factories with production lines that can quickly and easily be adapted to meet different requirements.

Dr Johan van Zyl, president and CEO of Toyota Motor Europe, said: "We are very focused on securing the global competitiveness of our European plants.

"The roll-out of TNGA manufacturing capability is part of this plan. This upgrade [in the UK] is a sign of confidence in our employees and suppliers, and their focus on superior quality and greater efficiency.

"Our investment demonstrates that, as a company, we are doing all we can to raise the competitiveness of our Burnaston plant in Derbyshire. Continued tariff-and-barrier-free market access between the UK and Europe that is predictable and uncomplicated will be vital for future success."

By 2020, the majority of Toyota's global models will be built using TNGA platforms. TNGA already underpins the new, fourth-generation Prius and the all-new Toyota C-HR crossover, which is built in Turkey.

Toyota predicts more flexible plants









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MEDICAL

Ultrasound homes in on liver cancer

Cancers could be destroyed without the need for invasive surgery Helen KNIGHT REPORTS

iver cancers could be destroyed without the need for invasive surgery, thanks to technology being developed in Europe. The EU-funded

Trans-Fusimo project, led by the Fraunhofer Institute for Medical Image Computing MEVIS in Bremen, is developing a technique in which high-intensity focused ultrasound targets specific areas of the liver.

High-intensity focused ultrasound uses sound waves to target a precise location in the body, generating a hot spot that can destroy diseased tissue.

However, the method has only been approved for use in treating conditions such as prostate cancer.

"The ultrasound focuses this acoustic wave into the body"

Prof Dr Tobias Preusser, Fraunhofer MEVIS

Treating organs that move as the patient breathes, such as the liver, is much more difficult, according to Prof Dr Tobias Preusser at Fraunhofer MEVIS.

"The liver is located directly below the diaphragm, which means that with every breath the patient takes the liver moves down and up," said Preusser. "So as the ultrasound transducer focuses this acoustic wave into the body, the target would constantly move out of and into focus."

But the researchers have developed a technique to allow the ultrasound device to follow the movement of the liver. The patient lies in an MRI scanner, which produces an image of the liver's position every tenth of a second. The ultrasound transducer is placed on the patient's stomach and directs the acoustic waves onto a precise point on the liver. The MRI scanner then measures the temperature in the liver and ensures that the correct spots are sufficiently heated.

But to allow the system to follow the motion of the liver, it also needs to predict where it will be ahead of time. To this end, the researchers have created a model, which they have developed using data on how livers move within the body.

The system compares this model with the movement of the individual patient under the MRI scanner, to predict how the motion will continue.

To avoid damaging the patient's ribcage, which sits above the liver and is sensitive to high-energy ultrasound, the system must also ensure the waves do not pass through the ribs, according to Preusser.

"The algorithm computes which elements of the ultrasound transducer to switch off, to ensure it does not heat the ribs," he said.



The technique follows the movement of the liver

ENERGY

From slate to storage

Abandoned quarries will be the site of new electricity storage facility in North Wales

Construction of the first grid-scale electricity storage facility to be built in Britain for more than 30 years could begin as early as 2018.

Snowdonia Pumped Hydro will turn two old slate quarries at Glyn Rhonwy near Llanberis, North Wales, into water reservoirs that will store 700MWh of electricity. The £160m facility will use surplus electricity, for example from wind and solar, to pump water through an underground tunnel from the lower to the upper reservoir.

During periods of reduced renewable power output, or when fossil-fuel generators fail to start, the water will flow back down the tunnel, spinning a turbine in an underground chamber to regenerate the stored electricity at a power output of 99.9MW.

The only visible evidence of the pumped hydro storage facility will be a modest building on an industrial park, and two reservoirs contained by slate dams blending with existing slate tips. **JE**

AUTOMOTIVE

Data acquisition is now on the move with Intel

Organisation will leverage autonomous vehicle data

JASON FORD REPORTS



Data will be key to cars in the future

Intel is investing in the future of data acquisition from autonomous vehicles with the \$15.3bn purchase of Mobileye, a leading computer vision technology company based in Israel.

According to Intel CEO Brian Krzanich, the autonomous vehicle systems, data and services market is estimated to reach \$70bn by 2030.

"The combination of Intel's high-performance computing and connectivity solutions with Mobileye's best-in-class computer vision technology will put us in a position to accelerate innovation for car-makers," he said.

Krzanich added that the deal has been motivated by data acquisition, adding that at four terabytes of data per day, the average autonomous car will generate the data equivalent of approximately 3,000 people.

He said: "Put just one million autonomous vehicles on the road and you have the data equivalent of half the world's population. This massive amount of data requires all of Intel's assets to provide the cost-effective high-performance solutions our customers need.

"The addition of Mobileye to our family provides the data path to our computing solutions becoming the intelligent set of eyes that will allow a vehicle to see and define the world around it."

The combined organisation, which will consist of Mobileye and Intel's Automated Driving Group, will be headquartered in Israel.

"We expect the growth towards autonomous driving to be transformative," said Ziv Aviram, Mobileye co-founder, president and CEO. (19)

MEDICAL

Setting sights on a greater restoration

Technology directly stimulates retinal cells to combat results of neurodegenerative diseases stuart NATHAN REPORTS



Animal models have given encouraging results

Ithough some progress has been made towards restoring sight using electronics and implants, the level of sight they can produce is still well below the accepted threshold for blindness.

Engineers at the University of California – San Diego and La Jolla-based Nanovision Biosciences report that they have developed new technology that directly stimulates retinal cells to potentially restore high-resolution sight lost through neurodegenerative diseases.

The technology is some years away from human trials, but animal models have given encouraging results.

Two technologies are key to the system. First, an array of silicon nanowires detects light and electrically

stimulates retinal cells. These are bundled into a grid of electrodes whose density approaches that of the light-sensitive cells in the retina. This grid is implanted behind the retina and links up to the other key technology – a wireless device that transmits power and data with high efficiency, using an inductive charge-transfer system. The wireless signal also times the stimulation of the retinal cells. The team claims that 90 per cent of the energy transmitted by the system is delivered to the implant and used for stimulation.

"To restore functional vision, it is critical that the neural interface matches the resolution and sensitivity of the human retina," said Gert Cauwenberghs, a professor of bioengineering at the Jacobs School of Engineering at UC San Diego and senior author of a paper detailing the research published in *Journal of Neural Engineering*. Cauwenberghs led the team that developed the inductive charging and data-transfer system, which was part funded by Qualcomm.

The team's device does not need a camera outside the body, although one of the coils for the inductive system is outside the body – the other is implanted in the eye. This advance results from the dual action of the silicon nanowires.

The team tested the technology by implanting a nanowire electrode grid behind the retina of rats with induced retinal degeneration.

The in vitro experiment, which stimulated light and colour-sensing cells in the retinal tissue, showed that action potentials, which indicate cell activity, were produced when the augmented retina was exposed to light and electrical potential from the inductive system.

ROBOTICS

Squeezing into difficult spaces

Semi-autonomous teleoperated robots could be used for maintenance work

Intelligent, semi-autonomous tele-operated robots that can squeeze into difficult spaces for maintenance work are being developed by a UK consortium.

The Shadow Robot Company is leading an Innovate UK-funded project to develop a demonstrator of a semi-autonomous teleoperation system designed to be simpler to use and more intelligent than existing devices, said the company's managing director Rich Walker.

"The way teleoperation systems have historically worked has been quite limited, they've been very mechanical, very direct-drive," he said. The 13-month project, which also involves OC Robotics, Cambrian Intelligence and UCL, will use Shadow Robot Company's Dexterous Hand – a robotic device with the same capabilities as a human hand – on the end of OC's snake-arm robot. Cambrian Intelligence will create an augmented reality (AR) user interface, while UCL researchers will install a vision system.

"There is a lot of intelligence that can be brought to bear on SAT systems from robotics, including vision systems, mapping, grasp generation, grasp control, and these are not being used at present," said Walker.

By combining an AR interface with a robot hand and snake arm, the consortium hopes the system will make remote inspection, maintenance and assembly work simpler and more cost-effective.

"When a large plane is assembled, for example, there are various ports throughout the wing, where you stick your hand in to fasten a nut inside," said Walker. "If you could use a snake arm with a (robotic) hand at the end of it, those ports could be placed a lot further apart, which would improve structural integrity and decrease the number of ports, reducing weight," he added.



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Will robots take our jobs and dignity?

With a looming robot revolution, we need to think urgently about different scenarios and the likely impact they could have on basic human rights



arb the builder whistled on her way to work today. Her new exoskeleton suit has arrived and her back will be saved from lifting and laying bricks to build houses. But the happy mood took a nosedive when she read about Hadrian X in the

newspaper. It's a new bricklaying robot that can lay 1,000 bricks an hour. It could build a house in two days that would take Barb and her team six weeks. 'How can we compete with that,' she thought.

And Barb is not the only one who should be worried about robots taking her job. There has been a rapid upsurge in the number of robotic applications planned to replace human workers. Robots have been operating in factories since the 1950s but now they have moved outside into the service industry to serve food and drinks, to make burgers and pizzas faster than any human, to clean up and to take over transport with autonomous cars, trucks and buses. The mining industry is being transformed with robotics, as are agriculture and delivery services. And this is just the beginning.

Reports abound about AI and robotics creating mass unemployment within a couple of decades. One of the earliest studies by Frey and Osborne (2013) forecast that 47 per cent of all jobs in the US could be computerised within 20 years. Predictions were based on criteria including repetitiveness and social interaction. Deloitte (2014) followed with studies in Britain, Switzerland and the Netherlands, showing similar results. And more recently the banks of the US, UK and Italy have expressed grave concerns.

Is there a solution? No, but there are a number of suggestions. The Dutch report *Mastering the Robot. The Future of Work in the Second Machine Age* suggests an inclusive robotisation, with the core concepts of complementarity between human and robot skills and capabilities, and ownership of work. McKinsey & Company suggest that we should rid ourselves of the concept of "occupations" and instead utilise the concept of "work activities". Robots may be used to replace or assist specified portions of a job rather than replacing or assisting an overall trade or occupation. They argue for a five-factor approach to predicting the automation



of particular activities. Among these are: the benefits of automation and the cost of workers who might otherwise perform the activity. This leads to a conclusion of only 5 per cent displacement of workers. However, it does not take into account the plummeting costs of robotics and the accelerating number of tasks that can be performed.

Bill Gates has suggested that companies pay tax for a robot replacing a human. This would then be used in some way to compensate redundant workers. While tax sounds like a good idea it is not an ideal solution and is fraught with difficulties such as defining a robot and how many jobs it actually displaces. For example, it may be a new automated robot system that never had human workers such as the Ocado supermarket that uses a swarm of co-operating robots for picking, packing and sorting groceries. And there are serious concerns that a robot tax could slow down this sort of innovation and possibly create more unemployment over the short term.

Providing a universal basic income (UBI) is another widely heralded suggestion. This takes a number of forms such as giving everyone the same amount and then taking some away for every dollar earned. This has difficulties as well. Who will set the basic amount and can it be guaranteed when new governments come into power? And where will the money come from? With significantly fewer people being employed we will need new economic models. We need to think about different possible scenarios and the likely impact they could have on our basic human rights and dignity. What kinds of inequality could emerge with a new technocratic elite? Will it aggravate gender, age and ethnic biases?

A recent head-in-the-sand vote at the European Parliament went against both robot tax and UBI without offering any alternative or promise to investigate the issues further. Other countries are less forward in their deliberations. Yet this is an urgent matter as the potential for a robot revolution in all areas of the workplace unfolds over the next decade.

Whether or not mass unemployment is immediately on the cards, we need to decide what responsibilities we will allow companies to delegate to a robot or AI. We currently have no policies in place. Society needs to be better informed and play a larger role in decisions about the kind of good life we want to have and how robots fit into this picture. We need to shape a future with robots worth wanting.

Prof Noel Sharkey and Dr Aimee van Wynsberghe, Foundation for Responsible Robotics

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Deal or no deal

The industrial implications of Brexit proved to be a major talking point among readers



European countries will remain our largest export and import partners due to their proximity. We therefore need to make the thousands of daily transactions as cheap, fast and transparent as possible. We have decided to surrender free movement of goods, people, services and capital. We now need to be realistic and seek the next-best thing. Personally, I would also seek reassurances for our skilled workers from the EU, many of whom have been living and working in the UK for over a decade. **NA Brodev**

Full and unimpeded single-market access is the most important thing. That means being able to ship goods around without needing paperwork and customs inspections, let alone the possibility of having to run tariffs through the ERP systems. **Alex**

We need to be in a position after leaving the EU and all its red-line member rules to concentrate on our ability as a sovereign state to trade freely with as many countries of the world as we can. The customs union will be a burden in that regard. If we can negotiate a clean, fresh, tariff-free trading deal with the EU upon our leaving, that will be splendid. If not, then we have to be prepared to go it alone, as the fifth- or sixth-biggest economy in the world and get back our confidence, unshackled by EU bureaucracy.

Philip Bott

This is essentially a trade-deal negotiation where both sides want to continue a very successful trade relationship. Therefore, the outcome will be good for both. John Molyneux

There is no such thing as a hard or soft Brexit: the only outcome is a negotiated Brexit that will be speculated about by economists using their computer models, which proved themselves so spectacularly in 2008. The world economy seems to be unwilling to listen to the banks et al and goes its own merry way. I suppose that a soft Brexit would be to give in to all the other side's demands; and a hard one would be to refuse to consider reasonable demands. Negotiations imply the achievement of mutual benefit. Jack Broughton

Industry's main concern should be with designing and making excellent products, with increasing levels of productivity; looking at its own performance rather than using the issues around trade agreements to avoid this self-examination. **Paul Reeves**

I find it worrying that there seems to be a growing belief that any deal, however bad, is worth having. If the remaining members of the EU are not prepared to compromise at all – unlikely, but not impossible – then we should walk away from negotiations and accept that this does not represent a disadvantage, but merely the loss of a previous advantage. The rest of the world is still happy to trade with us. **Richard Jenvey**

If it all goes to pot in a couple of years can we look forward to PPI claims solicitors calling us every day to ask if we've been mis-sold Brexit? **Steve Boyd**

Inyouropinion

Power lines

Our online poll on electric vehicles (EVs) and UK energy supply sparked a lively debate

Clearly the grid infrastructure needs improving. But it is more the old technology such as voltage and frequency-sensitive trips that present most of the problem. A grid with better resilience can cope with the variable load presented by EV charging. In return, the EVs with standardised charging systems can adjust performance to suit in periods of difficult supply, without leaving themselves short of power for their main purpose. **Michael Bradley**

monuci Didulcy

The grid will be pushed to the brink of blackouts unless we radically change the way it is currently managed. EV drivers need an incentive to charge up when demand on the network is low i.e. night-time and weekends, and allowed to sell power back to the grid when demand is high i.e. 4pm to 7pm on winter weekdays. Currently there are absolutely no incentives. As an EV driver I follow human nature and like to keep my battery topped up, which leads me to charge up when I get to work (coinciding with the morning peak demand on the grid) and charge up again when I get home (coinciding with the evening peak on the grid). **Andy**

EVs are pushing the development of battery technology, which, if then used for renewables storage, solves a multitude of issues. Look at the example of T'au, which is now nearly 100 per cent solar and Elon Musk's offer to fix South Australia's power problem in 100 days. **Stephen**

EVs also have the capacity to be used as storage devices. It is not good enough just to think of them in a separate context of road travel. If they are not being used on the roads they could be used to power homes at times of peak demand, while storing at times of excess power generation. As part of a distributed energy grid, used in conjunction with smart energy, they will help to shape the future of the UK energy system. **Helen Poulter**

Forget EVs and costly batteries that take an age to charge up and discharge in no time. The future is hydrogen fuel-cell electric vehicles. H2 can be produced using surplus wind/solar energy when the government gets its act together and puts serious investment in the refuelling infrastructure. Hyundai is working on a car with a 500-mile range that can be refuelled in three minutes. **Nik**

It doesn't matter how well the automotive and energy sectors work together unless we have sufficient generation of power then it will fail. The government needs to think about bringing on nuclear power stations, as environmental power stations are too weather conscious. **Stephen Poole**

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Thesecretengineer Our anonymous blogger is underwhelmed by the autonomous car revolution

A short while ago I read, in the ethereal pages of this august publication, about a test race between two autonomous cars. These new racers promise less risk of injury due to less crashes (having removed human error from the equation) and there being no one on board anyway even in the unlikely event of it all going pear shaped. Therefore much sniggering was to be had when it ended in a crash.

No matter, those behind this novelty took their setback in good grace and promised to

interaction that is key. Ask what was the first man-made vehicle to land on the Moon and a few will know, but not many (Luna 2, in case you are wondering). By contrast, virtually everyone reading this will know that Neil Armstrong was the first man to set foot on our celestial partner. Sputnik 1, as the first man-made object hurled into space, is probably the exception but I'd still wager that – overall – manned achievements are better known than their unmanned equivalents.

I cannot help but feel that this is reinforced by another not-totally-unrelated story in the news:



'improve' things. Opposing these laudable aims, there are those who feel that an inherent risk of death adds to the gladiatorial element and therefore enjoyment of the racing. For me, this is all secondary to the skill involved. Admittedly crashes are exciting, in the truest meaning, but that is different to actively looking forward to one.

Is this brave new world, as a dyed-inthe-wool enthusiast, what I want though, especially given my avowed interest in overtaking over mayhem? No – probably – I'll undoubtedly watch one or two rounds to give it a chance but I am fairly confident about this prediction.

It's all very clever from an engineering point of view but, even in motor racing where the reliance on technological superiority is more obvious than in other sports, it is not the complete story. A car held just on the verge of spinning, or in the middle of a breath-taking pass conducted with superlative human skill and flair, is what really excites me.

Whatever the finer points of the argument may be, the point is that it is the human

the sale of tickets for flights to orbit the Moon. Few have the chance to truly blaze a trail but as the novel and the inherently risky heads towards the normal and the generally safe, the opportunity for new, thrilling experiences are opened up to more and more. Although it is only the rich

and fortunate who can fly around the Moon at the moment, in 50 years it will be more common and in 150 years possibly commonplace. Of course, by then, there may be tickets on sale to follow in the footstep of the next trail-blazers to Mars.

It need not be the latest thing that appeals to this hardwired compulsion. There

is still a thrill for many, but I concede not all, from the now broadly accessible activities of driving a quick car or taking to the air. We never tire of the vitality of such experiences.

Autonomy can be used to reduce risk, to remove the requirement for human pioneers. However, this is to ignore that for some it is a need and a choice: something yearned for.

Look to the latest spate of freefalls from stratospheric balloons and the like to illustrate just how much some are willing to invest in pursuit of this thrill. Perhaps, more importantly, it is inspirational and although autonomous vehicles – whether racing or acting as pathfinders – are hugely impressive; it is a truth that they just don't engage like their manned equivalent. Let us safeguard life as much as we can, but don't let us forget the meaning of what it is to be alive in the process.

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A big step in the right direction

The government's plans for the reorganisation of technical education are a good move but there is still much more work to be done



lot has happened in the last few weeks, including International Women's Day, when I had the privilege of visiting 10 Downing Street for a special reception, hosted by the prime minister. Preceding this was another fascinating meeting, hosted by Chris Skidmore MP, minister for the constitution, on how to include more women in public appointments. The women around the table represented a wide variety of careers, from tech and computing to banking and the military. I wondered what the common spark was that had

led us all to this destination from such different contexts and, more importantly, how we can offer the best possible career opportunities and training routes to today's young people, whatever their gender, abilities, interests or backgrounds.

Good career opportunities start with readily available information, and responsibility for providing this currently rests with schools – sadly without any dedicated funding. Coupled with the reduction in the provision of work experience for young people under 16, this has resulted in the disappearance of worthwhile

careers information for young people across many schools in England. The industrial strategy green paper promises a new careers education strategy, which is welcome news and vital to our future productivity. Getting it right should result in students making informed decisions, leading to better outcomes for them, for industry and for the economy.

One route to better career opportunities is undoubtedly through engineering, where skills are in high demand. A bill is currently passing through Parliament that could revolutionise the way in which it is taught and experienced in colleges,

and, in turn, make it more accessible to learners of all abilities and backgrounds. The Technical and Further Education Bill will put into legislation the recommendations of the Post-16 Skills Plan developed in response to an independent panel review of technical and professional education chaired by Lord Sainsbury. Published last year, the Sainsbury panel review aimed to create a simplified progression pathway at age 16 – the Royal Academy of Engineering was an early supporter of the proposals and is ready to help implement the much-needed Skills Plan.

The further education sector makes a significant contribution to the engineering skills landscape, yet it has had significantly lower investment over many years than schools, and higher education. However, the chancellor's recent announcement of an additional £500m a year for the FE sector in the Spring 2017 budget will transform colleges' ability to deliver the new Skills Plan. For many, it will enable them to increase teaching on their courses from three to five days a week.

The Sainsbury review identified a multitude of qualifications in FE of varying quality and value to students. The system was confusing for both young people and employers, and led to a significant decrease in standards. Government has recognised the problems with FE over many years, but successive initiatives to tackle them have run into short-term funding problems and have failed to make sufficient impact.

The review recommended developing one qualification or



The two-year T-levels will incorporate technical skills and a relevant work placement

'route' per cluster of occupations, creating 15 distinct progression routes for 16-19 year olds, with the emphasis on occupation-led rather than content-led routes to ensure that the qualifications are as useful, and portable, as possible. The two-year T-levels will incorporate technical skills, plus English and maths at GCSE level and a relevant three-month work experience placement. There will be opportunities for students to transfer between the A-level and T-level routes, and an important new provision of a 'transition' year for students who need to improve their GCSE results.

Importantly, each route will be shaped by a panel of industry experts. Employers have long reported difficulties in finding entrylevel employees with the right skills sets for their needs, and this will provide a means of addressing that challenge. For the engineering and manufacturing route, mapping occupations has been particularly challenging, with 130 discrete occupations for engineering technicians identified and clustered together, each of which corresponds with a current apprenticeship standard or a real technician iob offered by a real company. The process has been informed through consultation with employers and other organisations across the engineering community and the next step is to develop the content for the qualifications. The academy will play a leading role in this, working with partners, including the sector bodies, professional engineering institutions, employers and FE colleges.

The key challenge in developing these new qualifications is to identify the core knowledge and skills that all technicians need, whatever their specialist area. Some roles will have very different needs to others, so the profession will have to strike a balance in determining what is included in this core content.

Ultimately, our aim should be to enable young people and adults to develop the skills necessary for a lifetime of rewarding employment and to meet the demands of a developing and diverse modern economy. The government's plans for technical education are a big step in the right direction, but much work is needed, to ensure that they result in the step change in skills enhancement that we need in the UK. @

Dr Hayaatun Sillem is deputy chief executive of the Royal Academy of Engineering

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Thrills, spills and mechanoids

Artificial intelligence and robotics are combining with human skills to bring us to the verge of a new era of sport. Andrew Wade reports

> port is as intrinsic a part of our civilisation as the expression of art or the use of tools. Cave paintings dating from thousands of years ago, in places as far apart as France, Libya and Japan, depict humans engaged in competitive wrestling, swimming and archery.

And just as art and technology have evolved in step with our species, so too has sport. The birth of the car in the late 19th century gave rise, almost overnight, to motorsports. And the advances of the 21st century have brought us to the verge of a new

era of sport, where technologies such as robotics and artificial intelligence are combining with human skill in spectacular ways.

One example is the exciting new sport of drone racing. If ever a technology has emerged ready-made for the world of sport, the drone is surely it. Remote-control quadcopters have, in recent years, been used for everything from industrial inspection to filming scenes in Hollywood blockbusters. It was only ever going to be a matter of time before we started racing them.

At the vanguard of the fast-growing sport is the Drone Racing League (DRL), the second season of which is set to air soon on Sky Sports and ESPN. Pilots wearing first-person-view (FPV) goggles use radio controllers to fly small drones around themed 3D courses, reaching speeds in excess of 100mph. Made from carbon fibre, the drones use high-performance electronic speed controllers that modulate the amount of power that goes to each of the four motors. This allows them to speed up or slow down extremely quickly, enabling jaw-dropping manoeuvres that resemble a live-action video game.

"We develop all of our drones in-house," Nicholas Horbaczewski, DRL founder and CEO, told *The Engineer*. "We started, at the very beginning of the company, working on drone design to see if we could create the ultimate racer for a sport like this. It needs to balance incredible speed and performance with things that are necessary for a spectator sport, such as visibility and identifiability in the air."

While all the drones are identical in spec, they have ultra-bright LEDs in different colours so that viewers can follow the action. Unlike commercial drones, the DRL models are built primarily for speed rather than stability, with pilots able to exert incredibly precise control. According to Horbaczewski, uniform equipment and a level playing field were fundamental for a number of reasons.

"It was important to make sure that when you saw a pilot win a race, you knew that was the best pilot, not necessarily the person flying a faster drone," he said.

"I think the other reality is that we build over 500 drones for our races. When you consider there's 12 pilots in every race, you would almost be asking every pilot to show up with 50 identical, hand-built drones."

Over the course of a single race weekend, virtually all of those 500 drones will suffer damage, with many getting totalled during the helter-skelter action. The DRL then rebuilds the fleet between races, allowing it to constantly iterate. Horbaczewski said he could see the sport evolving to a point where pilots are backed by organisations that build their own drones – similar to how Formula One operates – but that type of paradigm is probably some way off.

For now, the only thing pilots need to worry about is going as fast as they can. Wearing the FPV headsets, they are fed a real-time HD video stream





from a camera on the front of their drone. This is sent over a proprietary radio network infrastructure, which also facilitates the incredibly responsive controls required to navigate the intricate tracks.

"You need absolutely uninterrupted control uplink between the controllers and the drones," Horbaczewski explained. "And then you need ultra-fast, low-latency video between the drone and the pilot's goggles. When I say low latency, I mean well less than 60 milliseconds."

That network needs to be built out over the complex 3D courses, which are generally several kilometres long, often incorporating hallways and tunnels. Tracks for the first season included the Miami Dolphins stadium and a disused shopping

mall in LA. The 2017 season is set to culminate in a world championship decider at Alexandra Palace in June – a slight change in pace from the snooker and darts the venue is used to hosting.

Allianz has already been signed up as the headline sponsor for the forthcoming season, and with major media partners also on board, it's easy to imagine the sport gaining mainstream traction. While ESPN and Sky will broadcast the DRL,

the league itself captures all the footage and edits it into packages ready for distribution. According to Horbaczewski, the speed of the action presents some unique challenges.

"We spent a long time before we even did our first event experimenting with techniques on how to film them," he said. "I'd love to be able to say there's one silver bullet that we came up with that solves it all, but, in reality, the solution is a thousand small decisions we've had to make."

Those include everything from the type of cameras and lenses used, to the camera operators, camera positions, and the overall system used for capturing media. The breakneck pace of the action has also encouraged some innovative filming techniques, such as the use of ultra-high-speed cable cams that travel at 80-90mph, keeping up with the drones in full flight.

With quadcopters racing through the air at such speed, crashes are inevitable, and indeed a much-loved part of the spectacle. Not having a human on board provides degrees of freedom that traditional motorsport simply cannot allow. It's a concept taken to the extreme by Roborace, a new motorsport series where humans not only aren't behind the wheel, but aren't even in direct control.

Set to make its debut in the coming months on the Formula E undercard, Roborace will feature 200mph driverless cars autonomously controlled by >>

"It's the ground-based equivalent of a military dogfight"

Bryn Balcombe, Roborace





01 Fully autonomous and fully electric Roborace car

> **02** 'Prosthesis': the first step towards a 'mech' racing league



03 The carbon-fibre quadcopters used in the drone-racing league reach speeds in excess of 100mph

>> artificial intelligence (Al). As with the DRL, all vehicles will be identical, but software engineers will compete with 'Al Drivers', where algorithms and feedback loops will replace human instinct and reaction speeds.

"The primary focus is on the ability of the AI Drivers to perceive and act within the dynamic environments that we create," Roborace chief technical officer Bryn Balcombe explained. "If an AI Driver is more accurate in perception it has a better chance of taking the correct actions.

"It's the ground-based equivalent of a military dogfight with AI Drivers continually engaged in an OODA Loop [observe, orient, decide, and act]. The key challenge is to get inside the OODA loop of a competitor to gain an advantage."

Those feedback loops will be powered by the Nvidia Drive PX2, a processor capable of 24 trillion AI operations per second. Feeding that big brain will be a massive sensor suite made up of five lidar, two radar, 18 ultrasonic and two optical speed sensors, as well as six cameras and a GNSS module.

As for the Robocar itself, it's been designed by Daniel Simon, the man behind the light cycles in *Tron: Legacy*, who has also worked with Bugatti and Lotus. It's an incredibly striking vehicle that has already drawn much praise for its looks. But Roborace intends to thrill with substance, as well as style.

"Under the beautiful design, we have four independent electric motors," said Balcombe. "That's quite unique in motorsport and enables torque vectoring algorithms to be used in controlling the vehicle dynamics. With only a single throttle pedal, that level of control is not available to human drivers. "We also expect more side-by-side racing manoeuvres given the cars have 360-degree real-time situational awareness of other objects. That exceeds the human's current perception ability when relying purely on forward vision and a pair of wing mirrors."

But personalities have always been an integral part of motorsport. The DRL has worked hard to portray its pilots as individual characters with different strengths and flying styles. While the Roborace action may well be incredible, will Al Drivers be able to capture the imagination in the same way that the icons of motorsport have?

"It's interesting to think about what we love about past and current racing legends," said Balcombe. "It may be some time before Roborace Al Drivers have the off-track charisma of James Hunt. However, on-track personality is always defined by the driver's actions and our own personal interpretation of intent, so there is no reason why we won't see Al Drivers akin to Niki Lauda."

It will be interesting to see how the different 'personalities' of the various AI Drivers shine through on the track. It's hard to imagine a machine enjoying the same kind of adulation enjoyed by someone such as Ayrton Senna, but perhaps audiences will develop affinities for different Als over time. In the meantime, Roborace will have to captivate in other ways. The absence of humans from the centre of the action presents an opportunity to push the broadcast boundaries.

"Roborace is truly unique in being able to combine the real and virtual worlds together," said Balcombe. "That opens creative opportunities for the TV broadcast audience, the spectators at our events and the increasing market for gaming, AR and VR experiences."

That merging of the real and virtual worlds is something that Jonathan Tippett would almost certainly appreciate. What started off as a Burning Man art project for the mechanical engineer and sculptor over a decade ago has evolved into the prototype for one of the most exciting future sports around – a planned mech racing league where humans pilot giant robots using their bodies.

If all this sounds like science fiction, that's because it essentially is. Mechs have long been a popular sub-genre of science fiction, gaming and Japanese anime, but until now no one has made them a reality. Tippett, along with a big group of friends and volunteers, began working on the concept via their educational charity eatART (energy awareness through ART). At their workshop in Vancouver, the crew spent several years developing the Alpha Leg – a two-thirds-scale prototype limb that would lay the foundation for what was to follow. But it wasn't until Matt Fidler, co-founder of tech company Furrion, saw the Alpha Leg that things took off.

"He was totally inspired by it," Tippett told *The Engineer* at the recent SolidWorks World event in Los Angeles. "He thought it was just crazy enough to succeed."

Having demonstrated the Alpha Leg, Tippett was able to

sell the bigger picture to Furrion – full-scale mechs competing against each other in a racing league. Working with Furrion, Tippett set about building Prosthesis, a 5m-tall, 3,000kg, four-legged wearable machine, powered by a hybrid-electric power plant. Once operational, it will be able to clock nearly 30kmh and jump 3m in the air. Prosthesis was first unveiled in January, and loomed over Tippett and myself when we spoke in LA. The prospect of several of these monsters facing off in the desert is quite something.

"The mech racing league used to be a fictional back story to support the art project, as a Burning Man-destined, single one-off thing," said Tippett. "But it took so damn long to make, that 10 years down the road not only had our community and my resources and my skills expanded, but with Furrion on board we were able to dream bigger, and this fictional back story actually became a good idea.

"That was the original dream, just ripping around in the dirt, jumping over stuff. You could have a stadium track race, or you could have a long desert race. Basically any off-road or on-road motorsport could be done in a mech. Plus any

"It may be some time before Roborace AI Drivers have the off-track charisma of James Hunt"

Bryn Balcombe, Roborace track and field event. So it's this crazy panspectrum platform for human competition."

As with drone racing, controlling mechs will require extreme skill. The robots will have no autonomy, no gyroscopes to self-balance, no Al to assist the pilots. Despite their gargantuan size, they will be finely tuned machines designed to operate in sync with their onboard drivers, accentuating human skill rather than replacing it.

"You know there's so much automation going on these days, I felt it was important to make something that was celebrating the process of human skill, and keeping the human agency central to the experience," Tippett explained.

The pilot – who sits in the centre of the mech – controls the two outside limbs with their arms and the inside limbs with their legs, protected by a chromoly steel frame and lots of suspension. A fully functioning Prosthesis is due to be unveiled in May, and it's been reported that the mech will appear at the first ever World Future Sports Games, in Dubai in December 2017. That event will also feature drone racing and driverless car racing, as well as robot soccer, robot swimming and, bizarrely, robot wrestling. Thousands of years after humans first gave birth to sport, robots are competing in the same pursuits. It's interesting to imagine what our ancestors would have made of it all. () NVIDIA® Quadro® is the world's largest most advanced visual computing platform for workstations.

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Picking up the pace

The accelerating rate of technological change in the defence sector continues to pose challenges. Stuart Nathan reports



hanging times are difficult for everyone to adjust to, but for the defence and security sectors - charged with protecting the safety of the nation - some aspects of change are more difficult than others. The participants in The Engineer's recent roundtable on innovation

in the defence sector explained that the accelerating pace of technology development is a cause for much potential anxiety.

In past decades, the defence sector has enjoyed a position of primacy in innovation. It was at the forefront of technology development, and its inventions were often adapted to cascade down to the civilian sector. But this is no longer the case.

Animal Dynamics CEO Alex Caccia noted that his company's development of small drones that mimic the flight capabilities of insects depends to a large extent on the availability of technologies - in particular, the sensors, used in mobile phones - that until recently were prohibitively expensive. This, he said, is both an opportunity for his company and a threat to others. "For example, there's a chip issued by Texas Instruments called a sensor tag that contains every kind of sensor you can lay your hands on, and it costs about \$17. Ten years ago it would be in the hundreds of thousands. That opens up a set of possibilities to develop more sinister applications for very small budgets. We need to develop the capability to offset that.

Prof David Delpy summarised one aspect of the changing times by stating that while once the defence sector could effectively control access to technology this is no longer the case. "To be honest you can't control anything now," he said. "Anyone can build anything and if you can't build it yourself you'll find someone on the internet who will build it for you."

The MoD's Heather Goldstraw said that there still remains a culture within the defence sector that it has to be a leader in technology and not a follower. But this can be counter-productive, she added, because it means the sector risks missing out on possibly useful technologies developed for other industries. "We are now identifying where people have similar problems: oil and gas has similar challenges to some parts of defence, so has transport and telecommunications, medical and education, simulation, training and modelling." She went on to highlight the other challenges facing the sector. "We have to be more systemic. Because, now, everything is a

challenge," she said. "Money is a challenge, emerging threats are a challenge, being more sustainable is a challenge, looking after the environment and contributing to the economy is a challenge. We need to innovate on all of those fronts."

The MoD is in the unique position as the main buyer for most of the defence technology developed in (or for) the UK. Goldstraw observed that much of the time this is in response to threats and opportunities, as it always has been. "There are both changing threats and proliferation of threats," she said. "The secretary of state for defence is clear that we have resurgent Russia but at the same time we have Daesh - so-called Islamic State, and unpredictable insurgent-type threats. We have to be able to cope with both."

As an example of how defence needs to draw on other sectors. Goldstraw pointed out that one of the often-ignored aspects of the sector is that it operates very large fleets of vehicles, and therefore has much in common with the transport sector (not a parallel that would tend to occur to many people, she ventured). "We are looking at a number of things that are already well established in the transport sector to make vehicles more fuel-efficient, for example," she said.

Goldstraw also pointed out an aspect of innovation that will be familiar to many readers of The Engineer: it's not just about technology. "To me innovation is about the exploitation of ideas; and they can be process or service ideas. We need to become more agile, much more able to respond to threats and opportunities; whether it's through tactics and training, or different intelligence and information, so we change what we do and how and where we actually deploy, or if it's being able to very rapidly roll out a counter to a particular threat.'

In part, she said, this means being able to look at other sectors and realise that they face similar problems. "We need to be able to embrace new suppliers, new technologies, through our commercial models, through the way we acquire, through building our supply chains, through building links with other sectors, and not just the traditional defence trade associations."

Chris Guyott, engineering director of Frazer-Nash Consultancy, said that other sectors of industry tend to find it easier to innovate because they don't typically have to deal with the shear breadth of challenges that the defence sector faces. "Other sectors can often organise themselves a little bit more readily to get on and do it. They're trying to solve detailed problems that are relevant to them. That's a little bit easier because you're solving a focused problem."

Despite this, Guyott said he has come across a number of examples of other sectors borrowing







Alex Caccia CEO, Animal **D**vnamics

Prof David Delpy Chair. Defence Scientific Advisory Council





Heather

Goldstraw

Director of

Technology

Jon Excell Editor, The Engineer

Delivery, DE&S, Ministry of Defence





Rob Solly

Defence and

Security

Accelerator

Chris Guyott Engineering Acting Head of Director, Frazer-Nash Consultancy



Association



Andy Wright Director of Strategic Technology. **BAE Systems**





"We need to become more agile, much more able to respond to threats and opportunities"

Heather Goldstraw, MoD innovative approaches from the defence industry. One major influence, he said, has been on the rail sector, which has based much of its approach to safety management and how to understand risks and hazards on lessons learned from defence.

Nevertheless, technology now tends to flow in the opposite direction. And of all the sectors that the world of defence can learn from, motorsport – a harsh and demanding industry with short timescales and hard deadlines – is perhaps one of the most interesting examples.

"Everybody in our environment is constantly in a state of trying to catch up and get ahead," said Nick Wills, who leads the Motorsport Industry Association's efforts to build relationships in defence. "This drives a behaviour, a performance and a mind state among the engineers that work there that is different compared to other sectors. How you can bring that to bear on problems outside of just being at the front of the grid is something that a number of the topend motorsport engineering companies are now bringing to the market."

Some of the time, this common ground can be a positive advantage for the sector. Andy Wright of BAE Systems observed that one problem is that it is difficult to describe problems faced by the sector, because in doing so weaknesses in the UK's ability to respond to certain situations is revealed. "We worked on programmes called Aladdin and Orchid that were about getting information around a battlespace, but we asked them to work on disaster recovery as an analogy to that," he explained.

Wright said that one of the advantages of the defence >>

>> sector is that it has an abundance of hard problems, and because these tend to stretch the capabilities of technology they are inherently a strong spur to technology development.

Alex Caccia went even further: "What's been very interesting for me... is being presented with a very specific, very hard problem that is not in the civil domain. There isn't a requirement for, in our instance, a gust-tolerant, tiny drone. The fact that the problem is so extreme has forced us to think about problems we would never have thought about before."

Animal Dynamics' work on its Skeeter drone, which is based on a dragonfly, has led to the development of technologies that would otherwise have not been necessary, he added. "To make Skeeter work we had to design a new kind of motor because we had to get the power-to-weight ratio really high and the coulomb losses down really low. We now find all sorts of applications for that because the requirement is so extreme; and it wouldn't be extreme were it not a military requirement."

UAVs have already led to important process innovations in defence, Goldstraw said. "The current nano-UAV capability that Skeeter is looking to build on came out of experimentation in urban combat, where you have to face problems such as seeing around corners and over walls. How you engage in an urban environment is very different from the environment our equipment was developed for.

"Black Hornet was a nano-UAV the team spotted on YouTube in 2009, we invited the developers to engage with us and, after further development, it was trialled by the army in 2011, which gave it the evidence to raise an urgent operational requirement – UOR. It was in the field in Afghanistan within 12 months following a competition and some minor development. The big innovation with Black Hornet was it put that surveillance and intelligence in the hands of the unit on the ground rather than relying on larger surveillance assets sent from further away or having to send men forward to check areas. It changed the traditional methods of disseminating that information and who was making the decisions on intelligence gathering."

The DSTL's Defence and Security Accelerator is facing similar issues, Rob Solly said, citing an example in the overlap between defence and medical technologies. "We've been working with the University of Strathclyde to develop a very simple device so that when a serviceman is injured and losing a lot of blood, that blood can be salvaged and returned back to their body rather than having to rely on large amounts of donated blood. We've helped it find a commercial partner and that will lead to off-the-shelf technology. Who's going to buy it? You can see that front-line ambulance staff could benefit enormously from this."





Saving the blood helps save lives

Assisted by the **Defence and Security** Accelerator, the HemoSep system was developed at Strathclyde University and has now been licensed to Advancis Surgical, a medicinefocused part of Nottingham-based engineering and research company Brightwake, which is manufacturing the device in the UK and marketing it worldwide.

HemoSep springs from research led by biomedical engineer **Prof Terry Gourlay** between 2008 and 2013. The key to the system is a special blood bag that contains filters to remove harmful substances from spilled blood while letting through the oxygen-carrying red cells, infection-fighting white cells, and the platelets and proteins that make up the vital mechanisms of blood clotting. The bag also contains an absorbent pad that soaks up excess plasma that has diluted the blood, locking it into a harmless gel form

for easy disposal. The reconcentrated blood is then suitable for transfusion back into the patient.

Autotransfusion has many advantages. It reduces the need for medical facilities to keep such large stocks of donated blood on hand for emergencies; it completely removes the risk of rejection of donated blood, as the patient's own blood is used and compatibility is therefore guaranteed; it is also suitable for patients whose religious beliefs prohibit transfusion from donors. Although autotransfusion has been used for some years during open-heart surgery, it has relied on complex machinery using centrifuges and pumps that need to be operated by specialist technicians.

A funding call from the military spurred the research on, and led to the development of the commercial version that had been successfully used in an operation to repair the aorta of a patient suffering from the connective tissue disease Marfan syndrome, but who as a Jehovah's Witness could not receive a donor transfusion.

Accelerating the research

The Defence and Security Accelerator brings together staff from the Ministry of Defence, the Home Office, the Defence Science and Technology Laboratory (DSTL) and Defence Equipment and Support (DES). It aims to fund proof-of-concept research in the defence and security sector, taking its funded research towards implementation and market exploitation, and to open up the daunting and sometimes hard-toaccess sector to a wide range of organisations, with particular emphasis on SMEs.

Launched in December 2016, the Accelerator operates a programme called Enduring Challenge, with £6m annual funding, which aims to provide a route into the sector for organisations that have had no contact with the sector before. In part, according to the MoD, this is a response to the impossibility of knowing all developments that might be relevant, in terms of technology, business processes and training. Typically, the programme provides funding of £50,000-£90,000 for work of up to nine months' duration. It operates in nine areas: protection, situational awareness, power, communications, data, lethality, mobility, human performance, and lower cost of ownership. It operates in monthly assessment cycles, with feedback given to applicants shortly after the closing date of each cycle.

Organisations wishing to apply to the accelerator should contact the organisation directly at https://cde.dstl.gov.uk.

"The key to the system is a special blood bag that contains filters to remove harmful substances from spilled blood"

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Vert Rotors' technology forces fluids between two conical rotors

Not-so-good vibrations

Compressors are a vital piece of equipment in many industries; compression of gases is very common for many processes. But many versions of compressor technology tend to create vibration, which can be a problem, for example, in space and medical applications. Screw compressors are a low-vibration option, but they tend to be large (above 2kW) so are not suitable for all applications.

Edinburgh-based Vert Rotors has developed a version of the screw compressor that can deliver vibration-free compression at low volumes, First demonstrated in 2013, it uses a single coneshaped inner screw in a similarly shaped housing to perform gas compression, rather than the two cylindrical screws side-by-side of a conventional screw compressor. In a traditional system, the clearance between the two screws and their housing allows

gases to leak back, reducing efficiency; the conical compressor system eliminates this problem, producing 30 per cent better energy efficiency, the company claims.

The compressor works by trapping air between the inner and outer rotors, with intake at the wider end. As both rotors revolve, the air is forced down to the narrow end, and as the space between the rotors decreases pressure is progressively increased. The size of these compressors is 100 to 1,000W.



As the space between rotors narrows, pressure increases progressively The reluctance of some companies to work with the defence sector is an issue, Goldstraw acknowledged. The sector still has special requirements that some companies find difficult to meet.

"Sometimes defence does have to worry very much more than other sectors when making its procurement that things are safe, reliable, compatible and secure," Goldstraw said. "We know that isn't cheap or easy and for an SME to meet defence standards, volumes and quality may be a real challenge for them, but we are constantly looking at ways to make it easier for these companies to do business with us by challenging our standards and adopting new contract models where we can.

"The biggest challenge we have is not unique to defence at all; it's understanding supply chain and how acquisition can be continually improved to reflect the market," said Goldstraw. "When we use a prime contract model, we as an organisation do not directly buy subsystems, components or materials, we buy products or systems that give us military capability. So potential new suppliers might have a fantastic idea, but it might need to be targeted at someone lower down in the supply chain, not directly at the MoD. The oil and gas and transport sectors have similar issues as procurers of large and complex systems."

Alex Caccia agreed, highlighting another difficulty. "What's missing is an understanding of at what point a start-up has to engage with regulators and standards, and it's a lot earlier than you think," he said. "The industry's very stratified: it appears to be very big companies at one end and very small ones at the other. The venture capital industry doesn't back technology risk or business in the phase of technology, so you need to get beyond just having the MoD as a customer. Building the company is a delicate process because it requires business and technology knowledge."

One effect of this, he explained, is that it can be very difficult for companies to grow. "When most of your income is from research grants, they tend to be squeezed so much that there's no money left over to grow the company," he said. But this is often not the case when dealing with government. "A normal commercial relationship is a zero-sum game, and it's not when you're dealing with government. There's an interest in our business succeeding, albeit as long as our success aids our partners' success."

Rob Solly was keen to highlight a counter-example. "A company called Vert Rotors came to one of our face-to-face meetings, and we said its conical rotors for compressors could be used in satellites and gave it a small grant; it then used that to help raise £1.5m, which it has invested in machinery to help it grow its capacity and capability. It was also having difficulty getting funding for the business governance side, which is something that small businesses don't necessarily have any expertise in." This can be a big problem for SMEs working with defence, he added. "There's phasing that needs to happen here. If you're buying a warship there are strict stages of requirements, that all the parties understand; but if you're applying that to an idea that's only just getting off the ground, there's a real danger of snuffing it out. You need to be slightly more agile in requirements."

Andy Wright quoted another example. "We've invested in a company called Intelligent Textiles. It's a small business that's invented a novel textile that allows you to transmit data through a textile rather than with wires. The need for that is to allow a soldier to plug in all their devices without wires trailing everywhere, but the impact is potentially much broader. It had a really good idea but the cost point was too high, it couldn't sell it; so we worked with the company to drive down the cost." The business has since expanded and is now moving into new premises in Lancashire. (**)

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Getting right back to black

The iconic London black taxi cab is getting a makeover for the 21st century. Jon Excell reports



ack in 2012, the UK manufacturer of London's iconic black cabs was facing an uncertain future. Having failed to make a profit since 2007, and with administrators poised to take control of the finances, it appeared that the London Taxi Company's (LTC's) 70-year history of producing

one of the UK's most distinctive-looking vehicles was about to come to an end.

That was until Chinese automotive giant Geely Group – already a major shareholder – stepped in with an

£11.4m rescue package, took ownership of the firm and unveiled a bold plan to expand production, target new overseas markets, and reinvent the company as a leading developer of specialist lightweight, low-emission vehicles.

Four years and £300m of investment later, these plans are

01 Black cabs on the new Ansty production line in Coventry

now beginning to come to fruition. And this month LTC officially opened a sparkling new production plant in Ansty, on the outskirts of Coventry.

The first facility of its kind to be built in Britain for more than a decade and the first dedicated electric vehicle (EV) factory in the UK, the plant will initially be used to manufacture the TX5 – the firm's next-generation, low-emissions taxi. In the longer term, LTC plans to use the lightweighting and powertrain expertise gained during the development of the cab to launch a wider range of low-emissions vehicles. But, for the moment, it's the TX5 – which will begin rolling off the production line later this year – that's the focus of attention.

Cosmetically, the new vehicle looks much the same as its predecessors, retaining the functional and friendly box-like shape that's been a familiar sight on London streets for decades.

But scratch beneath the service, and this is a radically different vehicle from the firm's current diesel-powered TX4. "This is a total redesign," LTC's CEO Chris Gubbey told *The Engineer*. "There's not a single carryover part from the current cab. It's completely new."

Designed to meet legislation due to come into force in 2018 specifying that all-new London taxis are zeroemissions capable, the TX5 features an electric powertrain and a three-cylinder petrol engine that's used as a range extender. It is claimed that the car has a pure EV range of over 70 miles. Both the electric powertrain and the IC engine were supplied by Volvo, which is also owned by Geely.

As well as the powertrain, there's been a fundamental overhaul of the vehicle's structural components, with the old chassis replaced by a bonded aluminium frame that's clad with composite panels. Although LTC hasn't yet revealed specific figures, this is claimed to dramatically reduce the >>



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>> weight of the taxi, thereby improving efficiency, and reducing the cost of ownership.

In common with its predecessors, the new vehicle is designed to last. But with automotive technology evolving at a rapid rate, it has been developed with upgrades in mind. And just as Volvo has fed into the powertrain design, Gubbey expects breakthroughs made by other areas of the group to filter through to the taxi business. "It's an area where we benefit from being part of a larger group," he said, "in terms of making benefit out of rapid development, that's a very positive thing for us." Some of these developments may be made by the Ansty site itself, which Geely aims to turn into a centre of excellence for lightweighting R&D – building on an area where the UK already has a worldleading reputation.

Indeed, the plans for the LTC's revitalised operation stretch way beyond simply manufacturing black cabs for London, and Gubbey – whose previous roles include a spell in China as vice-president of Shanghai GM – hopes to expand the taxi business into new international markets and diversify the product range beyond its core. "We're not going to be able to return that £300m investment just selling taxis into London, we need to get better throughout the UK and plug into continental Europe," he said.

With this in mind, the firm is currently eyeing up plans to launch the TX5 in a number of European cities during the course of 2018.

Amsterdam, Paris, Berlin, Oslo and Barcelona have all reportedly expressed interest in the vehicle.

LTC also has ambitions to use the powertrain architecture developed for the new cab for a number of urban commercial vehicle applications, and recently announced that the second vehicle to come off the **02** The new London taxis have had a thorough testing schedule

03 Chris Gubbey of the London Taxi Company

Ansty production line will be a dedicated, range-extended electric light commercial van (LCV).

"When you look at purchasing trends you've now got this plethora of small vans running around the city clogging it up. Ours is a perfect philosophy for those vehicles," said Gubbey. "Most of the depots are going to be outside the city; one of the things you can do with a range extender is run it in maintain mode and then when you get to the low-emission zones you've got a full battery charge." Gubbey added that he eventually expects the LCV operation to grow to at least the same size as the taxi business.

Given the disruptive impact of Uber, it seems a little strange to be talking about a resurgence of interest in something as traditional as a black cab. But unsurprisingly, while stating there are lessons to be learned from



"With the focus now on clean air, electrification is going to come a lot faster"

Chris Gubbey, London Taxi Company

the tech start-up's success, Gubbey rejects the notion that it's called time on the black cab, pointing to its easy-toaccess design and the specialist knowledge of its drivers as factors that will ensure it endures for years to come.

At a time of such rapid technological change, however, it's difficult to predict what the black cab of 2040 might look like. "There are so many changes going on in the automotive industry. With the focus now on clean air, electrification is going to come a lot faster. But from a powertrain perspective predicting where we're going to be is very difficult – it might not even have wheels on it!" • tcardsonline 🧇

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Where physical meets digital

The interface of humans and technology is a major focus for PARC's chief executive. Stuart Nathan reports

02

San Francisco has arguably been responsible for shaping more of the way that we live our everyday lives than any other. Silicon Valley, as it is known, was the birthplace of the commercial transistor, the microprocessor and the technologies they depend anal computer, the beginnings

relatively small area near

on: everything from the personal computer, the beginnings of the Internet, and the current generation of portable computing and smartphones, all had their genesis in the area. The office equipment company Xerox was one of the pioneers of Silicon Valley, establishing its corporate R&D division, then known as Xerox PARC, on the valley edge near to Palo Alto and Stanford University in the 1970s, among the first large companies to set up there.

PARC has not been Xerox's captive R&D division for nearly two decades, being spun off into an independently run although wholly owned subsidiary of Xerox in 2002. But on a visit to the UK recently, PARC chief executive Tolga Kurtoglu told *The Engineer* that the heritage of the company is still probably the main thing that most people outside its immediate community know about it. "There's a very strong legacy and brand with Xerox PARC, going back to our formation and often people make the assumption that it's still the case [that we are not an independent company]," he said. "We wanted to come to the UK to raise awareness and build some relationships. It's a market we want to grow. We already have commercial partners in the UK and some academic institutions we collaborate with, and we're looking to continue those and build new ones."

The early days of PARC were characterised by developments that brought information technology into offices, and were particularly concerned with how people work with computers. "A lot of technology we take for granted today was partially or fully invented at PARC."



01 PARC developed the first three-button mouse for Xerox in the early 1970s

02 Flexible displays are a focus for PARC

"My assessment would be that next-generation jobs would be concerned with how you put computational agents together with robots and Al"



Kurtoglu explained. "That ranges from the graphical user interface to the very concept of the personal computer; Ethernet, which we developed in 1973, was a big success and had a huge impact on Xerox; object-oriented programming was another; aspects of the mouse around 1970 and the frame of 'ubiquitous computing' was coined at PARC."

The interface between humans and technology is still a major focus of PARC's research, even though the business structure has changed. Kurtoglu estimates that slightly less than half of the company's research projects are now Xerox-related. "Today, PARC is a combination of computer scientists, people with advanced engineering degrees, IP professionals and a team of commercial people and social scientists focused on developing technology options for a wide variety of clients," Kurtoglu said. "We've moved to working for a wide variety of customers and different areas of deep science, such as for the US government agencies, DARPA and its energy department equivalent, ARPA-E, but we also work for customers from start-ups all the way through to Fortune 500 and Global 1000 companies."

Open innovation is a major strategy for PARC but, as Kurtoglu concedes, this is a term that notoriously means something different to almost every institution that uses it. For him, it simply means that the company collaborates closely and widely with a very wide range of organisations, some commercial, some governmental, and some academic. "Another aspect is that our business relies heavily on IP generation, and transferring that IP into a set of technologies that can be commercialised and implemented in a practical way takes a variety of different forms. Our basic definition is working with a set of clients who most of the time have a pretty strong internal R&D capability to develop new technologies and work with them to do the knowledge transfer and technology transfer.'

Apart from a small office in Tokyo staffed mainly by commercial departments and some social scientists, all of PARC's activities are in Palo Alto. "We have about 190 people in the technical staff, 85 per cent with PhDs, and they have backgrounds in computer science, aerospace and chemical engineering, electrical engineering and materials science," Kurtoglu said. "Alongside them, we have theoretical and applied scientists in chemistry and physics, and our technical team also includes social scientists with PhDs in ethnography, anthropology and social studies." IP specialists, commercial teams and support staff account for another 50 or so employees at the site, he added.

The work these teams undertake mirrors many of the concerns found across industry at the moment, while also harking back to the company's origins in man-machine interface; but while in the 1970s and 1980s the machine tended to be a computer on somebody's desk, today it is just as likely to be a piece of industrial automation. One of PARC's largest research areas is concerned with energy technologies and batteries, Kurtoglu said. "We look at next-generation battery systems and battery management systems with applications in smart cities, smart grids and things of that nature." Other groups are concerned with customisable sensors, which may have applications in industrial automation and autonomous vehicles. "We are also working around advanced manufacturing and digital manufacturing, Industry 4.0 and the application of machinelearning and AI," he added, the last of these being a particular speciality of Kurtoglu's and the subject of much of his postgraduate studies after qualifying in mechanical engineering. "If I were to summarise the work that we do, the majority, if not all, of our clients are at the intersection of the physical and the digital. That's what we see as the next wave of technology; more and more real-time data that's becoming prominent and available, no matter what industry

"The majority of our clients are at the intersection of physical and digital. That's what we see as the next wave of technology" and application you pick. And then more and more real-time interaction between the physical and digital worlds."

PARC's facilities are organised around four main laboratories, two specialising in hardware (one, with systems and the other with materials, devices and electronics); the other two labs work in software (one in a systems sciences and the

other in interaction and analytics). In general, Kurtoglu said, where PARC works in hardware it is of the type where software is essential to its operation and research has a very strong tendency to be interdisciplinary in nature. "A big part of our value proposition is the ability to put these teams together to solve tough technological problems."

Sometimes this work depends on taking a new approach to sensing and bringing analytics to existing problems. One example given by Kurtoglu is a new type of fibre-optic sensor for lithium-ion batteries that is able to detect changes in the structure of the cell materials on a much more fundamental level than conventional sensors that can only monitor parameters such as temperature, voltage and current. "We didn't ask the question about how can we write or develop better analytics algorithms for batteries; we asked what can we sense differently and what hardware technology might enable so that we can really have a breakthrough to the development of how its management works with the analytics layered on top," he said.

Industrial automation is one reason that PARC employs so many social scientists, as well as physical scientists and engineers. While Kurtoglu admits that there are very real fears that bringing increasing amounts of robotics and Al into manufacturing may threaten jobs, he believes the future of work is more likely to lie in changing the nature of the jobs that humans do, with far more cooperation between humans and robots as technologies such as additive manufacturing become more widespread in factories. "My speculation is that the next-generation jobs would not just take those very

CareerCV

Tolga Kurtoglu chief executive, PARC Corporation

Education

1999 Bachelor's degree in mechanical engineering, Middle East Technical University, Ankara, Turkey

2001 Master's degree in mechanical engineering, Carnegie Mellon University, US

2007 PhD in mechanical engineering, University of Texas at Austin

Career highlights 2001-2003 Mechanical design engineer, Dell

2003-2004 Systems lead engineer, Dell

2006-2010 Research scientist, NASA Ames Research Centre

Kurtoglu developed computer-aided tools to design human machine interfaces

2010-2014 Research scientist/area manager, PARC Inc

Managing teams in computational sciences, artificial intelligence, and automation

2011-2016 Programme director, digital and design manufacturing, PARC Inc Developing software solutions for virtual product development and digital manufacturing markets

2014-2016 Vice-president, director of system sciences lab Overseeing PARC's R&D investments for Xerox and managing its innovation portfolio

January 2017 Appointed chief executive of PARC Inc

repetitive tasks and automate them; it would be concerned with how you put computational agents together with robots and AI, and put them with humans in collaborative ways to solve increasingly complex tasks together. That intersection is very important for us. Our social scientists specialise in understanding how technology is used or can be used, and they do user studies and work closely with our technology teams to understand what technology might mean for the end users."

Kurtoglu also studied additive manufacturing (AM) as a postgraduate, and has continued his interest at PARC. "One of the most significant challenges with AM is the processes are not as characterised as traditional technologies. We've been building systems that allow AM models to be converted into computational models that can predict the physical outcome of different AM techniques. That's a way to help the design side by embedding those process capabilities into intelligent design tools to help them to catch up with the potential of the various techniques, so they can feed into the next CAD/CAM tools." (a)



scifi eye | jon wallace

Humankind's next evolutionary leap

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, technological implants and the idea of the 'transhuman'



ast month, *The Engineer* reported on progress towards bionic eye implants. An array of silicon nanowires arranged in an electrode grid, implanted behind the retina and linked to a wireless device, has potential to restore sight. Once again engineering news astounds and delights –

the scifi eye given life.

Technological implants play a solid role in science fiction as a crucial component of the idea of the 'transhuman': that is an evolutionary leap that sees man combine with technology to alter his perception and abilities.

Interest in implants tends particularly towards the neural interface: as science has come to understand consciousness as more a product of the brain's complex functions (as opposed to the awareness granted an immortal soul), so science fiction has explored the fascinating prospect of tampering with our brain's computing.

Writers like to explore the farthest reaches of such progress: will implants unlock some hidden potential or do irreparable damage? Could they unite humanity through a new, shared reality, or create new conflict – between those who embrace transformation and those who refuse it? Can we forfeit some precious part of ourselves yet be better people for it?

These are all excellent foundations for stories: the fact that this research centres on the eye only rings more scifi bells: eyes are often the giveaway 'otherness' in the implanted or adapted: see *Star Trek*'s Seven of Nine and her bulky ocular attachment.

The Borg are a reasonable representative for the portrayal of implanted characters, who are often disfigured, manipulated figures. The Borg's implants are their chains, playing on our fears of an inescapable totalitarian commotion in our heads, countless voices drowning out our thoughts. *Star Trek*'s writers return to the Borg (again and again) because the stumbling, mindless drone, 'awoken' from captivity, makes a wonderful character. As long-lost relatives they can comment on our society with pleasing effect.

'Implants' generally bad rap in cinema extends to many other forms. In *The Matrix* they are part of a

ruthless trick, both duping man into oblivious service of machines and harvesting his energy. In *Johnny Mnemonic* and *Elysium* they are the tool by which men are made data mules: heroes chased and harried for the precious treasure in their heads. Novels such as lain Banks' *Feersum Endjinn*, meanwhile, see implants deployed by the ultimate future surveillance state, allowing the King to jump into his subjects' heads at will and see through their eyes – although they also grant humans a kind of immortality beyond 'base reality'.

Still, *The Engineer*'s news shows we don't always have to view implants as obscene, probing devices that subvert our natural function. They can repair and even enhance us too. In recent decades, man has proven himself more than willing to bond to technology, to lose himself in other realities, and it hasn't been all bad. Should we really fear the inevitable plunge into more intimate relations with technology?

What need will we have of dreary office spaces, when in the blink of an eye implanted workers can transfer to a virtual workspace? We might well imagine that in such a world senior management would be unable to resist exploiting the technology to eavesdrop on employees – but would that be so bad? In our story, tyrannical chief execs around the world eagerly monitor their employees' conversations, only to find complete and universal scorn for their abilities. Depressed, they resign en masse; the employees learn to go on without them

> "Should we really fear more intimate relations with technology?"

> > Jon Wallace

Technological implants have always played a solid role in science fiction easily enough, and an entirely new system of labour is established, free of redundant hierarchies.

Might implants be used invasively by the government? What of a police force that boasts an implant that compels suspects to speak the truth? We could tell the story of a prime ministerial candidate who volunteers to have the device implanted, along with his own party, to prove the purity of their politics. They are wiped off the political map, as the electorate turn to the rival parties' comforting fantasy and falsehood.

Then there is the promise of *The Engineer*'s news story: of restoration and even enhancement of the senses. Implants could help release the victims of strokes and debilitating syndromes, allowing them to express themselves again by providing bridges over damaged synaptic pathways.

Being human, their use might be more frivolous. We could follow the adventures of a Harley Street implant clinic that exploits a craze for implantenhanced senses, offering its clients a dog's sense of smell. The service is hugely popular, and has mixed results: many lose their jobs (being prone to wandering off into woodland and openly peeing during meetings). The more influential clientele do however, make a difference: pushing through a great world clean-air act.

Jon Wallace is a science fiction author living in England. His new book *Rig* is out in paperback from Gollancz in April



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Park Assist comes of age

The VW Tiguan's self-parking function is a tangible demonstration of the power of driverless technology. Chris Pickering reports

f you ask a typical person what their least favourite aspect of driving is, there's a very good chance the response will be 'parking'. And not without reason. Squeezing into a tight spot is the most complex test of spatial awareness that most people will encounter behind the wheel. In fact, in a recent survey of British drivers, one in four admitted to often parking 'some distance' from where they needed to be in order to find an easier space.

Fortunately, technology has the answer. Assisted-parking systems have been around for more than a decade now. Although some, it has to be said, are more adept than others.

Today we've come to Volkswagen's UK base in Milton Keynes to try the Park Assist function on the new Tiguan. As modern SUVs go, the Tiguan's visibility is actually very good. You don't find yourself peering out of a letterbox-slot-sized rear window as you do in some of the more coupé-like crossovers. Nonetheless, it is a fairly sizeable high-riding vehicle, so it's exactly the sort of application where this system should come into its own.

Park Assist relies on 12 ultrasonic sensors – six in the rear bumper and six in the front. In both cases these wrap round the corners of the bumper, giving 360 degrees of combined visibility. They are networked over the vehicle's CAN bus to a dedicated Park Assist control unit, which sends instructions to another ECU in charge of the electrically assisted power steering.

The Tiguan's Park Assist function toggles between reverse parking and parallel parking modes



The system is primed by prodding a button on the centre console. It allows you to toggle between reverse parking and parallel parking modes, after which you can drive forwards at up to 25mph and the system will start scanning away. Once it finds a suitable space, a graphic comes up in the instrument cluster indicating that you're ready to go.

As you'd expect, there are a series of safety functions built in to stop you doing anything stupid. For a start, the system won't trigger if it detects that the vehicle is towing a trailer; it also doesn't allow you to pick spots on tight bends and there's a 4mph speed limit (plus an emergency braking function) during the manoeuvre itself.

You retain control of the brake and the accelerator at all times, but as soon as you move off the car takes over the steering. It's a real leap of faith the first time, with the car happy to get quite close to neighbouring vehicles before it emits a cheerful ping, telling you to change into Drive to go forwards. Again, the steering wheel spins in front of your eyes until you're summoned to go into reverse.

Depending on how well you've positioned the car in the first place it can take a few bites, but no more than the average human driver would do in the same situation. Interestingly, the system remains active if you chicken out before the tone sounds, so you can leave as much margin for error as you like – handy if it's the first time you've tried it and your scientifically controlled test environment happens to be the local Sainsbury's car park.

In some respects, watching the steering wheel whirl back and forth at 2mph in a car park is actually a more tangible demonstration of a vehicle's self-driving capabilities than one that can steer itself at 70mph on a motorway. Once you learn to trust the system you can reverse quite rapidly, and it generally manages to steer into the space in one go.

The parallel parking mode is equally accomplished, guiding you into spaces that even the most confident drivers might think twice about tackling in an unfamiliar car. It can also steer you out of them, which can be just as important if you can't see the extremities of the front bumper.

There are a few limitations to bear in mind. Because the system relies on ultrasonic reflections it can't park unless there's a car (or some other obstacle) to serve as a reference point. It also means you're at the mercy of other people's positioning – so if the cars on either side are off-centre, your miraculous parking skills will appear to have taken a downturn.

Aside from those, the only issue we could see is that it doesn't always pick up on a space; sometimes it takes a couple of attempts to register the same spot, even though the speed and angle of approach are more or less identical. Generally, though, it is very good. Assisted parking may sound like a gimmick, but we suspect a lot more than one in four drivers would secretly use it.

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Product testing is a job ready-made for a robot

Robots are programmed to load and operate dishwashers. Supplier: Universal Robots

When it comes to relieving humans of extremely tedious and repetitive tasks, automation has a big role to play, and nothing is more repetitive than product testing.

Daily tasks such as loading and unloading a dishwasher are chores at the best of times, but having to do it over and over to test the durability of a product is a job ready-made for a robot. That's why scientists from Fraunhofer IPA in Stuttgart have programmed machines from Universal Robots to step in.

Bosch Siemens Hausgeräte (BSH) is the largest manufacturer of home appliances in Europe, with dozens of dishwashers spread across several brands. Universal Robots are programmed to load and operate dishwashers for endurance testing, fulfilling tasks such as loading detergent and testing the internal baskets. The process frees up employees for more productive tasks, and allows testing operations to be carried out around the clock. Integrating collaborative robots, or cobots, into the workplace can also bring a competitive advantage. Scott Fetzer Electrical Group in Tennessee uses a Universal Robots UR10 for data collection and life-cycle testing of new designs. The cobot is programmed to test small motors that operate inside customer products. During testing, the robot is set to turn the product's switch on and off, running the motor for a minute, turning it off for 30 seconds, continuing this cycle for 400 hours.

"It's enabled us to engage our customers in the testing as well," said Matthew Bush, director of operations at Scott Fetzer Electrical Group.

"They're excited to see us use new technology to push our design faster into production. It gives us an advantage over our competitors in low-cost source countries." (a)

Automation is at the core of industrial PC

C6015 IPC can be used for automation, visualisation and communication tasks. Supplier: Beckhoff

At the recent ISE 2017 trade fair in Amsterdam, Beckhoff demonstrated its new ultra-compact C6015 Industrial PC (IPC), designed with building automation in mind.

According to Beckhoff, the C6015 IPC can be used for automation, visualisation and communication tasks, including directly linking audio/video, media and lighting technology, along with device management. The company claims that all system information being available on one platform helps simplify operations, enhance occupant comfort, and reduce costs.

A robust control cabinet IPC is equipped with a 1.91GHz Intel Atom CPU with up to four cores, offering performance reserves for a variety of functions. The compact housing dimensions of 82 x 82 x 40mm and flexible installation options make the fanless multi-core PC a good choice of controller for applications with high-performance requirements where mounting space is limited.

Beckhoff said the interfaces for transferring electrical signals, IP, image and audio signals - which are available by default - make the C6015 a cost-effective product for the control of multimedia walls. Another new feature highlighted by the German firm is the integration of PJLink technology into the Beckhoff control platform. In conjunction with support for typical audio/video communication standards such as AES 70 (OCA), DMX. SMPTE timecode. Crestron. Bang & Olufsen, Art-Net, streaming ACN (sACN) and PosiStageNet, all the important devices and systems for media and stage technology can be controlled via the centralised PC platform.

In addition, the CX51x0 and CX20x0 Embedded PCs from Beckhoff are now available with a DisplayPort option. This enables direct connection of monitors with a resolution of up to 2,560 x 1,600 at 60Hz. A second monitor can be connected via the DVI interface. (e)

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Moulding and robotics make for more affordable vision

Glasses have lenses difficult to manufacture with conventional injection moulding. Supplier: Fanuc

Eyejusters was founded to create affordable adjustable glasses, particularly in areas where there are no optometrists to measure and provide prescription glasses. Fanuc's expertise in injection moulding and robotics helped to realise this ambition, along with automation partner Hi-Tech's skills in 3D simulation and its experience in defining production automation.

Because the lens design has varying thickness profiles, it is difficult to mould the lens with conventional injection moulding; the injection melt front tends to move around the thicker sections before completing the fill at thin sections centred in the lens.

Fanuc ran moulding development tests while Eyejusters perfected the tool design to work in combination with CNC Roboshot's functions. The outcome was a final production solution comprising patented mould design, combined with Roboshot's precision pre-injection/compression function. The material was injected into the tool under reduced clamp force. At a precise point, full clamp force was then applied to compress the moulding as injection completed.

Roboshot's CNC control meant selected positions to control the process were repeatable within 0.001mm.

The next stage was to integrate the injection moulding process within a production cell, which brought Hi-Tech Automation on board.

Hi-Tech's initial task was to develop a working specification for each of the production processes.

Step one determined how to remove individual mouldings from the tool, with the team deciding to have the individual moulded parts attached to a runner/ sprue for handling and orientation.

The team then turned to lens coating, component de-gating, ultrasonic welding and packing into thermoformed trays. Hi-Tech used Fanuc's Roboguide simulation software to design, model and create the layout virtually.

With the automation cell built and operational, a Class 5 Clean Room needed to be built around the cell before production-level components could be made. Hi-Tech specified a solution that met all cleanliness standards and incorporated full air handling.®

Smart controls make for a better brew

Automation aids beer fermentation process in Cumbria. Supplier: Siemens

Smarter automation is playing a considerable role in today's busy world, including Britain's micro-breweries where Siemens technology is helping to maintain high standards.

Dave Bailey, at Hardknott Brewery in Cumbria, described the fermentation challenge: "Control of the fermentation temperature helps to considerably improve the quality and consistency of beer," he said. "It takes place over several days and on a practical basis the process cannot be watched continually. Temperature control systems can be expensive and complex to set up and micro-breweries tend to use fairly rudimentary on/off controls, or even manual ones, which by definition are not overly accurate. However, some sort of automatic temperature monitoring and control system is essential in my view."

Bailey sought a solution that would overcome cost barriers and technical hurdles around automated temperature control. The Logo 8 system replaced time switches and relays, counters and protective relays, with potential to be networked with other Siemens technology.

At the 220-year-old Palmers Brewery in Dorset, head brewer Darren Batten was using diaphragm valves that

required regular checks. By installing a Simatic S7-1200 PLC, the brewery team was able to fully control the temperature during the fermentation section, and also to run a profile – for example, a controlled temperature rise and a specified hold time at a top fermentation temperature.

For the final duration of the process, temperatures are dropped by around 15° to stabilise and condition the brew. The 1200 brought consistency and acts as a blind device working for the team and supplying info on screen. It can be viewed or adjusted from anywhere in the plant so when ambient temperatures vary in the winter and summer months, the 1200 can be programmed to incorporate cooling capabilities such as running mains water round a tank.

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Advanced Manufacturing

Casting around for some bigger things in aero

ome of the biggest titanium aerospace components in the world can now be produced in the UK, with the launch of a new castings facility. The newly operational furnace, at the University of Sheffield Advanced Manufacturing Research Centre, has

Manufacturing Research Centre, has three interchangeable crucibles with the capacity for melting 250kg, 500kg and 1,000kg of metal.

This allows it to produce titanium components weighing between 60-500kg.

There are only a few furnaces in the world capable of producing titanium castings of up to 500kg, which requires a molten mass in excess of 1,000kg, according to AMRC castings research and development manager Mark D'Souza-Mathew.

To produce complex, near-netshape components, the titanium is first melted and then poured into a mould representing the intended part.

But titanium is highly reactive when exposed to atmosphere, so the process must be carried out in a vacuum to prevent explosions, said D'Souza-Mathew.

"There are many safety and cost considerations when casting titanium, and it is for these reasons that foundries don't tend to go above the 100kg poured mark," he said.

The researchers are studying the risks and benefits of casting large-scale near-net-shape components in titanium and also planning to improve the process by reducing the amount of material wasted, said D'Souza-Mathew.

"When you cast titanium it's so reactive that even under vacuum it

reacts with the mould, so you have a 300-micron interaction layer that develops all over the surface, which is essentially unusable," he said.

The researchers hope to reduce the size of this interaction layer by up to one-third, using a previously developed technique.

Casting titanium produces near-net-shape components, which in itself reduces wastage considerably when compared to traditional forging techniques. The so-called buy-to-fly ratio, or the amount of purchased material that is eventually used in the finished component, can be improved from 5:1 with forging down to 1.5:1 using casting, he said.

The technology can also produce improved material properties, such as the use of enhanced cooling to better control the material microstructure.

The new Sheffield furnace is being supported by the UK's Aerospace Technology Institute; Innovate UK; and the High Value Manufacturing Catapult.

In just under two months' time over 500 exhibitors and three shows – Subcon, the Advanced Manufacturing Show and The Engineer Design & Innovation Show – will come together to create one of the events of the year for British engineering.

Subcon is the UK's only event dedicated to outsourced manufacturing, while The Advanced Manufacturing Show covers every aspect of production technology. Meanwhile, The Engineer Design & Innovation Show offers everything a design engineer needs to create innovative new products.

Individually, each event caters for an important area of industry, but, together, the three shows represent a compelling proposition for visitors and exhibitors alike.

Away from the exhibition, floor two packed conference programmes will provide visitors with a great opportunity to catch up on the trends and technologies shaping industry. *To find out more and to register for free visit: www. advancedmanufacturing show.co.uk*

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AUTOMOTIVE

Hyper-car set for 'ferocious' feats

New T1 Evo by Liberty has been designed to exceed previous Evo models Helen KNIGHT REPORTS

The T1 Evo incorporates active aerodynamics and canopy-style cockpit

new hyper-car inspired by fast jets, which will be engineered and manufactured in the UK, has been unveiled

today by Liberty Vehicle Technologies. The new T1 Evo by Liberty, which will be produced at the group's new £10m centre of excellence at Learnington Spa, is designed to exceed the performance of previous Evo models.

The T1 Evo, which is being developed by the group's Liberty 920 Engineering (920E) business, will incorporate features, including active aerodynamics and suspension, a heads-up display, and canopy-style cockpit, said Anthony Blackwell, managing director of 920E.

"While the exact specification and experience will be reserved for its eventual owners, I can say it is expected to stand shoulder to shoulder with some of the most ferocious performance vehicles on the planet," he added.

Limited to a production run of 25 vehicles, the Evo will also include a bespoke powertrain system with optional all-wheel-drive configuration, a new carbon-fibre chassis, and driveability enhancements, including ABS, traction and stability control. The vehicle is designed to showcase the engineering capability of the Liberty House group, to which Liberty Vehicle Technologies belongs, said Blackwell. "It will be created at the new advanced engineering facility, and will be led by the engineering team there," he added.

As a technology showcase, it will incorporate high-performance brakes developed by 920E, which supplies advanced braking systems to Formula One, NASCAR and other motorsports, as well as precision castings and control electronics from elsewhere in the group.

"There will also be an element of electrification and hybridisation," said Blackwell.

The company will also be using 3D-printing technologies to produce some of the titanium components.

Although the company has yet to finalise the production schedule, vehicles can be reserved from today, according to Blackwell.

The hyper-car is the next generation of the T1 high-performance vehicle that still holds the original *Top Gear* track record. Early development of the hyper-car has been undertaken by Liberty's engineering team, in collaboration with Daventry-based race-car design specialists JRM Group.

Also unveiled is a new 50,000ft² centre of excellence, which is set to open in early 2018 and has been designed in a bid to boost the group's technological development firepower, and to enhance its manufacturing capability in advanced automotive components.

The engineering centre, which will be built next to the existing 920E facility in Learnington Spa, will act as a group-wide development centre, housing a range of design and manufacturing activities. These include the 920E braking systems business and its integrated electronic lightweight park brake system.

The new centre of excellence will also design and manufacture the Trillion by Liberty range of premium bicycles.

Liberty, a supplier to several major vehicle manufacturers, including Jaguar Land Rover and Nissan, also announced that it has acquired Daventry-based vehicle control systems business Shiftec, which develops advanced mechatronics.

"There will also be an element of electrification and hybridisation"

Anthony Blackwell, Liberty Vehicle Technologies

Announcing the new investment, Sanjeev Gupta, executive chairman of the Liberty House Group and the GFG Alliance, said the UK has a vibrant vehicle manufacturing industry, which produced over 1.7 million cars and 93,000 commercial vehicles in 2016. "That provides a huge opportunity to grow our own domestic supply chain and provide UK auto producers with local alternatives to the flood of imported components currently used in British vehicles," he added.

The GFG Alliance, of which Liberty is a member, is pursuing a strategy known as Greensteel, in which it is attempting to connect low-carbon UK metal, manufactured using recycled materials and renewable energy, with advanced engineering, to produce high-value automotive components.®

AUTOMOTIVE

Making a new generation of London taxis

Electric black cab plant opens in the Midlands

JON EXCELL REPORTS

A new facility for manufacturing electric black cabs has been opened by the London Taxi Company (LTC). The new plant, at Ansty Park, near Coventry, is the first all-new vehicle facility to be built in Britain for more than a decade and the first dedicated electric vehicle (EV) factory in the UK.

It will be used to produce rangeextended electric vehicles, including a next-generation London taxi: the TX5, a purpose-built, mass-market electric taxi.

This new vehicle, which will go on sale in London later this year, features a three-cylinder Volvo petrol engine that is used as a generator for the vehicle's battery pack and electric motors. The car is claimed to have a pure EV range of over 70 miles. The facility, which has the capacity to build over 20,000 vehicles per year, is the result of a £300m investment from LTC's Chinese parent company Geely Automotive.

The site will also become a globally connected research and development centre in EV powertrains and lightweight aluminium body structures, which will be applied in all vehicles made at the plant.

According to LTC, all vehicles produced at the plant will go through the most stringent testing regime in the company's history. Each test vehicle will cover almost 500,000km, often in extreme conditions. Chris Gubbey, CEO of LTC, said: "Today marks the rebirth of the London Taxi Company. A company with a singular vision; to design and build dedicated urban commercial vehicles that can operate without emissions in cities around the world and bring down running costs for drivers."

Business secretary Greg Clarke added: "Our iconic black cabs are famous across the world. The London Taxi Company's impressive new factory and R&D facility showcases the innovation that makes the UK a leader in new automotive technologies." *Turn to p29 for more on the London Taxi Company.*

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Don't believe (all) the hype

Prof Richard Hague, chair of the Additive Manufacturing and 3D Printing International Conference, talks myths and modelling

s someone who's been living and breathing additive technologies for the best part of 20 years, it will come as no surprise that I am not a fan of all the hype surrounding consumer 3D printing. For me,

it's a relief to see a marked decrease in stories on the 'wonders of 3D printing' appearing in the tabloids and mainstream media on a regular basis.

Cynical as this may sound, I have good reason: we are still constantly dispelling the 'plug-and-play' myths that have led to frustration, disappointment and unmet expectations with the technology. However, in spite of the confusion it may have caused, I also acknowledge that much of the hype surrounding 3D printing has also played an important role in advancing the technology.

The increased exposure has helped to attract the attention of a wider spectrum of companies looking at how they can benefit from additive manufacturing (AM), which has also opened an opportunity to better educate industry and governments about where the technology fits and what it can achieve.

The conversation about AM has moved from taking place almost exclusively in labs and on manufacturing shopfloors into business boardrooms. With management teams taking notice, AM is attracting more strategic buy-in and investment. Business and industry are starting to take it seriously.

Where business goes, governments also begin to follow. No one wants to be seen to be left behind, so in a drive to be the leader in profiting from additive technologies, governments – as well as industry – are starting to dedicate serious resource to developing strategies around AM.

So why does all of this matter? Does AM need to be a topic discussed in the boardroom if it works just fine in the manufacturing plants? Do governments really need to be paying attention to its potential? Is this not just another form of the dreaded hype around the technology?

The increased awareness of the strategic value of AM we're seeing is different from the hype – people are putting their money where their mouths are. We're beginning to see companies designing products specifically with AM in mind. The automotive industry is a good example of this. After mainly focusing on these technologies for prototyping purposes, it has not previously entertained the use of AM for end-use parts as costs proved too high and the materials just weren't available. Automotive companies are exploring next-generation AM systems and virtually every major car company is investigating serial productions. Cost is still a major factor, but with faster builds and more materials available, we'll soon be seeing the industry's return to embracing additive technology for larger volumes.

And speaking of materials, the growing awareness of the opportunities in additive has not been lost on the material companies. Greater investment has fuelled further research and development, and we are beginning to see a lot of exciting advances in materials, especially in metals.

We're seeing wider applications with titanium in everything from custom competitive cycle handlebars to defence technologies. Speakers at this year's Additive Manufacturing and 3D Printing International Conference will be discussing the benefits of printing metals over more traditional methods and materials such as carbon-fibre moulding.

Advancements such as those recently seen in metal AM and other materials cannot happen without research. This is where the need for greater awareness and government funding really comes to the forefront. It helps us continue to innovate and move the technology forward for maximum benefit to industry and society.

Advancements in AM cannot happen without research or funding from the government and other bodies

"It's a relief to see a marked decrease in stories on the 'wonders of 3D printing' in the tabloids"

Prof Richard Hague

Increased efforts on modelling are essential in driving development in additive. Closed feedback control modelling will help ensure repeatability of the processes, which is absolutely key for all AM.

And the innovation doesn't appear to be stopping with processes. Lawrence Livermore National Laboratory is speaking at this year's conference about pushing the AM boundaries. It has built a prototype for ultra-rapid 3D fabrication that fabricates mm-scaled structures to be printed all at once, rather than the layer-by-layer approach from which additive manufacturing derives its name.

AM has always been a disruptive technology, even before – and now after – the hype of consumer 3D printing. Education, training and success stories will only help to strengthen this perception, helping the industry to continue to develop, evolve and thrive.

Want to hear first-hand about new developments in AM? Engage with the experts and dispel the myths at the Additive Manufacturing and 3D Printing International Conference on 11-13 July

New directions on the shopfloor

A round-up of some the latest developments and innovations in the arena of machine-tool technology. Mike Excell reports

> he UK's largest machine-tool builder, Yamazaki Mazak, has signalled a renewed commitment to its UK manufacturing presence with major investment at its European manufacturing plant in Worcester. The plant opened in 1987 and produces more than 1,000 machine tools annually; as part of a programme to increase manufacturing capacity, Mazak has invested in two large machining centres from its Japanese factories. The Versatech machines will be used to precision-machine the cast-iron beds for all the machine tools manufactured in Worcester.

Marcus Burton, European group managing director, said: "This investment is a clear demonstration of Mazak's confidence in our Worcester manufacturing facility and its dedicated workforce. There is an increasing demand across Europe for the new products that have been introduced and this latest investment is part of Mazak's continuous investment strategy."

The Versatech machines are multiple-surface, 5-axis double-column machining centres, among the largest in the Mazak range, specifically designed to tackle exceptionally large workpieces. "The new machines will significantly improve our capacity for heavy-duty precision machining operations in Worcester," said Burton. "We anticipate a significant increase in productivity, due to the machine's cutting feedrate and spindle speed, which will flow through to other areas of our manufacturing operations."

While Mazak boosts capacity, other machine builders with a strong UK presence continue to launch new and improved products to meet the specific needs of UK manufacturing supply chain companies. DMG Mori, for example, has introduced a new turning centre to deal with large parts within a relatively small footprint. Its CLX350 lathe occupies under 5m² of shopfloor space, but can turn components from bar up to 51mm diameter (65mm optional) and has a maximum turning diameter of 320mm; Z-axis travel is 530mm. Spindle speeds up to 5,000 revs/min can be programmed and the cartridge design means that exchange is simple and rapid. The machine has a VDI 30 turret with 12 tool positions, all of which can be driven on request; and can be augmented with modular additions, including automated workpiece handling.

Also with a nod towards the need to make productive use of space, specifically in small part turning and turn-milling, Citizen Machinery UK has launched the third generation of its compact R-Series sliding head machines. The latest R01 and R04 in Type-VI have bar capacities of 1mm and 4mm, with common front and back spindle modules and the ability to carry up to 17 tools. Floor area required is just 1,465 x 535mm. This expands the modular design concept being progressively introduced by Citizen, and the small **01** The DMG Mori CLX350 lathe has a small footprint on the shopfloor frame construction aims to enhance rigidity and thermal stability, helping deliver precision for medical and miniature component production.

A need for stability is not confined to small components, and latest introductions from Starrag Heckert underline a claim to deliver "the most thermally stable horizontal machining centres available". Heckert Solid Rock machining centres feature a combination of water-cooled main drive motors and ballscrews, plus a temperature-controlled structure, a natural granite machine bed and thermal compensation of the linear and rotary axes. Other UK launches of note addressing larger components include a portal, 5-axis machining centre, from Italian company Mecof, via NCMT. The UMILL 1800 is designed for aerospace, oil and gas, power generation and automotive applications.

Looking at activities among machine-tool users, there's a growing awareness of changing opportunities, and SMEs such as Devon-based Investment Casting Systems (ICS) continue to look beyond historical markets and to invest in equipment to support these aspirations. ICS moved from general engineering subcontract work into toolmaking (and injection moulding services), and in 2016 set up a new >>

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>> division: Technical Composites Systems (TCS). Throughout these changes the company has looked to its principle machine-tool supplier, XYZ, for equipment and support.

"We bought our first XYZ machines, a Pro 2000 turret mill and a DPM bed mill 15 years ago and they are still with us today," said technical director James Head. The company currently runs 12 XYZ machines, including four 1060 HS (high speed) vertical machining centres, said to be ideal for the toolroom. Confidence in these machines has a significant influence on overall productivity. Some of the larger mould tools have single programme cycle times of 75 hours, so ICS schedules these jobs for Friday afternoon, leaving them running

over the weekend – and then leaving the machines free during manned hours to fit in shorter-cycle, more urgent work.

The latest machine to arrive is a 710 vertical machining centre, principally for composites work. "We created Technical Composite Systems to address opportunities in composite manufacturing," said TCS director Mike Sloan. "What we have created is a comprehensive composite manufacturing facility for the aerospace and defence sectors that will maximise the synergy between our toolroom activities and the world of composites."

Hurco has teamed up with honing specialist Bates Technologies to develop a high-precision honing process that can be carried out on standard machining centres. Benefits include cost reductions compared with purchasing and operating a dedicated honing machine; and the ability to combine general machining with honing on the same platform. eliminating a separate set-up. The process is performed on a Hurco VMX-series BT40 vertical machining centre. Diameter is rough bored to the correct size for honing, then a honing tool with a standard back end is exchanged automatically into the spindle and through-coolant is used to activate and control expansion of the tool.

02 Yamazaki Mazak has made a firm commitment to its plant in Worcester

03 Heckert's Solid Rock machines are underpinned by a thermally stable structure

04 Horn's 105 Supermini tool for single-point boring and internal grooving

05 Close-up of a bore being honed on a Hurco machining centre

"What we have created is a comprehensive composite manufacturing facility for the aerospace and defence sectors"

Mike Sloan, TCS

Toolingandworkholding

A pin vice for one-off parts, a new take on boring, and tools for the Industrial Internet of Things

A Matrix pin vice supplied by ETG (Engineering Technology Group) Workholding to Renishaw's Digital Manufacturing Centre (DMC) is enabling a cost-effective solution when finish machining one-off, prototype and first-off complex free-form parts created using additive manufacturing. Traditionally, a fixture would have been developed via initial CAD drawing, prototyping, machining and assembly; using Matrix pin vices, Renishaw can create a part-specific, stable, secure and repeatable workpiece clamping configuration that can be set up in minutes. The pin vices are fitted to the tables on Fanuc RoboDrill D21L machining centres.

Horn's 105 Supermini system is now available in new, high-performance versions featuring a new coating, substrate and microgeometry for boring, internal grooving, chamfering, threading, broaching, facing and parting-off exotic alloys and steels, including those that are structurally inhomogeneous. User benefits include improved productivity and significantly increased tool life.

Meanwhile, Sandvik Coromant has unveiled its CoroPlus suite of Industrial Internet of Things (IIOT) solutions aimed at helping manufacturers prepare for Industry 4.0. CoroPlus is the umbrella name for a new platform of connected tools and software; essentially comprising technologies that can send and/or receive data. The concept is designed specifically to improve the control of productivity and costs, through a combination of connected machining and access to manufacturing data and expert knowledge.

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State-of-the-art measurement

When commercial director Roz Bird asked Silverstone Park's engineering firms what further expertise they needed, the answer was unanimous: metrology. Mike Farish reports

ome to around 75 engineering businesses, and less than an hour's drive away for a staggering 4,000 precision engineering firms, Silverstone Park in Nottinghamshire, adjacent to the famous Formula One (F1) race track, is at the heart of one of the UK's most concentrated clusters of engineering expertise. While such a rich co-location of different

skills inevitably leads to collaboration, the park's commercial director, Roz Bird, is constantly on the look-out for ways to support the businesses there and help make them more competitive.

And when Bird asked the park's engineering firms what kind of expertise and equipment they'd like to see some investment in – the response was unanimous: "metrology".

"I was told that apart from the initial cost, the set-up, calibration and operation of the equipment required specialist skills, as did understanding the information it produced," said Bird. Moreover, having an appropriate installation on site equipped with state-of-the-art systems would also be equally relevant to many other companies nearby, not least – as Bird added – because the wider skills base that does exist tends to be monopolised by the plethora of F1 teams in the area. Hence such a facility might help extend the park's general networking activities beyond its own limits and also tackle a wider skills shortage by providing relevant training. Therefore, Bird was certain that such a capability was needed, as well as actively wanted.

The result opened in June 2016 - the Silverstone Metrology Facility, a 3,000ft² space in the park's Innovation Centre, comprising a laboratory area, plus associated meeting rooms. Equipment operated includes a Romer Absolute Arm; a Leica Absolute Tracker AT960; and an Optiv Performance multisensor measuring system. The total investment involved was some £1.4 million, of which £0.4 million came from MEPC in the form of direct outlay and foregone income from the space. The rest, however, came from the company selected by Bird to operate the facility: metrology specialist Hexagon Manufacturing Intelligence - a company chosen, she insisted, not as a mere contractor but as a "partner" precisely because it "understood that the venture is not about selling kit".

The essential details about the facility are confirmed and amplified by John Drover, sales manager with Hexagon. He is confident that the way the facility operates makes it "unique in the UK – there is nothing else like it". He said that there are several different strands of activity. At one level it is a membership organisation for around a dozen companies – whether from the **01/02** Inside the Silverstone Metrology Facility

03 Roz Bird, commercial director of Silverstone Park park or the surrounding area – and at another a provider of contract metrology services on an ad-hoc basis, which has so far worked with as many as 100 local manufacturing businesses. The key point, he said, is the absence of "hard sell" and the determination to provide companies with access to state-of-the-art metrology equipment and expertise on an as-needed basis.

One of the first on-site companies to sign up to the facility was design consultancy Performance Projects. The five-strong operation carries out work in three distinct, if related, areas: motorsports, niche vehicles and veteran cars, with the latter often including a need to 'reverse-engineer' old parts to produce replacements by modern means.

Managing director Chis Horton said that the facility can support the latter type of work in two ways. The first involves the use of its scanning or CMM (coordinate measuring machine) capabilities to record the precise dimensional details of an existing component. The other is to record an existing physical example of a part to which the intended new part would be mated. Either way the variety of parts and shapes involved is extensive. "We've done blocks, heads, timing covers and water pumps," he said.

Performance Projects may also send the facility both a

physical part and a "coarse model" in digital form that it has constructed itself on the basis of manual measurements so that the metrology equipment can then be used to improve the fidelity of that model to the required degree of accuracy.

Hence the Silverstone Metrology Facility effectively provides a design verification service to Performance Products, whose own final output is the resulting 3D CAD model in any of the three 'native formats' it uses: SolidWorks, Siemens NX and Catia.

Interestingly, Horton added that one very valuable capability the facility provides relates less to the hardware it uses than the modernity of the software that runs on it. He said that the two parties have worked together to find ways to enable the facility to return to Performance Product very rapidly files that do not use the relatively cumbersome stl format normally employed in such instances but that are instead in the STEP or IGES formats more appropriate for communicating geometric data to 3D CAD systems.

For instance, Horton said, the time for verifying and returning models of cast parts in the STEP format, which might previously have been a "couple of days", is now an equivalent number of hours.

Nevertheless, Horton added that the ultimate value of the Metrology Facility to Performance Products lies in its utility as a strategic business tool. He said that the capabilities it provides could be found elsewhere but only at a premium price from another specialist metrology centre or, perhaps, more pertinently, from companies for which metrology might be a sideline and hence his own company's work peripheral. In contrast the Silverstone Metrology Facility is not just "more cost-effective and co-located"

but also crucially providing services that are its "main function". What that means in consequence, he added, is that when Performance Products' customers ask if its metrology capabilities are state of the art "we can look them in the eyes and say 'yes'".

But as Roz Bird also made clear, the Metrology Facility forms only one element in a wider strategy on her part to make Silverstone Park a trendsetter in how business parks can act as catalysts for wider forms of business development on the part of engineering SMEs.

Another is the educational activities that take place at the park, quite separately from the Metrology Facility. According to Bird, tenants include both a University Technology Centre (UTC) with around 400 students in the age range 14-18 and

the National College for Motorsport, which tutors older students for technician roles in that sector. Students from the UTC, by the way, are a frequent presence in the Metrology Facility. She also reported that contact has been made between the park and Buckingham University, which is keen to explore how departments in areas such as law and marketing could become involved.

Moreover, the park has become involved in an initiative that is in a sense a wider version of itself – the Silverstone Technology Cluster launched right at the end or 2016 and intended to involve companies within a one-hour travel radius. By the early part of this year it already had 19 members. An enabling factor in all of this, said Bird, is simply the cachet of the Silverstone name – it is, she added emphatically, "a global brand", one that is now becoming associated not just with F1 racing but also with the development of high-tech manufacturing.

Hexagon Manufacturing Intelligence will be exhibiting on stand B63 at June's Advanced Manufacturing Show at the NEC

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Less scrappage and more quality

Measuring system helps presswork specialist. Supplier: Mitutoyo

High-speed CNC vision measuring has helped C Brandauer reduce scrappage and guarantee quality.

Birmingham-based presswork and stamping specialist C Brandauer & Co has invested over £1m in new presses and associated management systems, including an advanced 3D CNC vision measuring system from Mitutoyo.

The companies have enjoyed a long and fruitful relationship, said Brandauer quality assurance manager Robert Freeman. "Our inspection requirement is for equipment that is highly automated, fast, accurate and repeatable. Our first purchase of a Mitutoyo CNC Vision Measuring System, made 17 years ago, satisfied all of these criteria. As the system proved to be a great success, two further Mitutoyo systems were soon added. An increase in customer volumes and new business wins have necessitated the need for further investments. We also wanted to ensure we were at the forefront of advancements in the measuring field. Following an in-depth demonstration of the Quick Vision Elf Pro, performed on a cross section of our parts, we agreed that the Mitutoyo machine was ideal for our current and future needs."

The new system has allowed C Brandauer to reduce its inspection times, Freeman added. "The precision and speed of Vision Elf Pro means that we are able to give prompt feedback to production regarding component features that are beginning to deviate from their nominal conditions and ensure there are no reject parts going to the customer," he explained. "The early intervention has further reduced our already low scrap levels and helps to guarantee the continued delivery of quality components."

The Mitutoyo Quick Vision Elf Pro is an advanced 3D CNC Vision Measuring System with a resolution of 0.1µm. It provides accuracy in the 2.3µm class, when measuring up to 100mm. The machine has a measuring range of X 250mm, Y 200mm and Z 200mm and is able to accommodate multiple smaller components or a single larger part. Fine control of obliquity and direction provides optimal illumination for measurement. This type of illumination is most effective for enhancing the edges of inclined surfaces or very small steps. The Mitutoyo Quick Vision Elf Pro's programmable Power Turret (PPT) offers a threetube lens selection to provide three magnifications with the same objective lens. (9)

Metrology walks with dinosaurs

Museum uses laser scanner to measure skeleton. Supplier: Faro

Some of the UK's best-known museum pieces are getting a new look and reaching wider audiences thanks to German-based metrology specialist Faro. In what is becoming an expanding niche sector for the business, the Natural History Museum has used the portable Faro Focus laser scanner system, used commercially for surveying applications, to make accurate measurements of its famous Diplodocus skeleton that has occupied its main entrance hall, now known as the Hinze Hall, since 1979.

The Diplodocus, affectionately known as Dippy, has been on display in the museum since 1905. Over 20m long and composed of 292 bones supported on a metal structure, the skeleton is a delicate plaster-of-Paris cast of real fossilised bones owned by the Carnegie Institute of Pittsburgh, Pennsylvania.

Prior to cleaning, dismantling and packing up Dippy for its tour, the museum decided to capture the surface detail of the skeleton while it was in its mounted position. The Faro equipment was suitable for this, as it allowed multiple scans of the many component parts to be taken from different angles. The measurement process took around two hours, and the digitised model thus obtained will be used by conservators to re-erect the skeleton cast on a tour around the country.

The dinosaur skeleton is currently being replaced in the Hinze Hall by a real skeleton of a blue whale, previously on display in the museum's mammals exhibit, but being re-posed

in its new location as though it were diving from the ceiling.

Faro is also involved in this effort, with a ScanArm HD system being used to scan the bones during their move. This will give the museum a complete digital representation of the whale bones in case anything unforeseen happens during the project, and will allow it to repair or reconstruct parts of the skeleton if it was ever damaged. The first such project of its type at the museum, this is part of a much larger collaboration between the company and the institution.

The ScanArm HD system combines a fully positionable metrology arm with a handheld laser scanner, providing the option of both contact and non-contact measurement. Using a blue-line laser, the scanner captures 2,000 data points per scan line to digitise large volumes of data quickly.

Automating the inspection tasks

CMM gets to work on low-volume components. Supplier: Aberlink

Faced with a growing order book and rising pressure on its quality-control facilities, West Yorkshire-based Holtex Engineering solutions decided to automate as many of its inspection tasks as possible.

The precision engineering firm, which was launched in 2014, and specialises in high-quality prototype and low-volume production components, turned to UK CMM manufacturer Aberlink for a solution.

Following an in-house demonstration of Aberkink's Xtreme co-ordinate measuring machine (CMM) the firm decided to take the plunge and invest in one of the machines.

Designed with a novel non-Cartesian structure this stand-alone measuring system uses advanced linear motors and precise mechanical bearings. According to Aberlink, this configuration ensures that the CMM maintains its accuracy at very fast measurement rates and doesn't suffer from the accumulative inaccuracies that occur in conventional 3-axis Cartesian arrangements.

The system uses Aberlink's renowned 3D software, a key feature of which is that a simultaneous picture of the measured component is created on the computer screen. Dimensions between the measured features, mirroring those that appear on the component drawing, can be simply picked off as required. In essence this 'smart' software represents an intelligent measuring system that is able to automatically recognise and define the various features being measured.

Holtex director Ben Robinson said that the system has increased inspection precision capability and speeded up both production and inspection routines.

"The Xtreme CMM has proven very easy to use, extremely accurate and, due to its CNC nature, extremely fast. As our machine operators have responsibility for the quality of their own output, they have quickly mastered the use of the Xtreme and make regular use of the new CMM."

He added: "Typically, our personnel will use the Xtreme to measure first-offs before commencing on production runs, and to make occasional in-process checks."®

Aberlink will be demonstrating the Xtreme CNC Coordinate Measuring Machine on stand C63 at the forthcoming Advanced Manufacturing Show (NEC, Birmingham, 6-8 June)

Height gauge measures up

Trimos V5 gauge works on machined tubular components. Supplier: Bowers

In an effort to boost the efficiency of its manufacturing, Leicestershire automotive supplier Voestalpine Rotec Ltd invested in measurement technology from Bowers Group.

Based in Hinckley, Leicestershire, Voestalpine Rotec manufactures products ranging from simple bush tubes to complex assembled parts. The firm supplies components to a variety of global automotive OEMs, and even produces titanium frames for foldingbike manufacturer Brompton bicycles

Components are typically manufactured using laser-machining techniques, and many have complex dimensions that are notoriously difficult to measure. Indeed, particularly intricate components may have over 20 individual holes and slots, which, until recently, required operators to move away from their machines and use linear gauge and shadowgraph instruments.

Bowers Group supplied Voestalpine with a Trimos V5 Height Gauge to ensure the accurate measurement of machined tubular components for the automotive industry.

Suitable for lab use, the system can also be used with software that transfers the measurement data straight to a computer.

The firm's kaizen manager Keith Wileman said the system's ability to perform different measurement tasks, alongside its repeatability and accuracy, has made it a great investment. "The Trimos has enabled us to make huge improvements to processes with regard to both capacity and time," he said. "For example, a

measurement that may have taken 30 minutes to complete previously can now be completed in approximately three minutes.

"The automatic recording of measurement data has been a major impact in reducing time spent by quality engineers filling out results and has removed the possibility of human error," he added. "Also its ease of use were important considerations in the purchasing of the Trimos V5. The data acquired from the Trimos V5 has also enabled us to generate automatic spreadsheets as supporting documents that satisfy customer requirements on the part-approval process."®

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From ideas to execution

An end-to-end manufacturing service allows inventors and engineers to rapidly transform their CAD designs into tangible products. Andrew Wade reports

> he American venture capitalist John Doerr has a saying: ideas are easy, execution is everything. As a qualified electrical engineer and backer of some of the world's most successful tech companies, Doerr knows all too well that ideas are ten a penny. Forging an idea into something of value is where the real alchemy is.

> Plethora is a San Francisco-based start-up that aims to make that path from idea to execution a whole lot easier. Its end-to-end manufacturing service allows inventors and engineers to rapidly transform their CAD designs into tangible products with as little

friction as possible. Using software that works in tandem with SolidWorks, users are able to upload their designs, get instant feedback on price and feasibility, and choose their shipping date. It's a manufacturing solution designed for the iPhone generation.

"A lot of times people don't really care about how things are done in the backroom," Jeremy Herrman, Plethora's founder and CTO, told *The Engineer*. "They care about what actually drives the whole product development lifecycle faster. We're here to make it as easy as possible for companies to make their parts and get that quick prototype work done really, really fast."

According to Herrman, Plethora helps avoid the prolonged dialogue that often takes place between designers and manufacturers. Communication between the two can bounce back and forth multiple times before anything is achieved, with

discussions over price, quantity, materials, and shipping all necessary. With Plethora, a user knows immediately if the company can fulfill a design, how much it will cost, and when it will be delivered.

"We have a piece of software that lives inside SolidWorks, and it's basically able to analyse your designs," said Herrman. "You download our software, click one button to analyse the part, and it will tell you if our factory is able to make it and give you helpful feedback.

"Our software knows everything about our factory. It knows every tool that we have, every material, every piece of stock that we have, as well as all of our capacity to know if we're going to be able to make it. We think that the ability to have instant feedback in the workflow is a huge deal. It's a really big value-add, because as you're designing – even from **01** Plethora's software knows exactly what the factory can produce

02 Parts can be milled in a range of materials

03 Plethora founder and CTO Jeremy Herrman the first sketch and extrude – you can see if we're able to make that."

Perhaps unsurprisingly, Plethora's model is widely used for prototyping and short-run manufacturing. The company's 3-axis and 5-axis CNC milling machines can help turn orders around in as little as three days, with a coordinate measuring machine (CMM) used for quality control on all finished parts.

But not all production is short-run, and not all customers are operating out of garden sheds. Alongside the inventors and hobbyists, Plethora also counts major industry players among its fans.

"We also work with some of the Bay Area's biggest companies," Herrmann explained. "We have people that are making anything from flying cars to lab equipment. We definitely help a lot of folks across both big and small companies."

Having an eclectic mix of customers is clearly something that Herrman enjoys. Plethora's website states that part of the company's vision is to make manufacturing accessible to all, removing some of the high barriers to entry that currently exist. Someone with a new idea for a product or a part could easily be discouraged by the complexities of the manufacturing supply chain, and providing these

particular people with an outlet to bring their designs to fruition is a big part of Plethora's remit.

But enabling the little guy is only half the story. Herrman points out that many of the big companies in the Bay Area who started in software have begun branching into hardware. While lots of them have their own job shops, they can often get backed up with work. Plethora's manufacturing model means it is well positioned to pick up that slack.

"We've found that even companies that have their own machine shops in-house, if they're backed up on capacity we can solve that instantly," said Herrman. "They also want to deal with as little red tape as possible. That's what our model allows. Some of these guys, they need something yesterday, and they're able to very quickly see if we can make it or not." While the factory floor currently only hosts CNC milling machines, beta testing is under way for turning. The company has plans to add additional types of tooling processes further down the line, all incorporated into its highly automated manufacturing system. It's this holistic, 'full-stack' approach that distinguishes Plethora from its competitors, according to Herrman.

"Because we've automated a lot of the backend factory processes of turning a 3D design into instructions for machines – everything from toolpath and how we're going to hold it, to operations and process planning – we're able to crank out parts very quickly," he said. "And that's a lot of our special sauce."

Those parts can currently be manufactured in 24 materials, including a number of aluminium and copper alloys, various steels and stainless steels, and a wide range of plastics. All of these can be selected via the front-end interface, which also features a calendar that gives customers scaled pricing for the coming days and weeks. For rapid prototyping, a user might pay a premium for a three-day turnaround. Conversely, a hobbyist with time on their hands might prefer to pay a lower price for a later shipping date.

"We want to be flexible for our customers," Herrman said. "If you don't need your design in a couple of days, if you want to push that out, that lets us be more flexible with our capacity and we'll give you discounts for that."

Due to the sensitive nature of much of the work carried out by the factory, Herrman is reluctant to name names when it comes to customers. However, he does throw *The Engineer* a bone by saying Plethora has done work for a very large electric car company. Whether or not that company is Tesla, one suspects that Elon Musk would approve of the novel approach Herrman and his colleagues are bringing to manufacturing.

The company currently employs 45 people, including everyone from software engineers, to computational geometry scientists and factory foremen. That number is almost certainly set to rise over the coming years, as Plethora expands into different materials, tooling techniques, and perhaps even different markets. It's a model that has the potential to work virtually anywhere, and Herrman said that setting up additional shops was a possibility Plethora was looking at. For now though, everything is still manufactured in San Francisco, but the destinations of the parts extend much further afield.

"We have a lot of customers in the Bay Area, but we've shipped parts all across the US," said Herrman. "We've even shipped to the UK and to China, believe it or not. You maybe wouldn't expect to see a lot of activity there, but they need parts too!" B

Wiping the slate clean

The UK faces major challenges in dealing with nuclear waste, which means an abundance of opportunity in the industry. Evelyn Adams reports

ast month, a £6.1bn deal to clean up the UK's redundant fleet of Magnox nuclear reactors was pulled after the government mishandled how the work was awarded. Dr Paul Dorfman, University College London's nuclear power expert, believed it was "inevitable" the deal would fail. He claimed the challenges of decommissioning nuclear plant and dealing with their waste have

long been underestimated.

This has proven to be an expensive mistake. Taxpayers

must now pay almost £100m in compensation to companies who bid for Magnox work in the UK but failed to get it. The main problem, according to Dr Dorfman, is nuclear power plants were built in a rush in the 1950s with little thought given to how they might be decommissioned. Each Magnox reactor is unique so taking each one apart has its own very specific challenges.

Dealing with these challenges requires a range of engineering and project management skills, many of which are transferable from other industries. Opportunities for engineers in the sectors are many and varied, and most recruiters have their own training schemes to develop the next generation of talent. With the government waking up to the scale of the problem, there has never been a better time for engineers to embark on careers in nuclear waste management and decommissioning.

Graduate schemes are one route into the industry. "The Office for Nuclear Regulation [ONR] is sponsoring me through a graduate scheme called nucleargraduates," said Samuel Harvy, a nuclear graduate with ONR. "This scheme will give me a great depth of experience of the nuclear industry by providing the opportunity to complete three secondments at different organisations over a period of two years. Alongside these secondments, there are numerous training and development opportunities, including training zones, professional courses and STEM engagement."

Graduate schemes can help provide an overview of the industry.

01 Spent nuclear fuel in one of Sellafield's storage ponds

02 Sealed containers of high-level nuclear waste

"The Thorp and Magnox facilities present major decommissioning challenges"

Chris Hope

But there are also other routes, including short courses. Birmingham University currently offers a Nuclear Decommission and Waste Management MSc/PG Diploma. This can be gained through one-year full-time study, or a two-year part-time course.

Given the rapid nature in which its nuclear power plants were built, the UK has a varied portfolio of facilities to decommission. The ONR currently oversees the licensing of 17 nuclear sites that are slated for decommissioning and clean-up. These include Bradwell, Berkeley, Dungeness A, Trawsfynydd, Hunterston A, Hinkley Point A, Oldbury, Chapelcross and Sizewell A. But by far the most complex is Sellafield perched on the Cumbrian coast.

Currently, Sellafield has one of the large stockpiles of untreated waste in the UK, including 140 tonnes of civil plutonium. That's more than 14,000 times the amount needed to make a nuclear weapon. Material at Sellafield is expected to remain radioactive for 100,000 years. In 2002 work began to make the site safe. This involved engineers using an automated dismantling machine alongside a remote-controlled manipulator arm and crane to take the site apart.

Engineers must now manage what is left from early nuclear research at the site. There are no blueprints making it even tougher for those involved. But from this challenge, UK engineers have become world leaders in decommissioning, developing skills that they can export throughout the world.

In Cumbria, Sellafield is one of the region's main recruiters, with more than 500 engineering apprentices currently on its books along with hundreds of graduates and more than 10,000 employees in total. New recruits have a diverse range of skills, ranging from project management to chemical engineering and robotics.

Beccy Pleasant, head of skills and talent for the NDA, said: "The first issue is that we've got an ageing workforce. People have been in the industry a while and those people are starting to think about retirement now, so we need to replace those skills.

"The other issue we've got is that STEM subjects, more recently, haven't been very popular with school students so we haven't got the same pipeline pumped full of people with the basic-level science, technology, engineering and maths skills to be the future workforce."

Keiran Doyle, a nuclear worker apprentice at Sellafield, said the reason he chose an apprenticeship was because he wanted transferable life skills and to earn while he learned. "My role is to make sure all equipment and materials are prepped and ready to allow the plant to run smoothly," he said.

"Some of the activities I am involved in include bringing the waste containers over onto plant, introducing them into the cell, making sure that the glass and sugar are ready... I would definitely encourage people to pursue a career in engineering. There are a wide number of routes to take so whatever you are into there will be a role that fits."

In January, it was announced that funding of £3m will be offered by the UK Nuclear Decommissioning Authority (NDA) and Innovate UK to develop and demonstrate technologies that could help resolve some of the complex challenges associated with dismantling facilities at the Sellafield site. The Integrated Innovation for Nuclear Decommissioning competition will focus on robots and remotely operated equipment.

Two of Sellafield's major facilities for reprocessing used nuclear fuel are set to close by 2020, when the site will move to full-scale decommissioning and waste management. Technical innovation manager Chris Hope, who is on secondment to the NDA's Technology Team from Sellafield, said: "The Thorp and Magnox reprocessing facilities are unique, contain hazardous environments and we know they will present major decommissioning challenges in the years ahead so we are aiming to encourage early solutions."

It's not just Sellafield where there are plenty of opportunities. The British nuclear decommissioning industry is currently worth more than £1.7bn of business per year for UK companies, with around 21 per cent spent with small and medium enterprises (SMEs). And many of the skills can also be transferred abroad. So far, nuclear power stations have been built in 31 countries, but only six have either started building or completed construction of geological disposal facilities.

Regardless of the future of nuclear power, the need to manage radioactive waste will continue for many decades. Getting the skills to deal with it now could provide an innovative, rewarding and exciting career for engineers able to deal with the challenge. (e)

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Process control tools with multi-window technology

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For more than 20 years GESIPA® has been able to monitor setting processes that are carried out on safety critical components in many industrial production processes especially automotive sector. The production and installation of airbags, belt restraint systems and child seats have been monitored successfully and efficiently for years. Over the years, GESIPA® has developed technology to such an extent that it is now able to guarantee that the right blind rivet, rivet nut and nut studs are placed in the right place and in the right quantity for vital applications. The basis for monitoring the WinTech setting process is the tried and tested TAURUS® C. The setting process is evaluated with the aid of position and force sensors as well as integrated electronic circuitry. Up to three evaluation windows can be configured with special setup software. A coloured LED on the tool shows the result of setting process monitoring. With a data line, the values can also be recorded and further processed.

If an irregularity is detected, the process is immediately stopped. It is only after the customer has acknowledged the malfunction that the process can continue – making human error more or less impossible.

Clutches make sure of close coupling to diesel engines

Over-centre clutches are available in two mounting styles. Sponsor: JBJ Techniques

Mechanically and hydraulically actuated over-centre clutches are available in two mounting styles, speed increasing or decreasing gearboxes and oil bath clutches.

■ 'BD' series clutches for close couple to diesel engines with SAE-style flywheel facility.

- 'BDS' for independent, in-line arrangements, capable of accepting high radial loads and transmitting powers of up to 850 kW as standard. Versions available to close couple hydraulic pumps to the clutch output shaft.
- 'RM' version gearboxes are designed for close coupling to industrial diesel engines and are available in either speed increasing or speed reducing format.

Gearboxes can be supplied with output shaft either same or opposite rotation to input shaft. Input to the gearbox can be made either by rigid/flexible coupling or via a 'BD' series clutch.

Oil bath clutches are free-standing clutches of the multiple plate, oil bath type. These clutches are particularly suited to arduous applications and are capable of withstanding high radial loads. The PFI 60 and PFI 120 are

manufactured with input and output shafts. The PFI 60P and PFI 120P are intended for hydraulic pump direct connection with the same pump adaptor flanges and couplings as on AM 230-450 pump drives, which means the possibility to fit a large number of pumps with standard components.

Rapid insert moulding and overmoulding services expanded

Proto Labs has expanded its services.

Sponsor: Proto Labs

Leading digital manufacturer, Proto Labs, has officially launched insert moulding and overmoulding, supported by a fully automated quoting and manufacturing process, across its global business.

Rapid overmoulding and insert moulding processes produce custom prototypes and on-demand production parts in 15 days or less. They use aluminium moulds that offer cost-efficient tooling, and moulded parts that can be manufactured from a range of thermoplastic and liquid silicone rubber materials.

With overmoulding, the production of the substrate parts is a standard injection moulding process involving

an aluminium mould with no heating or cooling lines running through it. Cycle times are a bit longer, which allows Proto Labs moulders to monitor fill pressure, cosmetic concerns, and the basic quality of the parts.

When the total run of substrate parts are moulded, overmould tooling is then assembled to the press. The substrate parts are placed by hand into mould where each part is overmoulded with either a

thermoplastic or liquid silicone rubber material.

Insert moulding is a similar process but instead uses a preformed part – often metal – that is loaded into a mould where it is then overmoulded with plastic to create a final component. When the run is complete, parts (or the initial sample run) are boxed and shipped shortly thereafter.

April 1872 Time to

Our predecessors were not uniformly impressed with one of the 19th century's horological triumphs

n 1872 our predecessors published a lengthy article from an unknown contributor who had put considerable effort into describing a triumph of 19th century horology.

The timepiece – Auguste Vérité's astronomical clock – contains 90,000 components, including 68 clockwork automatons, and its numerous faces indicate time, tides and the movement of stars.

Needless to say, the editors at *The Engineer* were not wholly impressed. They understood that the 39ft-4.5in-tall timepiece was worthy of merit from a mechanical viewpoint but they doubted whether such a clock warranted the time and effort invested into bringing it to life.

Unlike our predecessors, the astronomical clock lives on in Beauvais Cathedral, France, where it has been keeping time since being installed there in 1873.

Originally unveiled at the Palais de l'Industrie in Paris in 1869, the astronomical clock – described by the contributor as "an exquisite work of mechanism and art" – was built between 1865 and 1868.

Our contributor noted that the clock – 16ft 9.5in wide and 9ft 3.5in deep – was "conceived in the severe style of the Roman epoch, but in its decorations all the riches of Byzantine ornamentation have been exhausted".

"It is composed of two very distinct parts; the first is altogether architectural, the second especially symbolical. The base is a long square and forms the ground plan of the case; and from this base rise solid pedestals which support four groups of five columns, on which rest the springings of a triple retreating archivolt, so that the case presents a porch on all its faces, having a depth of more than a metre, with an admirable perspective effect.

"On the side faces the concentric archivolts show a triple semicircular arch, which, with its three columns, enshrines a bay of unique character. On the front and back faces the two archivolts which are on the first plane form a large trilobed arcade, the top of which is 26ft 3in from the ground."

The overall description of the clock's case ends

"Scarcely has the last stroke of the hour sounded than the motor No.13 raises the hand of Christ, who gives his angels the order to announce his judgement" *The Engineer*

with a flourish, noting: "On the grand front façade, at the highest summit, in the midst of a great glory peopled with angels, appears our Lord, seated upon a rainbow; a simple cloud separates Him from Time."

While the frame of the clock bathes in divine glory, it is the workings within that bring them to life. According to the Haute Horlogerie Fondation, Auguste Vérité was a self-taught watchmaker who promoted the synchronisation of clocks using electromagnetic signals.

His first astronomical clock was built for Château de Frocourt, near Beauvais, and the clock for Beauvais Cathedral was no less complex, particularly in relation to the operation of the 12 dials that represent the 15-year cycle of Roman indiction. Visitors to *The Engineer*'s website will be able to read in exquisite detail how Vérité accounted for each of the clock's functions and the movement of automatons, which our contributor described more economically.

"Scarcely has the last stroke of the hour sounded than the motor No.13 raises the hand of Christ, who by a sign of the head gives his angels the order to announce his judgement.

"At this moment the motors No.9, 11, 12, and 14

Auguste Vérité's astronomical clock contains 90,000 components and 68 clockwork automatons

give or give back again the movement in turns or simultaneously by twos or threes, and the whole scene of the last judgement is accomplished.

"Over the principal motor may be seen an electrical commutator. This commutator would enable [Vérité] to keep mathematically to the rate of his regulator all the clocks of Beauvais.

"We think our readers will agree with us that the clock, thus graphically described with all the energy of a Frenchman, really deserves to be regarded as one of the most remarkable specimens of horology in the world," concluded *The Engineer*. "Whether it does or does not present an enormous amount of misdirected ingenuity as well, our readers must decide according to their individual proclivities." **JF** (***)

Word oftheissue

Anthony Poulton-Smith explores the origins of the word 'machine'

The use of a word today may be quite different from the traditional understanding. 'Cool' has been used since 1940 as a term of approval; yet to mean 'lacking warmth', it has more ancient origins.

Thus while 'machine' may be seen as simply something that does work, a device or contrivance, originally this had a rather different meaning. Tracing the word back to the Greek makhos or 'means, contrivance', and earlier to the Proto-Indo-European maghana 'that which enables' and from the root magh 'to be able', we find the modern use only from the late 17th century. Prior to this, any man-made device could be referred to as a 'machine'.

Interestingly, 19th century slang used 'machine' to describe human sex organs; indeed it is virtually unique in referring to male and female parts. Why? Because this slang term retained its age-old usage in 'that which enables'.

Bigpicture

London's largest-ever heavy-lifting crane is set to undertake a series of jobs at the site of the former Earls Court exhibition centre. The 120m-tall monster will be used to remove 61 'portal beams' – the large concrete beams that supported the weight of the exhibition centre – that weigh between 80 and 1,500 tonnes.

Prizecrossword

When completed rearrange the highlighted squares to spell out a tower on a castle. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

- 1 Reduced in volume by pressure (10)
- 6 Tariff in restaurant (4)
- 10 Without illumination (5)
- 11 Having capacity to soak up (9)
- 12 Be lenient with (7)
- 13 Reduces in worth or character (7)14 Shop selling miscellaneous items (7,5)
- 18 Gas mixture used in welding (3-9)
- 21 With hand brought down
- from above shoulder level (7)
- 23 Ancient galley with three tiers of oars (7)
- 24 Pad of metal strands (4,5)25 Mixture containing two or more metals (5)
- 26 Winder consisting of a revolving
- spool with a handle (4)
- 27 Small carved or moulded figures (10)

Down

- 1 Coupling that connects parts of a driving mechanism (6)
- 2 Capital of Lombardy in northern Italy (6)
- 3 Charge for getting money in another currency (4,2,8)
- 4 Mechanism that regulates movement (9)
- 5 Became more bearable (5)
- 7 Mechanical lifting device (8)
- 8 Not yet proved or trialled (8)
- 9 Loose affiliation of organised gangsters (5,9)
- 15 Plot of land rented for cultivation (9)
- 16 One worshipped to give victory in battle (3,2,3)
- 17 Used to express surprise (2,6)
- 19 A small sphere (6)
- 20 Coloured transparent gems (6)
- 22 Attach to a support (5)

March's highlighted solution was Modulate. Winner: Austin Branser

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