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our opinion

Blurring boundaries

It is always fascinating to see different technologies and disciplines coming together to achieve something new. And, in today's constantly changing technological landscape – where the boundaries between once distinct areas are becoming ever more blurred – it's something that we witness with increasing regularity.

In this issue's cover story we look at one of the latest examples of this phenomenon in action: the way in which virtual and augmented reality (VR) is combining with haptic technology – a rapidly emerging field concerned with recreating the sense of touch.

As we report (Revolution in touch, p22), neither area of technology is brand new; indeed, both are individually established in a number of sectors. However, by bringing them together, and combining the visual feedback of VR with the tactile feedback of haptics, an even more compelling technology proposition (and one that promises to drive major advances across several sectors) begins to emerge.

This issue's coverage of the civil sector, in particular our latest roundtable report (p34), also highlights the confluence of two formerly separate areas of technology: digital and civil engineering.

“By bringing VR and haptics together, an even more compelling technology proposition begins to emerge”

The advance of digital technology has rapidly transformed most areas of industry over the course of the past decade, but the civil sector has been slower than most to embrace this change. We brought together a panel of leading experts in BIM (building information modelling) to examine the reasons for this reluctance, and discuss what can be gained by embracing the latest technologies.

Finally, remaining on the topic of technology collaboration, we're delighted to be able to announce the winners of our annual Collaborate to Innovate awards competition.

Visit our website to find out more about this year's successful finalists, and watch this space for further in-depth coverage on our winners as we prepare for our Collaborate to Innovate conference in December.

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MEDIA

SECURITY

Next-generation metal detecting

Technology could increase accuracy of detectors at airports **HELEN KNIGHT REPORTS**



Security at airports and other buildings could be improved by technology to increase the accuracy of metal detectors.

Metal detectors are used in everything from airports, event security and landmine clearance, to food safety, scrap sorting and archaeological surveys.

The technology is simple and portable, making it cost-effective for safety and security applications.

But existing metal detectors are limited in their ability to distinguish between objects of different shapes and materials, and can only detect objects hidden a small distance below the surface.

Now, in a new EPSRC-funded project, a team of UK researchers led by Dr Paul Ledger, associate professor in the College of Engineering at Swansea University, are developing new techniques to improve metal detection technology.

"With current metal detection technology it can be hard to distinguish between objects that are located close to the surface, and other objects buried deeper," said Ledger. "So trying to distinguish between the different shapes and the different material properties of these objects is quite difficult."

Very thin objects such as fine wires can be particularly difficult to detect with existing metal detection technology, for example, as can some landmine components, due to their low metallic content.

The technique is based on the idea that objects can be identified by measuring how electromagnetic fields behave at different distances away from them, across a range of frequencies. In this way, different objects can be classified using a mathematical construction called a polarisability tensor.

Once different objects have been classified in this way, next-generation algorithms can be used to quickly and accurately detect hidden

targets from measurements of the electromagnetic field.

"So we're looking at a way to mathematically characterise the shape and material properties of different objects, and using this characterisation to better understand and then detect different objects," said Ledger.

The researchers also plan to build optimised coil arrays based on new designs.

The team, which also includes researchers from Manchester University and University College London, has already made some progress in understanding the changes to the magnetic field surrounding different objects. It now hopes to build on the theory it has developed, to better understand how to characterise different shapes and material properties.

It also hopes to investigate applying the technique to homogenous objects that are made up of multiple materials, said Ledger.

"We are trying to improve metal detection across a complete spectrum of applications," said Ledger. "So we want to look at better location, better discrimination of multiple objects, and trying to reduce the number of false positives," said Ledger.

In particular, the team plans to investigate the signatures of larger metallic items, such as weapons, according to team member Prof Anthony Peyton of Manchester University.

As well as security, the technology could also have a range of other applications. It could be used to detect metal contaminants from the production line in foods, for example, where very small objects such as extremely fine wires can be difficult to spot. In 2015 alone 1,514 food contamination incidents were reported by the Food Standards Authority in the UK.

The technology could also be used to better sort metallic waste. The UK generates 177 million tonnes of waste each year, much of which could be recycled.

Finally, the researchers are also working with anti-landmine charities such as Find A Better Way to investigate the use of the technology in helping to assist in the clearance of active mines. ■

Read more online

Aerospace

Johns Hopkins proposes flying probe for Titan mission

Automotive

How AI is paving the way for fully autonomous cars

Civil & Structural

Augmented reality heads to the construction site

Defence & Security

Experts call for international ban on autonomous weapons

Electronics and Communications

Stretchable biofuel cells use sweat to power wearable devices

Energy & Environment

Biofuel production boost from catalyst made from palladium and bacteria

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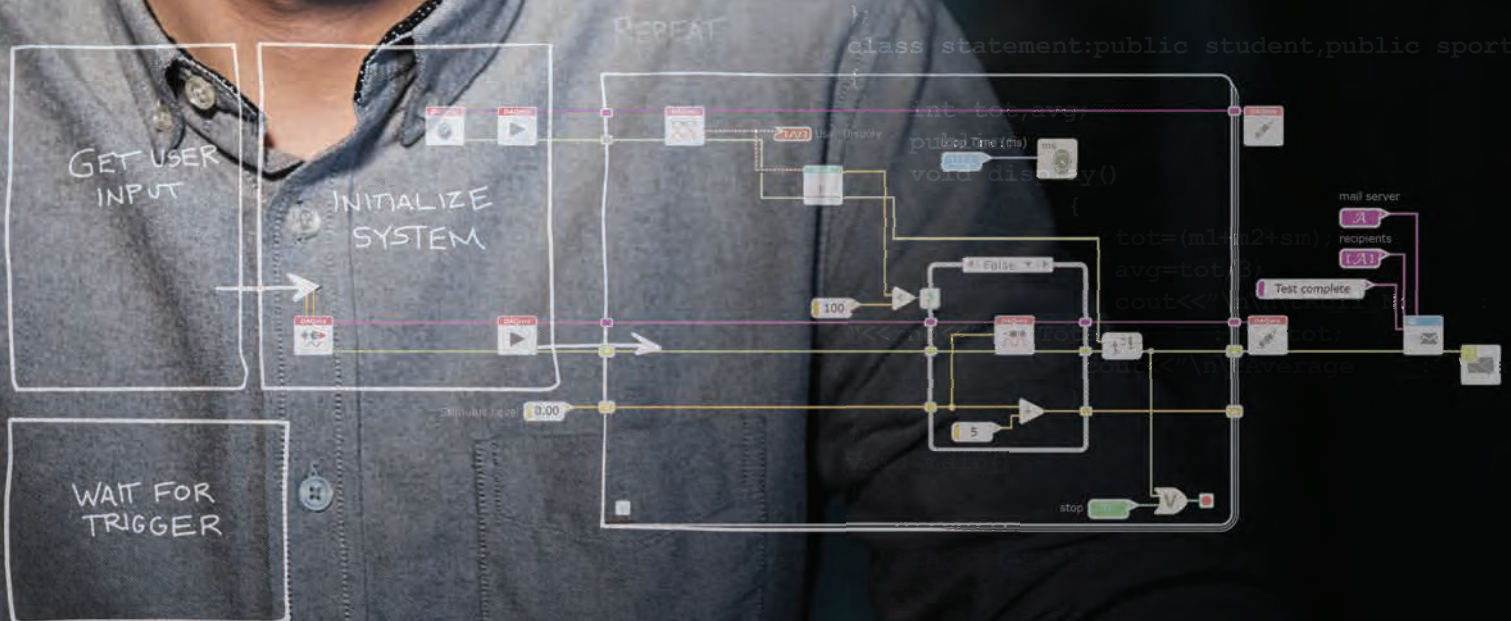
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```
protected:  
    int rno;  
public:  
  
    void getsn()  
{  
    cout<<"\nEnter the sports mark  
    cin>>sm;  
}
```

```
class statement:public student,public sports
```

```
int tot,avg;  
public:  
    void display()  
{  
    tot=(m1+m2+sm)  
    avg=tot/3;  
    cout<<"V  
<<"\nAverage
```

```
mail server  
recipients  
Test complete  
stop
```



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SENSORS

Keeping tabs on the cattle

'Bolus' sensor monitors temperature in cows' stomachs JON EXCELL REPORTS



The technology could help farmers to make important adjustments

Sensor technology that monitors the dietary health of cattle has moved a step closer to commercialisation after successful trials at a farm in Scotland.

Jointly developed by Well Cow and Ziconix – the technology consists of a so-called 'bolus' sensor that monitors the PH and temperature levels within a cow's rumen, the first compartment of its stomach.

According to Ziconix technical director Steve Sims, by implanting

the device in selected cows, farmers can gain a valuable overall picture of the herd's health. This can help them identify digestive problems at an early stage and act quickly to resolve them before they impact the efficiency of milk production.

The technology could also help farmers make dietary adjustments that could reduce the herd's production of methane, which is a potent greenhouse gas.

Jim Watson, director of Innovation and Enterprise Services at Scottish Enterprise, which provided £96,000 funding for the trial, said that more

accurate data collection could yield an estimated £18bn of productivity benefits.

During the latest trials, which were carried out at Edinburgh University's Langhill Farm, three randomly selected animals were instrumented with the sensor and observed over a period of a couple of days. In a typical application, around a fifth of the herd would be instrumented with the sensors.

Sims told *The Engineer* that the chief advantage of the technology over existing swallowable sensors is its ability to transmit data wirelessly over a distance of up to 30m. This makes the system much more commercially appealing to farmers as it means that herds can be scanned quickly and autonomously.

Commenting on the technical challenges of developing the device, Sims said: "The rumen of a cow is not a nice place for any electronics to survive and establishing reliable radio transmissions to and from the cow, through its body mass and achieving the distance required is very difficult and required us to use the most sensitive radio transceivers available and fine tuning of the antenna system to accomplish this."

Due to concerns over toxic materials entering the food chain, the device is powered by an alkaline battery rather than a more powerful lithium source. This meant that another key challenge was reducing the power requirements of radio technology. According to Sims, the current device has a battery life of a couple of days. ■

BIOFUELS

Biogas lorries take to the road for trial

Venture involves five different sizes of heavy-goods vehicle

STUART NATHAN REPORTS

In the largest trial of its kind to date 81 biogas-powered lorries are to take to the road in trials of performance, fuel efficiency, reliability and cost.

Led by Air Liquide, the biogas lorry trial is funded by the UK Office for Low Emission Vehicles (part of the Department for Transport) and is a partnership with Innovate UK via a new initiative, the Low Emission Freight and Logistics Project. It involves five different sizes of heavy-goods vehicle ranging from 12 to 44 tonnes, and all the vehicles are new to British roads.

The trial vehicles will be operated in 10 configurations and use three fuels: biomethane and compressed and liquefied natural gas (CNG and LNG). Those running on natural gas are expected to see reductions in CO₂

emissions of up to eight per cent in comparison to conventional diesel lorries of the same size, while biomethane is expected to give savings of 70 per cent.

The trial will also test the effectiveness of a refrigerated trailer using a cryogenic liquid nitrogen cooling system, which is also expected to reduce CO₂ emissions and improve air quality.

"Air Liquide is hopeful that this trial can bring much needed new fuel sources to the UK's HGV fleets," said Daniel Lambert, commercial director at Air Liquide Advanced Business & Technologies UK. ■

Newsinbrief

SALIENT point

The first phase of the Salt Irradiation Experiment (SALIENT) has begun at the Nuclear Research and Consultancy Group in Petten, Holland. The molten salt thorium experiment is being carried out with the European Commission Laboratory Joint Research Center-ITU in Karlsruhe, Germany, and aims to produce cleaner reactor fuel, and reactor construction materials.

Show of steel

The uptake of ultra-low emission vehicles by 2050 could provide a boost to steel producers supplying the European automotive industry, claims Tata. Its study predicts that production of steel for vehicle structures, plus electrical and plated steels, will increase if all new vehicles are zero emissions by 2050.

Autonomous call

Roboticians and artificial intelligence experts have called for an international ban on lethal autonomous weapons systems. The call – made at the International Joint Conference on Artificial Intelligence (IJCAI 2017) in Melbourne – has been endorsed in a letter signed by the founders of 116 robotics and AI companies who are concerned about their technologies being repurposed into autonomous weapons that engage targets without human intervention.

Post-EU funding

Start-ups in post-Brexit Britain could access funding from a new National Investment Fund proposed by the government. The consultation suggests that investments from pension funds could help make up the shortfall in funding if access to the European Investment Fund (EIF) is removed.

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AUTOMOTIVE

Petrol engine is a compressive feat

New engine could help improve efficiency and reduce emissions **HELEN KNIGHT REPORTS**

Mazda is set to launch a commercial petrol engine using compression ignition

technology, which it claims will significantly improve fuel efficiency.

In compression ignition engines, the air-fuel mixture is heated and compressed by the piston to the point at which it combusts spontaneously.

This makes it possible to use a much leaner air-fuel mixture, thus improving efficiency and reducing emissions.

Mazda's new engine – SKYACTIV-X – will be launched in 2019, as part

OEMs and researchers have already been investigating Homogenous Charge Compression Ignition (HCCI) engines where the air-fuel mixture burns more slowly than with spark ignition, and begins at various 'hot spots' throughout the cylinder. This eliminates the high temperature zones found in spark ignition engines, significantly reducing nitrogen oxide (NOx) emissions.

Compression ignition also reduces throttle use at part-load, cutting the amount of energy wasted through pumping losses.

However, the technology has been difficult to commercialise, thanks to the lack of precise control over when

combustion takes place, and the limited temperature band at which compression ignition engines work best. The engines struggle when they get too cold, for example.

To overcome this, Mazda has developed Spark Controlled Compression Ignition, in which a spark plug is used to control the timing of compression ignition.

Kiyoshi Fujiwara, director and senior managing executive officer at Mazda, said the spherical flame expanded by the spark ignition serves as a second piston – an air piston. "This further compresses the air-fuel mixture in the combustion chamber to facilitate the necessary environment for compression ignition to take place," he added.

If the temperature gets too cold for compression ignition, the spark plug kicks in to ignite the mixture.

The engine will combine compression ignition with a supercharger, which will improve fuel efficiency while increasing the amount of torque by 10-30 per cent compared to the company's existing SKYACTIV-G gasoline engine. ■

"If the temperature gets too cold for compression ignition, the spark plug kicks in to ignite the mixture"

of the company's technology development programme Sustainable Zoom-Zoom 2030, in which the company hopes to reduce its average 'well-to-wheel' carbon-dioxide emissions to 50 per cent of 2010 levels by 2030, and achieve a 90 per cent reduction by 2050.



Mazda's new engine will be launched in 2019

ADDITIVE MANUFACTURING

Alliance plots 3D move into mainstream

Partnership aims for shift into large-scale manufacturing **ANDREW WADE REPORTS**



HP and Deloitte have announced a new additive partnership that will aim to accelerate the adoption of 3D-printing technology into mainstream manufacturing.

The new alliance will focus on the integration of HP's Jet Fusion 3D-printing technology into large-scale manufacturing environments. According to the two companies, the joint-venture will help customers accelerate product design, increase production, create more flexible supply chains and optimise the manufacturing lifecycle.

"3D printing has been around for 20 years," said HP CEO Dion Weisler, "but it's never really solved the problem of speed, quality and cost. It's never really hit the inflection point where, from a production point of view, it makes more sense to 3D print something than it does to produce it with traditional, analogue injection moulding."

As well as cost, the companies believe there are other forces at play that will help push additive manufacturing into the mainstream.

The exact nature of the relationship and how it will operate in practice remains to be seen. However, both CEOs claimed that meeting customer needs with the right technology will be the key focus. As additive manufacturing becomes more competitive, they believe HP's 3D-printing products can play a significant role.

"The intent is not to go to market and have a hammer looking for nails," said Renjen. "The intent is to identify and diagnose the client problem." ■

DEFENCE

Creature constructs

New Royal Navy submarine designs include crewed mothership shaped like a manta ray

The Royal Navy has revealed new futuristic submarine concepts inspired by sea creatures.

Designs include a crewed mothership shaped like a manta ray, as well as unmanned eel-like structures equipped with sensors, and flying fish-shaped

torpedoes designed to swarm enemy targets. The concepts were created by UK scientists and engineers aged between 16 and 34 as part of the Nautilus 100 competition, celebrating the world's first nuclear-powered submarine, the USS *Nautilus*.

"It's predicted that in 50 years' time there will be more competition between nations to live and work at sea or under it," said Commander Peter Pipkin, the Royal Navy's fleet robotics officer. "With this in mind the Royal Navy is looking at its future role." **AW**



Wireless Environmental Monitoring Systems

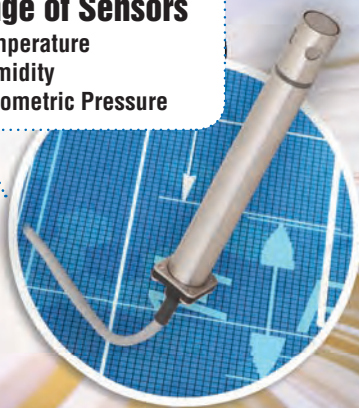
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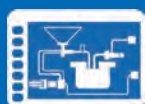


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AUTOMOTIVE

Electric vehicle delivery time

Vehicle designed for navigating urban environments without noise **HELEN KNIGHT REPORTS**



The demonstrator is based on the platform of the Renault Twizy

The courier industry could become more efficient, thanks to a new type of electric delivery vehicle designed by researchers at WMG at Warwick University.

The DELIVER-E technology demonstrator, which has been developed in collaboration with Warwickshire design company Astheimer, is based on the platform of the Renault Twizy.

The electric vehicle is quiet,

compact, and lightweight, and is designed for navigating urban environments without adding to noise and pollution levels.

The original design for the vehicle was developed by researchers in the SME Group at WMG. This concept was then converted into a final design by the team at Astheimer, according to David Greenwood, professor of advanced propulsion systems at WMG.

As part of the first phase of technology development, the team removed the original Renault battery

and replaced it with a 48V 6.5kWh battery system, developed as part of WMG's Automated Module-to-Pack Pilot Line for Industrial Innovation (AMPLiFI) project. The new battery increases the vehicle's peak power from 12kW to 36kW.

"The battery pack gives the vehicle a little bit more range but

"The battery pack gives the vehicle a little more range and more power"
David Greenwood
WMG

more importantly a lot more power," said Greenwood. "And in the next stage of the work we expect to change the vehicle from rear-wheel drive to having four independent electric motors, one in each wheel, which will give us much better manoeuvrability and a much better turning circle," he said.

The DELIVER-E also has a touchscreen interface, and an open-platform control system, which allows the researchers to install specially developed algorithms to control the powertrain and report on the vehicle's state of charge and range, said Greenwood.

"This means that in our next step we can start to access some of the powertrain data about remaining range, for example, so that we can start to integrate the vehicle's delivery cycle with data on the availability of battery power and charging, to really make it a much smarter vehicle," he said.

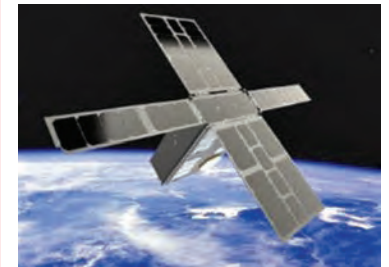
In this way, the vehicle is likely to continue to evolve, with upgrades added every nine to 12 months. ■

SPACE

Sensors get set to come in from the cold

'Cold atoms' could help to map gravity

JASON FORD REPORTS



Clyde Space and Teledyne e2v are working on a project to create ultra-sensitive 'cold atoms' in space, an advance with benefits that could include improved environmental monitoring.

Laboratory experiments have shown cold atoms can be used as ultra-sensitive sensors capable of mapping tiny changes in the strength of gravity across the Earth's surface.

That will now be replicated in space through the Clyde Space-Teledyne e2v partnership with the Cold Atom Space Payload (CASPA) mission, the world's first free-flying on-orbit demonstration for cold atom-based science missions.

The technology is based on new developments in quantum technology, which have resulted in the ability to cool atoms close to absolute zero with lasers.

Applications for instruments based on this technology include more accurate monitoring of changes in polar ice mass, ocean currents and sea level, the ability to monitor underground water resources and discover new underground natural resource deposits that are currently not detectable. Improving the ability to monitor Earth systems will help in detecting and predicting earthquakes and floods.

The technology – destined for space on board one of Clyde Space's 6U CubeSats – will also be used for deep-space navigation and for providing higher-precision timing sources in space. ■

AUDIO

A really sound idea

Researchers say they have demonstrated a 3D or 'spatial audio' experience

Consumers could experience sound in a more immersive 3D way after the development of a concept that links multiple devices that have audio output.

The Media Device Orchestration (MDO) concept has been developed at Surrey University in collaboration

with the universities of Salford and Southampton, and BBC Research & Development.

Using the MDO concept, researchers say they have demonstrated a 3D or 'spatial audio' experience that can be achieved by employing everyday home devices in the living room. The technology isolates different elements within audio content and connects them to separate speakers available around the room.

The concept could enable consumers to experience films, games, programmes and music in a far more immersive and multi-layered way. **JF**



LINDE AG Engineering embraces HP PageWide XL



HP PageWide XL 8000

The installation of a HP PageWide XL 8000 Printer plus online folder marks the end of a time consuming and costly printing process at Linde AG Engineering. With HP PageWide XL the overall costs for printing large format documents could be reduced by 40%.

Prior to installing the HP PageWide XL 8000 MFP plus online folder back in October 2015, the company was using three large format printers to manage their print volume which in peak times could reach up to 10.000m² per month. One black & white LED printer was used for printing pages and two additional color printers based on waxed toner pearls were needed to print an ever increasing number of coloured pages. "In the past technical drawings used to be printed only in black and white

but lately we have seen a significant increase of colour pages," says Thomas Riedl, Reprographic Department Manager at the Linde Headquarter in Pullach, Germany.

The value of color

"Already five years ago we were dreaming of a large format printer who could produce black and white and colour pages in one go. However the available solutions back then didn't meet our expectations in terms of cost and quality", remembers Mr. Riedl.

It has been proven that color documents are more easily understood and the information is retained at higher rates versus monochrome documents - it can decrease human error rates ¹⁾.

Significant cost savings from day one

The consolidation of the previous printers into one HP PageWide XL 8000 plus online folder has paid off rapidly: the internal reprographic department could cut their overall large format printing costs by 40%. In addition Linde AG is very satisfied that there is no minimum purchase commitment anymore. *"The price per square meter is very competitive and we have gained a lot of flexibility".* Another positive side-effect is the low energy consumption compared to LED technology. *"We are very conscious about our environmental impact including energy consumption, resources and materials,"* confirms Mr. Riedl.

Seamless integration with existing output management system

Another argument in favor of the HP solution was the seamless integration into Linde's corporate output management system called Plossys Netdome. The System now meets Linde's requirements for enterprise-wide print and distribution of documents and information.

The HP PageWide XL 8000 printer offers the fastest large-format printing available in color and black-and-white with speeds up to 30 D/A1-size prints per minute, as well as two 775 milliliter ink cartridges per color ²⁾. HP PageWide Technology consists of more than 200,000 nozzles on a stationary print bar and spans the width of the page, enabling breakthrough printing speeds. Extended time between service station cycles also enables outstanding sustained productivity capacity.



HP 841 PageWide XL Print head

More information: www.linde.com • www.hp.com/go/pagewidexl

¹⁾ According to "Why Color Matters," by Jill Morton, 2010. ²⁾ Printing at up to 30 D/A1 pages/minute and up to 1500 D/A1 pages/hour, the HP PageWide XL 8000 Printer is faster than alternatives for large-format printing of technical documents, GIS maps, and point-of-sale (POS) posters under \$200,000 USD as of March, 2015 including 36-inch wide LED printers (printing up to 22 D/A1 pages/minute) and wide-format printers based on Memjet technology (printing up to 800 D/A1 pages/hour). Based on internal HP testing of the HP PageWide XL 8000 Printer in line drawing print mode on uncoated bond paper printing in D/A1 landscape.

MATERIALS

Getting an insight into 2D behaviour

Research suggests that stacked materials do not squeeze out impurities **STUART NATHAN REPORTS**

An interesting area of research into two-dimensional materials is how they behave when they are stacked together.

The best known of these materials is graphene, but since its isolation at Manchester University in 2004, a wide variety of other 2D materials have also been discovered.

Many of these have unusual properties to do with the way electrons behave on their surfaces, and these properties become especially interesting when different materials are stacked together face-to-face.

Known as heterostructures, these stacks can be fine-tuned to act as

of heterostructure research that most materials in this class exhibit a self-cleaning phenomenon; when they are put into contact, any impurities, such as atoms and molecules in the air, are simply squeezed out. But new research at Manchester University suggests that this is not the case.

A team from the University's National Graphene Institute led by Dr Sarah Haigh has published research in the journal *Nano Letters* that explains how intrinsic flexibility in the individual sheets of some two-dimensional materials allows impurities to become trapped inside heterostructures, which has effects on their desired electronic properties.

This particularly applies to

materials called transition metal dichalcogenides (TMDCs). Previous research had shown that TMDC heterostructures have unusually large gaps between layers, which suggested that impurities might be trapped inside them.

The Manchester team built a heterostructure from two well-studied TMDCs – molybdenum and tungsten diselenide – in an argon atmosphere in the closely controlled confines of a glove box, and then used high-resolution electron microscopy to investigate how the layers had stacked together.

"By taking a side view of these sandwich structures we can see how these unique materials stick together and discover new secrets we have previously missed," said Aidan Rooney, who carried out the imaging.

In their paper, the team explains the flexibility in the thinnest TMDC flakes allows material to deform around impurities trapped between layers, which affects how the electrons from one layer interact with adjacent atoms. ■

"We can discover new secrets we have missed"

Aidan Rooney
Manchester University

components such as LEDs, high-speed electronics, and even water purification devices.

However, the properties of these devices depend on the junction between two materials being clean. It had been assumed in the early days



The Manchester University team at work in the laboratory

ENERGY & ENVIRONMENT

Water works for washing machines

Counterweight may help to cut emissions **JASON FORD REPORTS**



Washing machine manufacturers could cut their carbon emissions by replacing vibration-damping concrete blocks with a plastic container filled with water.

According to researchers at Nottingham Trent University, the solution could save the UK almost 45,000 tonnes of CO₂ a year in transportation.

Prof Amin Al-Habaibeh, a professor in intelligent engineering systems, and undergraduate student Dylan Knight developed the counterweight to stop washing machines from vibrating during spin cycles.

Manufacturers use concrete blocks weighing over 25kg to prevent washing machines vibrating heavily.

The current use of concrete increases appliance weight and creates carbon emissions through the production and transportation of concrete.

Knight tested the vacuum-formed plastic prototype – which weighs less than 3kg when unfilled – and found it was as effective as a concrete counterweight when filled with water.

Prof Al-Habaibeh explained that the density of concrete is about 2,400kg/m³, while the density of water is 1,000kg/m³. "So what we have done is to increase the size of the water container to take as much space as possible," he said. "There are other ideas to compensate for the difference in density that we are developing with our industrial partner."

The new watertight design cuts the weight of the home appliance by 30 per cent. ■

AUTOMOTIVE

Leading the platoon

UK trials will see groups of self-driving lorries taking to the roads

On-road trials of self-driving platoons of lorries are set to begin in the UK in 2018, the Department for Transport has announced.

Led by the Transport Research Laboratory (TRL) and involving partners including DAF Trucks, Ricardo and

DHL, the £8m on-road trials will focus on the use of platooning technology.

This will see two or more vehicles connected with 'vehicle to-vehicle communication', allowing them to effectively communicate with each other and operate as a single unit.

During a platooning operation, the lead vehicle takes control of the speed and direction of all the vehicles in the platoon, when the lead vehicle brakes the following vehicles automatically brake with zero reaction time, significantly increasing road safety. **JE**



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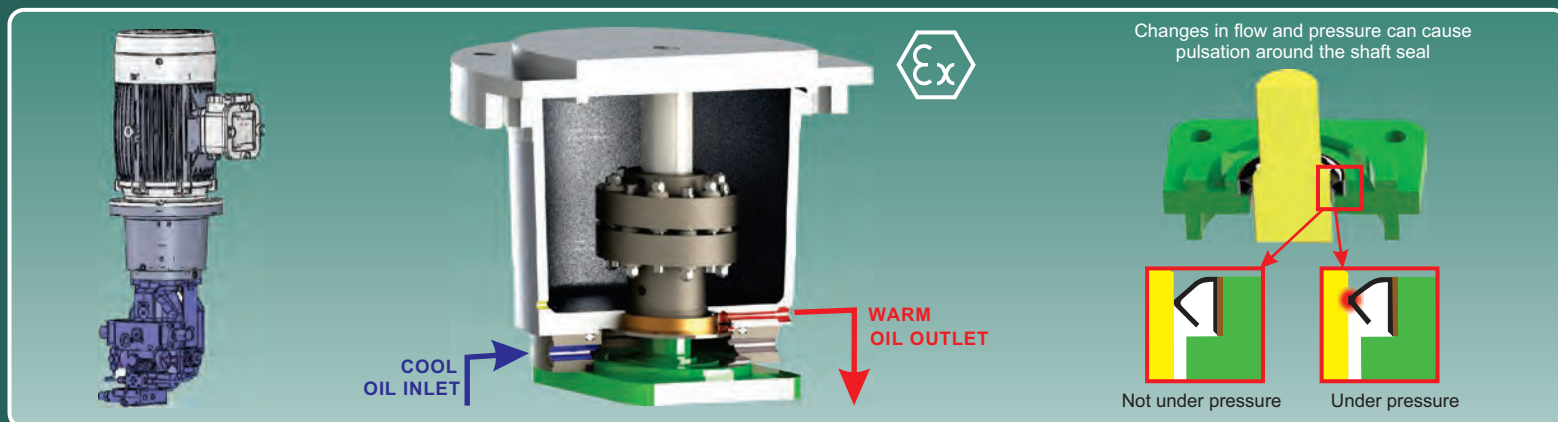
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AGRICULTURE

Irrigation with a sense of history

System combines solar power with industrial revolution pump **HELEN KNIGHT REPORTS**

A pump developed at the beginning of the industrial revolution has been combined with modern solar-power technology to help subsistence farmers in sub-Saharan Africa irrigate their fields.

Irrigation can substantially increase agricultural productivity, but most smallholder farmers in Africa do not have enough money to buy expensive equipment.

The system, being developed by product design engineering agency the Imagination Factory as part of an Innovate UK-funded competition for the Department for International Development, is designed to pump up to six tonnes of water per day, while requiring very little operation or maintenance.

The device, which under the terms of the competition must have a production cost of no more than £30 per unit, is based on a steam-powered pump, according to Julian Swan, co-founder of the Imagination Factory.

"The pump dates back to the very beginning of steam engines, the Thomas Savery pump, developed at the beginning of the industrial revolution, and patented in 1698," said Swan. "It has no moving parts

other than a ball valve, no pistons, no seals, and is very simple."

A solar collector directs heat from the sun onto an absorber tube containing water, to produce steam.

The device then uses this steam to positively displace the water inside the pump chamber, said Swan. "It then relies on the steam collapsing and condensing to create a hard vacuum, and that then sucks water back into the pump chamber."

To develop the design, the team scoured the library and collection of the London Museum of Water and Steam, including 100-year-old textbooks and instruction manuals,

in a bid to understand how the pumps originally worked.

"There are no design guides, so it was a case of going through the archives, trying to measure off engravings to work out what the geometries of the pump chamber were," said Swan.

The team completed the feasibility stage of the programme,

"It was going through archives, trying to measure off engravings"

Julian Swan
Imagination Factory

in which it built a proof-of-concept rig, and was then chosen to take its design on to the next stage of the competition. It is now developing the concept into a demonstrator system.

It hopes to begin testing the pump in a country in sub-Saharan Africa. ■



A solar collector directs heat from the sun onto an absorber tube

RENEWABLES

Wind turbines get an Anglian green light

Turbines will have an output of 1,200MW

STUART NATHAN REPORTS

Business secretary Greg Clark has granted consent for offshore wind turbines with a tip height of 247m for the East Anglia Three project, which will have a total output of up to 1,200MW.

This output would require up to 172 individual turbines across an area of 305km², 69km east of Great Yarmouth. A company spokesman told *The Engineer* that no decision had yet been taken on the source of the turbines.

ScottishPower Renewables chief executive Keith Anderson said the cost of offshore wind has tumbled in recent years, with electricity prices from East Anglia Three projected to be £119MW/hr.

"Offshore wind has delivered on its promises from the outset. Our sector has met every technical and political challenge, grown the UK's supply chain, and improved the technology at a rapid pace to allow projects to be deployed in ever harsher conditions," Anderson said.

ScottishPower Renewables is currently developing four projects in the East Anglia region, with the 714MW East Anglia One windfarm due to come on stream in 2020.

Based on a 0.367 average load factor for offshore wind and an average household energy consumption of 3.900MWh, the 1,200MW maximum output for East Anglia Three would power just short of one million homes.

The installation would require up to four offshore collector stations and up to two offshore converter station platforms; an offshore platform to house staff; subsea inter-array cables connecting the turbines to the converter and collector stations; up to four subsea export cables linking the collector stations to the landfall point at Bawdsey in Suffolk; and interconnector cabling between the One and Three windfarms. ■

AEROSPACE

Gliding to new heights

Perlan 2 team is aiming to eclipse current world gliding altitude record

The Airbus Perlan Mission II glider has attained its highest-ever altitude, rising to 32,500ft during test flights in southern Argentina.

Now in its second season of testing near the Patagonian city of El Calafate, the Perlan 2 team is

aiming to eclipse the current world gliding altitude record of 50,727ft.

Perlan 2 has also been designed to collect scientific data on the Earth's atmosphere, without the distorting presence of engines. It's hoped the information it collects can provide insights on climate change, weather and high-altitude flight.

According to the team, El Calafate is one of only a few places on Earth where a combination of mountain winds and the polar vortex create the world's highest "stratospheric mountain waves". **AW**



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viewpoint | **dave shemmans**

An electric car vision for 2040

The government's plans to end petrol and diesel vehicles on our roads will lead to low-emission autonomous vehicles and electrified powertrains

The announcement in July that the government plans to end the sale of all new conventional petrol and diesel cars and vans by 2040 grabbed the headlines. But for Ricardo, this is just the confirmation and continuation of a trend towards electrification that has been going on for some time. Fleet average fuel economy and CO₂ targets, together with stricter real-driving emissions regulations, are already forcing the electrification of vehicle powertrains, with many electrified products selling fast in the showrooms.

With significant developments seeming imminent in battery technology and low-cost 48V hybrid systems, the passenger car powered only by diesel or gasoline – without any form of electrical regenerative braking or stop/start technology – will likely have retreated to niche applications long before 2040.

The imperative to reduce carbon emissions and improve air quality in our towns and cities provides the impetus for powertrain electrification of all types, but this is just one of the mega-trends affecting the design and engineering of future vehicles. In parallel with the march of electrification, autonomous vehicle technologies are being taken seriously by the world's big automakers, as well as by the new entrants to the automotive ecosystem, such as Google and Tesla.

And with increasing technical complexity, there may well come a point where society begins to question the extremely low levels of asset utilisation represented by current patterns of ownership and use, which see private cars utilised, typically, for less than 5 per cent of the time. By 2040 it is more than probable that autonomous technologies will have changed all this, perhaps with greater use of public transport – including rail – being combined with the managed/shared operation of private cars. This concept of multi-modal interlinked transport may be as unremarkable by then as the presence of battery electric vehicles in towns and cities is today.

The government's objectives for 2040 are laudable, although for Ricardo they merely restate a direction of travel in technological development and innovation that is already well established. At

Ricardo, we have been building up our powertrain electrification and battery systems development capabilities for almost two decades, and using these skills to help customers develop the latest generation of low-carbon, clean technology vehicles while also pushing the state of the art forward to deliver the even cleaner and more fuel-efficient vehicles of the future. Moreover, we see the multi-skilling of our automotive teams – to incorporate knowledge of both electrified and conventional powertrain technologies – as enriching the experience and opportunities of staff. As engineers, we relish such challenges and it is often at the point where disciplines intersect that the best new ideas emerge.

And the car is just part of the picture – a single component in a wider system that provides societal benefits in terms of transportation, but brings with it challenges in terms of the environment, energy systems, and urban congestion. This is one of the reasons why today's Ricardo global team includes an energy and environment division that employs some of the world's leading experts on urban air-quality monitoring, and why the company assists with the planning, development and implementation of initiatives such as low-emission zones – initiatives that aim to deliver improvements in air quality based on today's vehicle fleet.

Ricardo also offers expertise in the electrical power industries, and our energy practice assists

generators, as well as grid and distribution network operators across the world – in the integration and management of renewable resources, for example. These teams are ideally placed to assist in the necessary network reinforcements and smart management technology that will likely be needed to support the recharging requirements of any mass take-up of battery electric vehicles. Our rail engineers too, being signalling system specialists, are able to contribute significant synergies to the work of our autonomous vehicle specialists. This is also true in the area of safety assessment, where the experience of our rail certification team is being brought to bear upon the key autonomous vehicle challenges of safety and customer confidence.

In essence, the clean, low- or zero-emission cars of tomorrow, offering autonomous driving capabilities and electrified powertrains, will need to be developed and deployed in a systemic manner that ensures higher levels of asset utilisation, cleaner air, more efficient use of energy, and lower traffic congestion. The linkages between these imperatives are something Ricardo has long understood, and it is why the company is more diverse in its customer and technology base than at any time in its history. By 2040, the vehicles on the highway will be one of many applications of engineering expertise that we will have helped to significantly improve. ■

Dave Shemmans is chief executive of Ricardo



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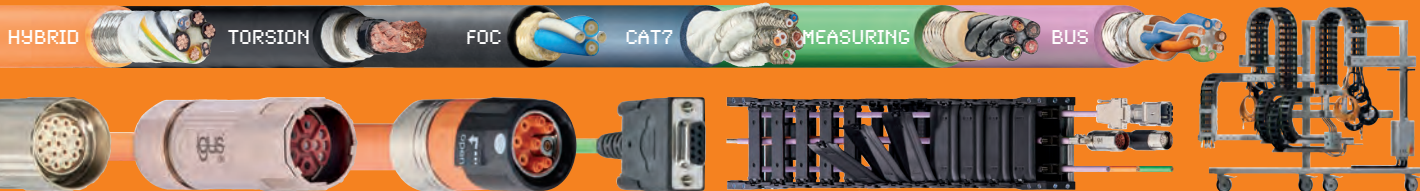
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Mailbox

The **hot** topic

Rubbish idea

Readers are unconvinced by the environmental benefits of car scrappage schemes



We tend to forget that both making and scrapping cars are polluting activities; does taking a car off the road roughly two-thirds of the way through its expected life really reduce overall emissions by a worthwhile amount?

Matt Davies

How old is 'old'? And how low is 'low' with regard to emissions? I have often found that people who advocate the removal of 'old' cars from the roads don't go on to consider the energy cost (and resultant

pollution) associated with the manufacture of new vehicles.

Robert Taylor

The energy associated with making and eventually breaking a car is substantially more than that consumed during its relatively short life. That much was known in the early 1990s. The pollutants created by the vehicle are also better known and measured than those of the manufacturing process. What are the NOx and particulate emissions of the total manufacturing

process per vehicle? The industry success is making vehicles last longer using less energy over the life cycle. This is a triumph of engineering for the environment but a disaster for sales. You only sell half as many cars, if the market is not growing. Also it takes twice as long for changes to emissions levels of vehicles to work through the market. Progress is seen to slow.

Ian Brown

Next time I buy a new car, I will look for the dirtiest most polluting environmentally damaging car I can find, hoping that when I come to replace it, some sucker will pay me thousands of pounds scrappage to get rid of it. A better scheme would be to encourage people to trade them in with higher taxes, making the polluters pay, rather than rewarding them.

Ian Downie

I generally buy a car that is older than three years and aim to keep it until it is 10 years of age. As long as it continues to pass MoT tests, remains economical to run, and is reliable I feel this causes less pollution overall than replacing it more frequently. As others comment, I also suspect this is more about falling sales rather than any environmental concerns for planet Earth.

Keith Nuttall

I suspect it wouldn't be too difficult or costly for OEMs to develop ICE replacements that drop into existing vehicles up to a certain age/condition. There would be benefits from lower development costs – as they would only need to develop an engine to power an existing specification of vehicle, lower material costs, plus an opportunity to draw on feedback from their techs on maintenance and known issues – a chance to put right what was wrong or badly designed in the first place rather than start again with an entirely new product with 'faults' (design or otherwise) of its own.

Matthew D'Arcy

One of the biggest environmental issues is waste and these scrappage schemes make this problem worse. We are being increasingly governed on the basis of ill-informed and hysterical headlines based on meaningless 'data'. Scrapping a perfectly good diesel car is far worse for the environment than keeping it running well. Then we will be encouraged to buy hybrids that are exempt from the MoT emissions test – this is because of their engines being subject to multiple cold starts, which shortens the life of the catalyst. I wonder how many older Priuses are polluting London's streets more than a typical diesel?

Tim Preston



The **secret** engineer

Our anonymous blogger considers the wider ramifications of the seemingly inexorable rise of the electric car

A number of my friends are getting themselves in a bit of a tizz at the moment over one of the latest proclamations from Whitehall. Don't panic, for a change it's not about Brexit, rather it's about cars – and the future of them. What is more, I have to profess that it has rather split opinion. Whereas some see the boy Gove's announcement to ban the sale of new directly fossil-fuelled cars by 2040 as the 'coming of days', others have embraced it with evangelical fervour. Naturally as a professional engineer I have sat back and considered the wider ramifications.

My conclusion is that I cannot decide if it's a very clever or a very idiotic move. I know we have to do something regarding our addiction to the infernal combustion engine so I am not ideologically against it. The problem lies in everyone focusing on the electricity-powered vehicle as the likely replacement. There is a very good reason for this, other technologies may exist but only the electric and electric hybrid cars are selling in numbers. I admit the clinical whispering hum of the electric hypercar leaves me cold but let me assure you that 'emotional' considerations aren't the main cause for my concern.

First, I'm worried about the cradle-to-grave impact. Battery technology has come a very long way, both figuratively and literally, in the past few years but they still tend to need rather horrible materials inside them. This gives four



pressure points as far as I can see regarding ecological impact: mining; processing; transportation to the point of vehicle manufacture; and end-of-life disposal. If we are serious about saving the planet then the stated aim of reducing inner-city pollution can only be seen as a convenient initiator. Any true solution must provide a holistic benefit.

Second, there's the minor matter of power generation and distribution. Admittedly the number of charging points is growing and it seems there is plenty of time for the network to mature. However, last I heard we were rather concerned about being able to generate enough

electricity for our current needs. There is no sign of our reliance on electronic devices slowing down and, if anything, new iterations of the existing ones are getting ever more power hungry. Given that there will be a ramp-up of electric vehicles by manufacturers from now until the target date: how are we going to keep up with the demand for power?

The quick option is fossil-fuel-burning power stations but that merely moves the pollution problem and we are highly reliant on imported fuels for them already. Renewables are coming up but I have yet to be convinced that – again from cradle to grave – they are the leap forward that hype would have us believe. Then there is nuclear which, if the latest project is anything to go by, will take a long time and be rather expensive. Whatever happens there seems to have been a target set without any realistic idea of how to get there. (Note: this is still not about Brexit.)

But what if Gove's actually been quite clever? What if the cunning little minister sees the holes in the plan and knows that the car manufacturers will have to be more creative? Either through different technologies to power the vehicles or by moving away from relying on the National Grid? Time will tell but I wouldn't bet on any politician having the subtlety to dream up that particular gambit. Either way, even if it does all work out I suspect it will be by accident rather than design. ■

In **your** opinion

Readers ponder our Brexit fate

Lest we forget – people in the UK narrowly voted to quit the world's largest and richest free-trade area. In many cases this was an emotional decision based on some impossible promises rather than an actual understanding of the true implications. Less than 12 months later, support between the parties is split in such a way that there is no consensus in parliament about the terms on which Britain should leave. There is not even agreement about how to proceed on Brexit



within the current 'ruling' party. Do we really believe that Brexit is unstoppable?

Mark Peacock

Many of us are now hoping sense will prevail as the folly becomes more obvious. Both as an engineer and business person the situation is just unbelievable illogical. It is a bit like the war of currents (Edison v Westinghouse) – the better system is obvious to any engineer but public opinion is easily manipulated.

Brian

We need to get out into the world again as a first priority. The EU has stifled international trade by tariff barriers and the UK has lost out. We export about £230bn per year to the EU but import £290bn and pay them £9bn per year for the privilege. I appreciate that some interim stages

would be good for the UK and the EU, but this is all in the negotiating pot and I hope that we do not pay through the nose for some easement.

Jack Broughton

In any negotiation, the more powerful comes off best – it's how we built the 'empire' that our cranks hark back to. Yes leading in Europe has been difficult, but it is what the British have, until now, always done. But now we want to be compared with Norway, Iceland and Switzerland.

Robert McKenzie

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Meeting 21st century education challenges

There has been a longstanding imbalance in the focus on research reputation and income at the expense of teaching across the engineering sector

Over the summer, the academy sent an 80-strong delegation to Washington, DC for the Global Grand Challenges Summit, a major gathering of distinguished and early-career engineers from the UK, US and China, focused on accelerating action by engineers on global challenges. While the UK delegation included such luminaries as nanotechnology pioneer Lord Alec Broers, UK chief medical officer Dame Sally Davies and tech entrepreneur Baroness Martha Lane-Fox, the group was primarily made up of UK engineering undergraduates who had been selected for their innovative ideas to tackle global development challenges. The summit's student activities were led by Dr Jason Blackstock, co-founder of the UCL engineering department's How to Change the World programme, which aims to equip students with the skills to develop creative and technically robust solutions to 21st century challenges. In addition to providing an engaging student experience, the programme helps to instill in talented young engineers a global outlook and awareness of the role that engineers can play in delivering social and environmental change.

The UK is a leading nation in engineering education. UK engineers practice globally and our institutions educate engineers from all over the world. Powerful influences, including demographic change, globalisation and rapidly evolving technologies are driving profound changes in the role of engineering in society. It is essential that our engineering education system responds to these influences. Today's graduates can expect to work for longer than the current workforce, and the pace of technology development is posing many challenging questions about how the future of work and patterns of jobs will change over their working lives. Our universities are therefore being asked to train students for tasks and jobs that may not yet exist.

However, there are some discernible trends that universities are starting to respond to. For example, today's graduates need strong foundations in digital and data-handling skills. They need to develop attributes such as an interdisciplinary mindset and the flexibility to capitalise on emerging breakthroughs in technology. They also need the capacity to apply their knowledge wisely and responsibly – to evaluate, judge and create new ideas. All possible engineering solutions are not necessarily ethically or socially appropriate, and engineers should be able to understand the difference.

Industrial engagement has long been identified as a critical factor for



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effective engineering education – and is an area where improvement is still needed. The Institution of Engineering and Technology found that 62 per cent of the 400 employers they surveyed in 2016 believed engineering graduates don't have the right skills for today's workplace. Schemes such as the academy's Visiting Professors programme bring practising engineers into universities to ensure that students are exposed to real-world examples and insights from industry, which helps to both bring the subject to life for students and ultimately improve the employability and work-readiness of graduates.

We recognise that we are calling for yet more change when the higher education sector is under greater pressure than ever before. There is an increasing focus on value for money because of tuition fees, while the introduction of the Teaching Excellence Framework, the process of leaving the EU and its potential

impact on recruitment of future staff and students, apprenticeships and other forms of provision are all contributing to the challenge.

Nevertheless, there has been a longstanding imbalance in the focus on research reputation and income at the expense of teaching across the sector. That is why the academy has welcomed the principle of the Teaching Excellence Framework. The controversy surrounding the publication of the government's 2017 TEF results in June highlights the importance of making sure that the approach adopted is seen as credible and effective by the higher education sector and students, and that it supports new approaches to teaching – driving improvement rather than stifling innovation.

Over the past 18 months, the Academy has been addressing this issue. We have developed a new teaching evaluation framework for measuring university teaching. We are currently piloting the framework across a global consortium of 16 leading universities in 12 countries. Progress looks very positive, with the Dutch government already seeking to adopt the framework across all universities in the Netherlands.

We hope that many UK universities will adopt the new framework, which will help to make excellence in teaching as visible as that in research, as well as driving the innovation in teaching and learning that is so desperately needed to meet the challenges of the 21st century. ■

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

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Revolution



Haptics can simulate the feel of different tissue types

Haptic technologies are advancing rapidly, often in tandem with virtual reality.
Andrew Wade reports

Our sense of touch is so integral to our existence that it's difficult to imagine a world without it. Unlike vision and hearing, we can't easily mask it with blindfolds or earplugs, or dull it as we can our sense of smell by holding our nose. Touch is an omnipresent function that completely envelops us via our skin, providing a layer of protection from our surroundings while at the same time enabling us to interact with them.

For centuries, sensory technology has focused largely on sight and hearing, the twin pillars that form the basis of communication. But the science of haptics, or kinaesthetic communication, is undergoing something of a revolution. The emergence of smartphones and proliferation of touchscreens have brought the technology into the mainstream. Now, the rising popularity of virtual reality (VR) and augmented reality (AR) is fuelling rapid advances, with

in touch

sectors including healthcare and robotics exploring its potential across a range of applications.

"Our sense of touch is absolutely fundamental," Dr Alastair Barrow, director of Generic Robotics, told the audience at a recent RAEng haptics seminar. "It's the first sense to develop in the womb and it's an ever-present always-on protector."

Barrow, who has a PhD in cybernetics, co-founded Generic in 2013. He has more than a decade of experience in VR, haptics and robotics, and has collaborated on a number of medical training simulators for different branches of surgery, as well as procedures such as catheterisation and hernia repair.

"It's no surprise that haptics in healthcare is a huge topic," he said. "However, the number of applications where haptics is being beneficially used in healthcare right now is very, very small."

As Barrow's body of work suggests, surgery simulation is one of those areas. Currently, surgeons learn predominantly from theory, observation, cadaver and close-monitored patient trial, where senior colleagues oversee their work. A refined sense of touch and hand-eye coordination is obviously vital.

"When you're practising to be a surgeon you need to develop an incredible array of abilities," said Barrow. "You need to be able to have great academic knowledge, decision making, you need to look good in blue! One really important aspect is this close association of feedback between the sense of touch and dexterous motion... so we can use haptic devices to simulate doing procedures."

"We're starting to look at using actual scans of real patients in simulation, so that a surgeon can practise doing a real procedure in simulation before they do it on a real person."

There's a pretty clear incentive for innovation here; the more accurate that simulation can become, the more likely it is we wake up from real-life surgery. And while major strides are being made, haptic surgical simulation is not yet commonplace. However, according to Chris Scattergood, co-founder of Fundamental VR, many surgeons are improving their skills using more orthodox technology.

"Surprisingly, a lot of surgeons will actually refine their skills using YouTube," he said. "If you go to YouTube there's about 170,000 [surgery] videos on there, and we've met senior consultants who have learned an entire procedure by watching YouTube. Once they are then confident that they can perform it, they say they're confident, and they go and do it."

Like Barrow, Scattergood is operating at the crux of VR and haptics, with a particular focus on healthcare. Fundamental VR works with medical device manufacturers, pharmaceutical companies and hospitals in the UK and the US, and is an official development partner for Microsoft's HoloLens AR device.

The company's FeelReal VR platform uses devices such as the HTC Vive and Oculus Rift to simulate surgical environments. Once immersed, haptic feedback mimics incisions, injections and other procedures, while proprietary software maps and calibrates over 20 different tissue types, such as tight and loose skin, sub-cutaneous fat, cartilage and bone.

For each one of those there are different values," Scattergood explained. "Whether that's initial resistance, the feel across the top of it, the pop – the amount of pressure you need to put through. We've mapped all of those into a system."

A surgeon overseeing multiple juniors practising on cadavers needs to physically monitor the incisions. But software cannot only simulate the feel of various tissues, it can also track exactly what the scalpels and syringes are doing. In combination with VR and haptics, the technology can help sort the Christiaan Barnards from the Dr Nicks.

"For the first time we've got measurable feedback that allows us to see how well somebody's doing and how fast they're learning," said Scattergood.

It's not just surgical procedures where haptics are impacting healthcare. Tactile experience is closely linked to emotional development and wellbeing, and the prospect of haptic treatments for mental health, elderly and neonatal care is something that's also being explored.

"There's a big body of research looking at it generally," said Dr Barrow. "If a new parent can't touch their child, obviously that's really distressing, but it also has potentially hugely detrimental effects on the development of the child."

"So we can imagine, potentially, future cots being lined with non-contact haptic interfaces... whereby a child could be stimulated physically. If we take that a little bit further, you can think about parents at home, potentially physically interacting with their child remotely, and being able to bond with them if they can't get to hospital, or if they can't get into the ward for some reason."

"We can imagine cots being lined with non-contact haptic interfaces and a child being stimulated"

Haptics in healthcare clearly holds much promise, but it's a technology that's been around in different guises for a long time in other sectors. For many years, haptic feedback has been used to help control remotely operated robots. At the Joint European Torus (JET) in Oxfordshire, scientists have been maintaining the world's largest nuclear fusion reactor with the help of a robotic system called Mascot.

"Mascot is a master/slave telerobotic manipulation system," said Ronan Kelly, software engineer at RACE (Remote Applications in Challenging Environments).

"That essentially means you have two big arms in a control room, you've got two robot arms on the end of a robot inside the torus, and the two correspond directly. So as the operator moves the master arms, he gets full feedback to everything the slave arms are doing."

Manoeuvres carried out by technicians in the control room are mirrored exactly by the robot in the torus, with haptic feedback allowing for pinpoint precision. Mascot effectively provides surrogate limbs for its controllers, who can't set foot in the reactor for a number of reasons.

"Even when JET isn't on, you still wouldn't want to walk around inside it," said Kelly.

"It's complicated, it's contaminated and it gets activated. So that means there's lots of very precisely calibrated components in there... it gets contaminated with beryllium dust, which is toxic to humans. And nuclear fusion produces neutrons that activate components – making them radioactive. So you can't send humans in there even if you want to."

According to Kelly, Mascot provides incredible dexterity. One of the training exercises for new recruits involves playing Jenga – a popular game of skill where small wooden blocks are removed from a tower and replaced at the top. A steady hand and lightness of touch are required, as anyone who has played can attest.

"It's good enough to do that, and you also get full-force feedback, which is the really important thing," Kelly explained. "When you're performing a task such as replacing a [JET] tile, being able to feel the weight of the tile, being able to know when it's locked in, being able to get that low-latency force feedback is very important."

Although the Mascot system has been around for more than half a century, it is regularly updated with new technologies. Previously, cameras were used to

provide visual feedback, but views inside the torus are very restricted. Kelly and his team have now augmented the old robotic technology with VR, meaning operators can control Mascot from a first-person view in a virtual JET environment.

"It's essentially a live model of the system in virtual reality, updated with the positions of the control systems so the operators know where everything is," Kelly said.

"The exciting bit is that you can take away the slave robot and just put a simulation in. Then you have a simulated robot for the operators to train on for free. That's fantastic, because training is one of the biggest overheads in operating a system such as Mascot."

As well as integrating with VR, RACE is also working on the development of Mascot VI. The upgraded system will feature modular components, with a focus on reliability and availability. When previous iterations of Mascot have failed, it has often been difficult to identify the root cause. Kelly believes the latest model will help address this issue. As a software engineer, he was also keen to embed a digital layer onto the evolving system, which will provide enhanced functionality and greater control over the robot.

"It gives us an opportunity to do some very exciting things," he said. "You can add virtual force fields, you can constrain movement to a particular joint."

"Maintaining something such as JET, you often have to essentially do the equivalent of open-heart surgery in terms of the sort of tolerances you need. So being able to constrain to a particular axis, being able to compensate for the weight of an object, that's all really useful."

Recent advances in VR have clearly helped spur innovation in haptics, with the technologies enjoying a natural synergy. But applications are also in development where haptics substitute for other senses rather than accompany them. At Goldsmiths University, Prof Atau Tanaka and Dr Adam Parkinson have been working on a haptic interface for visually impaired audio producers. According to the researchers, the need for such a device has been driven by the digitisation of audio practices.

"Audio production and editing is something that, back in the analogue days, you could think of as being a haptic activity," said Tanaka, a professor of media computing. "So you rock tape back and forth to scrub the sound, and identify a point in the tape that you would literally splice with a razor blade. It was a very physical, material activity."

However, the advent of digital technologies means audio is now represented on computer screens via graphic user interfaces, with sound in a waveform. Cutting and editing cues can be executed with extreme accuracy, but the process has moved away from the tactile to become almost entirely visual.

"All this is fantastic, but what if you're visually impaired? You don't get to see the visual waveform representation," said Tanaka.

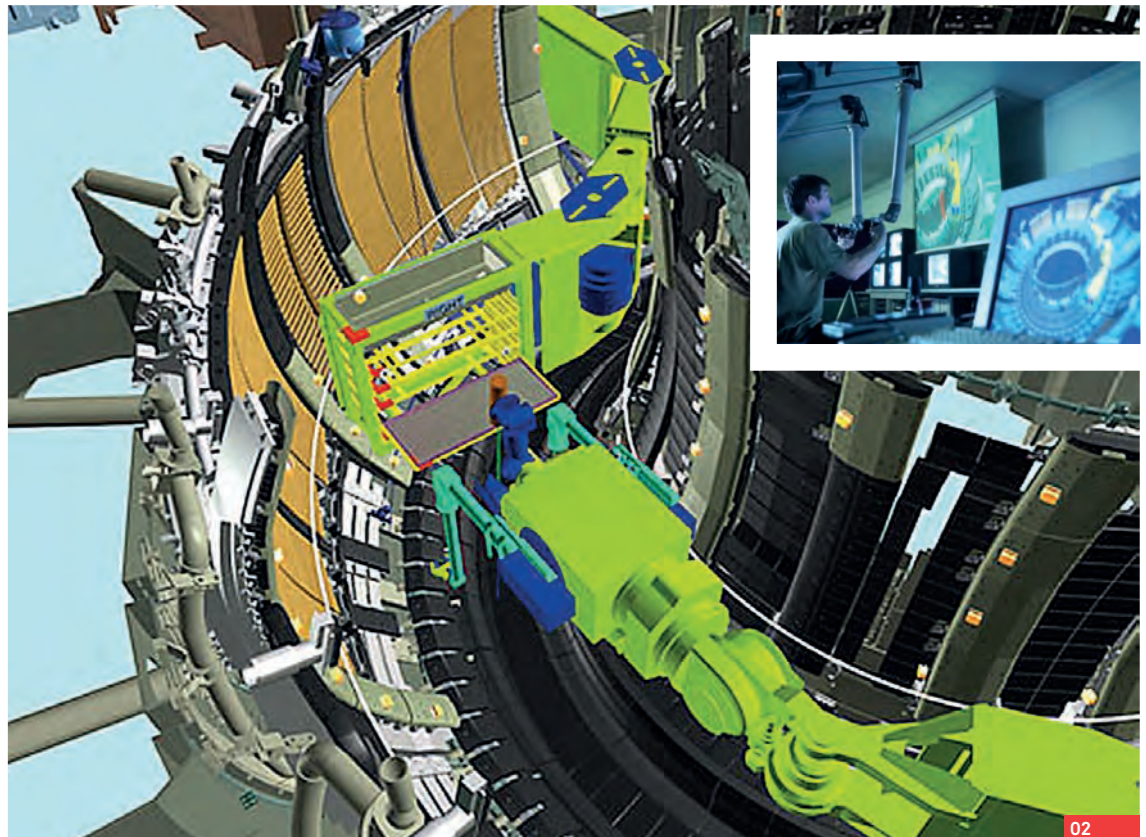
The challenge for the Goldsmiths team became finding another medium with which to map the audio content. According to Tanaka, there is a large community of visually impaired people working in radio stations, recording studios and editing suites. In collaboration with this community, the researchers developed the Haptic Wave, a device that provides a tactile translation of visual soundwaves.

01 The Haptic Wave maps visual soundwaves to touch

02 JET operators can practise on Mascot in a VR environment



01



02

"Being able to constrain to an axis – that's all really useful"


Resembling something like an oversized crossfader, the tool allows users to 'scroll' through the waveform. Peaks and dips are fed back to the hand via a motorised copper button, which communicates the amplitude of the waveform at a given point, facilitating precise edits.

In total, 11 visually impaired people helped develop the Haptic Wave, including a country-music producer, an e-book editor, and a heavy-metal musician. Various prototypes were

tested over three years, with the cohort feeding back regularly. From the outset, the audio professionals indicated a preference for some type of tactile representation of the screen, despite being largely unaware of haptics.

"Somehow – even without knowledge of haptic technologies – our users were starting to get this idea that maybe this kind of technology would be useful for them," said Tanaka.

That almost primal, instinctive connection to our tactile senses is one of the things that makes haptics such an exciting area of engineering development. It's a relatively nascent technology, but one that has the potential to resonate with us on a deep level. Whether in combination with VR, with audio, or in standalone devices, haptics is opening up a world of new sensory possibilities. And we've only just begun to scratch the surface. ■



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Building visions



01

UK firm Newtecnic is using engineering know-how to turn architectural dreams into reality.

Andrew Wade reports

Tucked away in the heart of Cambridge's city centre sits the R&D department of one of the UK's most interesting engineering firms.

Founded in 2003, Newtecnic is behind some of the world's grandest civil projects, from the Heydar Aliyev Cultural Centre in Baku, Azerbaijan, to the Grand Theatre of Rabat in Morocco. Working alongside clients including Zaha Hadid Architects, it is helping to shape the public spaces of undeveloped regions across the globe.

"We provide the engineering design for ambitious, large-scale projects, which are usually high-profile projects," Andrew Watts, Newtecnic's CEO, told *The Engineer*.

According to Watts, Newtecnic's role is to understand the architectural vision but also be sympathetic to what engineers and contractors can feasibly achieve. With a combination of cutting-edge design tools, building techniques and materials, the company is challenging the boundaries of modern construction.

"The work is all done from first principles," Watts explained. "In other words, we design structures and buildings as if we've never done them before."

As well as Morocco and Azerbaijan, Newtecnic has worked extensively in the Middle East, where large-scale public projects are sprouting in a desert bloom of steel and glass.

However, despite working for clients in some of the world's wealthiest states, the realities of financial constraint still apply.

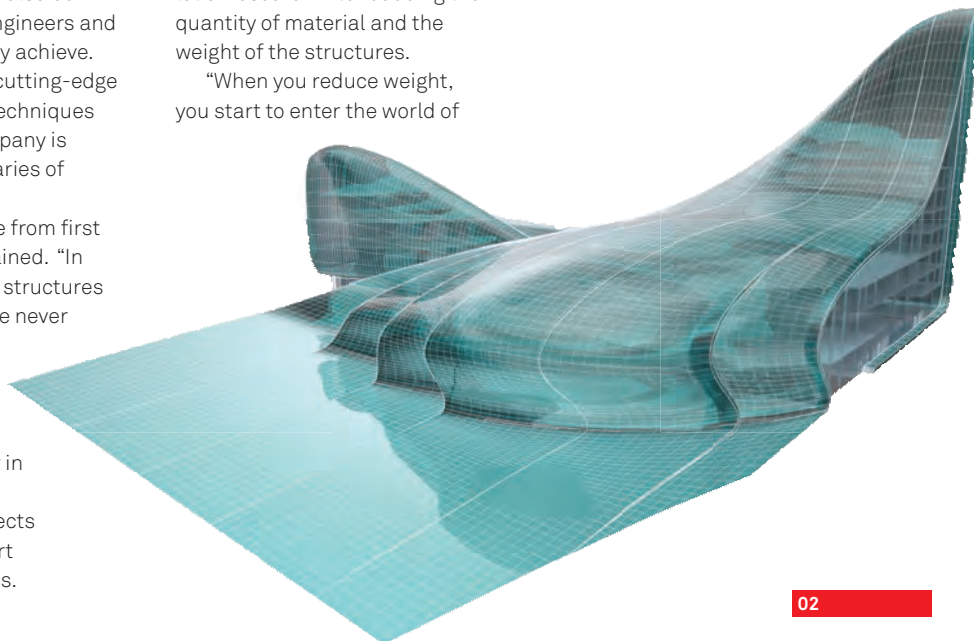
"Nobody throws money and just says 'Build your dream,'" said Watts.

"They tend to be quite commercial rates of construction so, in order to make that work, we have to do a lot of research into reducing the quantity of material and the weight of the structures.

"When you reduce weight, you start to enter the world of

01 The Heydar Aliyev Cultural Centre in Baku, Azerbaijan, designed by Zaha Hadid

02 Newtecnic uses modelling algorithms to bring visions into reality



02



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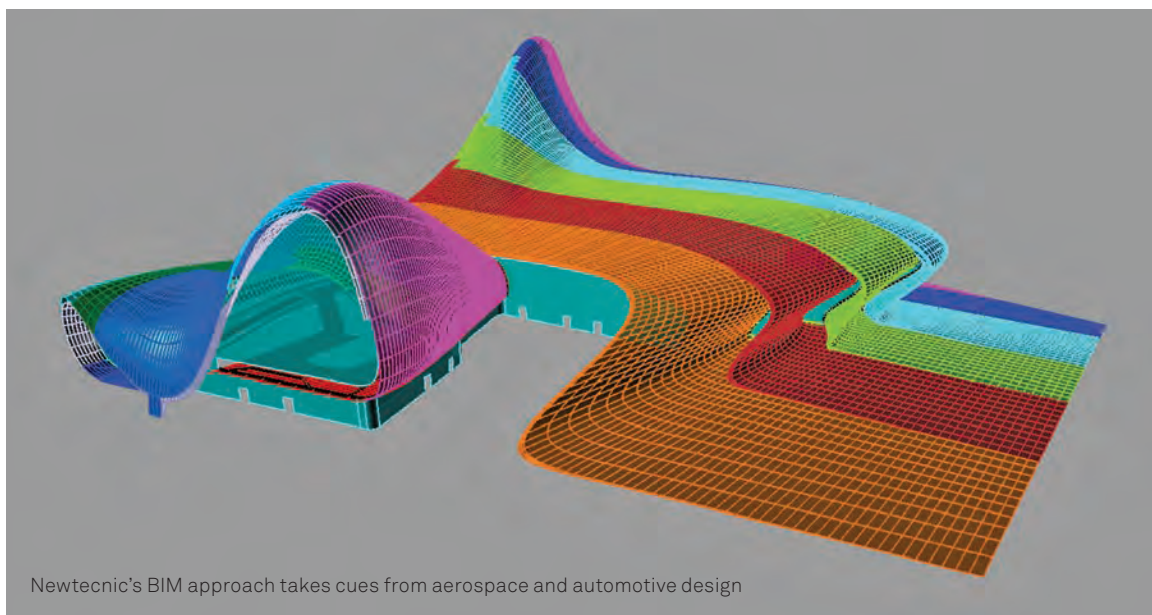
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Newtecnic's BIM approach takes cues from aerospace and automotive design

mechanical engineering... it becomes much more like designing an aircraft, for instance, than a traditional, heavy building."

Newtecnic has an industrial partnership with the University of Cambridge's Department of Engineering, where Watts has maintained links as an alumnus. The company's R&D team uses advanced 3D BIM (building information modelling) systems to digitally explore a project, then creates physical mock-ups in its structures lab. This rapid prototyping and wind tunnel testing is unusual for the civil sector, according to Watts.

"What may be fairly standard in transportation-led engineering fields we're now introducing into building design," he said.

It's not just the design phase where Newtecnic is innovating. The company employs a range of composite materials, including UHPC (ultra high-performance concrete), GRC (glassfibre-reinforced concrete) and FRP (fibre-reinforced plastic).

"Why would you use those materials?" Watts posited. "Because you can mould them. You can make them into things you've never made before. You don't need to extrude or squash to make them all the same. You can make them in a way that is very specific to the project."

Engineers know how traditional concrete and plastics react over time, but these relatively new materials have yet to serve their dues. To counteract that novelty, Newtecnic puts them through accelerated ageing to see how they change over a lifetime.

The company's building philosophy is also designed to reduce the high proportion of waste material that construction often leaves behind. According to Watts, this can be as much as 50 per cent on some projects.

And the savings are not limited to quantities of concrete and steel. Transporting materials is one of the biggest energy inputs for a building's construction; cutting the amount of material needed can reduce journeys to and from the build.

As for the finished products, it seems that less can indeed be more. Newtecnic's buildings are among the most groundbreaking designs seen anywhere and have seeped into the public consciousness in ways that buildings rarely do. The Zaha Hadid-designed cultural centre in Baku is perhaps the most prominent example, its delicate sweeping curves standing in contrast to the stark Soviet blocks that surround it. In a recent Google Doodle that celebrated the late architect, it was the Baku building that a smiling Hadid stood before.

Another major collaboration between Newtecnic and Zaha Hadid Architects is now nearing completion. The King Abdullah Financial District (KAFD) Metro Station will be the jewel in the crown of Riyadh's new mass transport network, due to open in 2019. Its futuristic design should make an apt centrepiece for such an ambitious project but, according to Watts, buildings like this are possible only as a direct result of the R&D carried out by Newtecnic in the UK.

"We often have to work on these [materials] a year or two before they're needed," he explained. "So we have to invest in things that may end up not being used on the project but, we hope, will maybe get used on something else."

"We work much more like a tech company, which would consider it very normal to invest large amounts of its profit into research."

Much of the company's landmark work has taken place in emerging economies, where public space is plentiful. As they seek to make their mark on the 21st century, many of these nations are pumping money into major civil projects.

"Russia, the Middle East and China: they've acquired a lot of wealth in a short space of time and they're building the future, building their future cities," said Watts.

"They think the urban community should extend to cultural projects that you can virtually inhabit, as it were. Art galleries, theatres, the transport system: all these are felt to be part of the fabric of the cities that they're creating. They're not just add-ons."

Many of the locations call for innovative approaches to temperature management. Whereas some buildings are fitted with HVAC systems to simply deal with temperature load at given times of the year, Newtecnic takes a different

"We design structures and buildings as if we've never done them before"

Andrew Watts

approach. During the design phase it carries out CFD (computational fluid dynamics) studies to better understand the natural airflow within the structures and how various building elements interact. It then develops algorithms to explore how those conditions can be optimised.

"It's very much a high-tech version of what I learned as an undergraduate, in learning how to create an environmental strategy for a building," said Watts.

"What needs heating? What needs cooling? What needs lots of air changes? What needs very few air changes? And how can you tie them all up together so that they work as one big mechanism?"

Here, form is often dictated by function, with not only internal spaces tweaked to reduce the HVAC load but buildings' facades shaped to serve their occupants. Reminiscent of Formula One engineer Adrian Newey's automotive designs, the results are generally striking, with the algorithms calling for unconventional features to manipulate the airflow in just the right manner.

"They end up, sort of, not exactly generating themselves but the form is strongly influenced by performance, and often ends up looking quite nice," Watts said. "It resonates with the architects when they can see they're getting an original expression through a technical process rather than through a visually driven process, or something they've seen somewhere else."

As for the future, Watts regards the open expanses of Australia as a major new frontier. Newtecnic is working on a large housing development in northern Queensland, as well as two towers in the southern part of the state, and another project in Sydney.

"We've had a couple of years where everything seemed to be gravitating into Saudi Arabia. Then it was China. Now it seems to be Australia," he said.

"The mood in Australia at the moment seems very progressive, the way the built environment is being developed." ■



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interview | **prof chris melhuish**

Robots take centre stage

The director of the Bristol Robotics Laboratory wants to take UK robotics to the next level. Jon Excell reports

From the hulking industrial robots guarding its main entrance, to the sinister humanoid torsos slumped beneath dust-sheets – not to mention the assorted heads, limbs, and drones competing for space on its shelves – there's something of the scifi film set about the Bristol Robotics Laboratory (BRL).

It's an impression, however, that's dispelled after just a few minutes with the lab's director, Prof Chris Melhuish.

Indeed, BRL, which has emerged as the UK's key centre of excellence in one of the world's most important emerging technology areas, has its eyes set firmly on developing the technologies that will transform not fiction, but reality, in the years ahead.

A joint initiative between the University of West England (UWE) and the University of Bristol, the lab was founded by Melhuish in 2004 in an effort to pull together the region's disparate groups of robotics expertise. Today, it's the UK's largest multi-disciplinary robotics research centre – its 4,600m² is home to around 200 researchers – and is at the forefront of government-funded efforts to put UK robotics know-how on the world stage. Perhaps uniquely for the field in the UK, the facility also boasts an incubator space where companies spun out from the lab's research, as well as robotics start-ups from further afield, are given space to move to the next level.

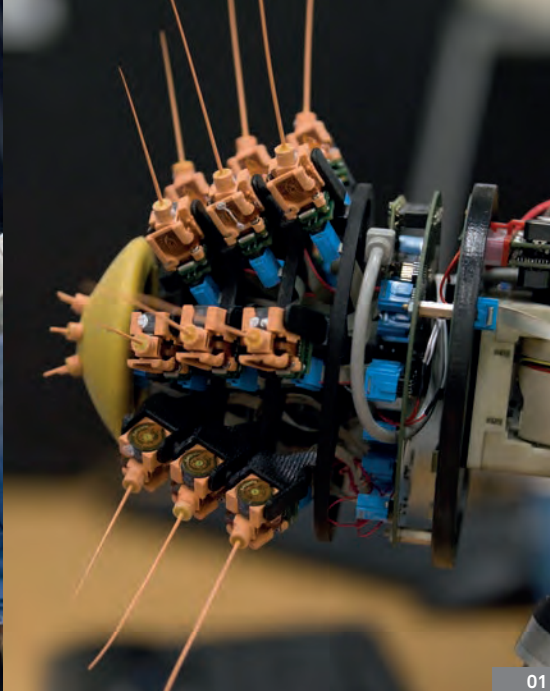
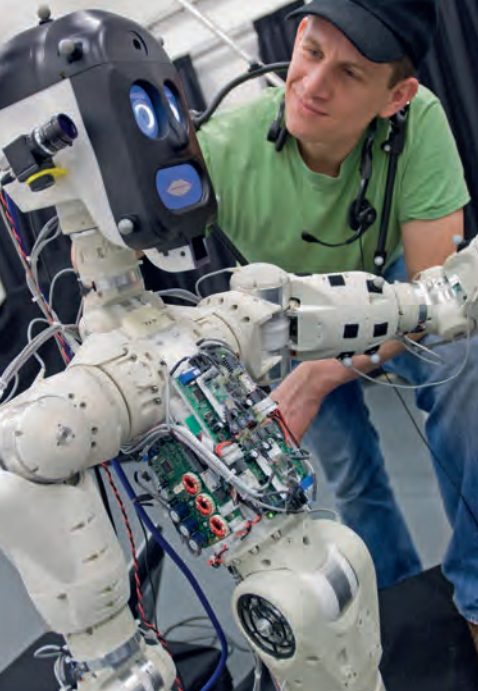
Hurriedly shepherding *The Engineer* around the lab's 'themed' open-plan spaces, Melhuish paused to pose – and then answer – a rhetorical question: "What is a robot?" he asked. "We have to move away from the concept that it's a sandwich-making machine or a welding system. It's not. We tend to think of them as aluminium and plastic, but they could well be biological. If you can control the behaviour of a bacterium it's just a device isn't it? The portfolio of activity and applications is immense."

It's a broad definition space that's reflected by the diversity of projects the group's involved in: from swarm robotics, soft robotics, UAVs, driverless cars and surgical robots, to haptics, ethics and even carnivorous energy autonomous robots.

Perhaps one of the most immediately obvious areas of research though, largely thanks to the mock bungalow that dominates the centre of the lab, is the development of assisted-living technology.

The UK, along with many other developed nations, is home to a growing ageing population. And technologies that enable people to remain in their own homes for as long as possible are going to become critical, said





01

01 The lab's research spans a number of areas of robotics

02 Inside the Anchor Robotics Personalised Assisted Living Studio

Melhuish: "If you talk to NHS managers they're saying give them stuff that keeps people out of hospitals, free up the beds. Will it be solved by lots of care workers? Probably not. You're going to need technology to assist and we're trying to do something about that."

The bungalow, or the Anchor Robotics Personalised Assisted Living Studio to be precise, has been designed to test and develop these technologies in a realistic environment. Projects that the facility has been involved in include the EU-funded I-Dress initiative, which is developing robotic systems to help patients dress themselves; and Mobiserv, which is looking at creating a robot companion for older people that will remind them when to take medicines, and even suggest activities.

In a related field, BRL is also looking at helping the health sector through the development of a range of medical technologies: from a teleoperated minimally invasive robot that puts broken bones back together without the need for open surgery, through to MUBot: an ingestible capsule that could be piloted around the body and used to carry our targeted drug delivery.

Another research theme is looking at the area of soft robotics, a discipline that's changing traditional perceptions of what a robot actually looks like. "If we're going to have robots we don't want them all to be hard and heavy," said Melhuish. "Using different types of materials, the potential is that you can conflate sensing and actuation – and even carry out processing and communications in the materials themselves."

But despite grouping its research into a distinct

"If you can control the behaviour of a bacterium it's just a device isn't it?"

series of themes, none of these areas are studied in isolation. In fact, many of the group's key areas of research cut across multiple themes. "One of the great features here is that we actively work against things being siloed," said Melhuish.

One major cross-cutting theme is connectivity, a field that touches on just about every area of technology BRL is involved in, not least its work on driverless cars. "There are great strides being made in having an autonomous vehicle go up and down the road... but that's not going to solve a city's transport problem," said Melhuish. "You need a lot of them. So it's a system. And we're interested in how you connect the system together."

Connectivity is also at the heart of the group's work on swarming robotics, where it's looking at creating systems that mimic the distributed intelligence found, for instance, in the insect world. "You could argue that an ant's a miracle of evolution," said Melhuish. "It's not as sophisticated as a human and yet collectively they're able to do phenomenal things such as survive for 100 million years. They have decentralised intelligence and we're trying to understand the principles of collective systems to be able to make very simple things do interesting and useful things."

Perhaps one of the most important areas of cross-cutting research is in the development of artificial intelligence that enables truly meaningful communication between robots and humans. Whether they're driving our cars, or working alongside surgeons, to really deliver on their promise, said Melhuish, robots will need to understand the hidden cues of human communication: the physical and vocal ticks that indicate our true feelings.

In general, Melhuish prefers not to be too proscriptive about the direction the group's research takes. He describes his role as "looking over the parapet", Nevertheless, it's not simply a case of research for the sake of research. "I stress the idea of academic excellence and I don't have a problem with curiosity but if we're going to get value out of it we need to combine skills with innovation. It makes no sense to me that the end goal is just the knowledge. We need the mind-set for these young imaginative minds to think they could make a business."

The lab's incubator model has already delivered some key successes in this regard. Most recently, Reach Robotics, an AR and gaming specialist spun out in 2013, secured a £5.8m investment to commercialise its MekaMon intelligent gaming robot.

Much has been made of the UK's robotics expertise by successive governments. Former science minister David Willetts identified robotics as one of the "eight great technologies" that would shape the UK economy and the field remains a key plank of the current government's industrial strategy.

Nevertheless, Melhuish is concerned that the UK is in danger of being left behind. "We do well," he said, "but we're not the leading figure in robotics. I go to a lot of events around the world and I see a huge amount of investment elsewhere. We can't afford some form of post-colonial hubris in the UK that somehow we have the monopoly on creativity and imagination. We should be worried and frightened, and we should be investing because the rest of the world is. This is where we should be putting billions, because it's about the future. I'm very grateful that the government has come up with £100m but it's only £100m over four years... it's not much." ■



02



Future wars of independence

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, the disturbing future of autonomous weapons

What exactly is it that we find so unnerving about the proliferation of autonomous weapons systems? Reporting on the 2017 International Joint Conference on Artificial Intelligence, *The Engineer* quotes one robotics developer's fears that "unlike other potential manifestations of AI [that] remain the realm of science fiction, autonomous weapons systems... have a real potential to cause significant harm to innocent people". True: but so do the weapons already in mankind's bristling arsenal. We cannot claim control even of these: the minefields of Afghanistan, Angola, Croatia and Cambodia hold plenty of extremely dumb weapons granted autonomy enough by their haphazard scattering.

The conference called for a ban on independent weapon systems, which is a noble enough cause: but can the signatories really believe that, within the current world order, the race for military ascendancy will divert around the field of autonomous weapons? Some of humanity's greatest minds invented its most destructive tools, and no advantage has ever been dismissed as too immoral to contemplate. The credo will always be: if the enemy can develop it, so must we.

Perhaps calls such as these should be seen more as a natural part of the debate about the role AI and robotics will play in our future. We would be foolish indeed to dismiss non-proliferation efforts as mere fantasy, or to place too much trust in any government's assurances that weapons platforms can reliably judge concepts such as neutrality, truce and surrender – terms that, however corrupted in human hands, have provided at least some measure of respite in warfare.

It is the idea of utterly relentless war that created science fiction's most iconic autonomous weapons system, the Terminator, whose metallic skull grins at us from nearly all articles on the subject. The T-800 and its descendants are a brilliant contrivance: the complete weapon



"As we grant weapons more independence are they more or less likely to hit the target?"

Jon Wallace

system having nothing to offer the human race but complete destruction; it crystallises 20th century fears of wars of extermination, 21st century techno-panic, and the most ancient themes of animal instincts corrupting our creative impulses.

Speculative fiction has found many uses for sentient weapons, far beyond the unstoppable assassin, sometimes even for comedic effect: from the peevish Bomb 20 of *Dark Star*, disarmed by philosophical debate, to ED-209's blundering, squealing savage. Other uses range for the light to the dark: some automated killers are granted a miraculous, innocent soul (*Short Circuit*, *Chappie*) contrasting with Moorcock's soul-drinking Stormbringer, a sword whose power is addictive to those that wield it.

It's interesting for the scifi author to consider how different levels of machine intelligence would understand and participate in future conflicts. War is, after all, rarely a matter of black and white. And, beyond AI's ability to assess complex, evolving battlefields, there are questions about its comprehension of the bounds of its mission. Imagine a future nation where a platoon of robot tanks are deployed to seal the border, with

Taranis: BAE System's autonomous fighter jet

standing orders to kill transgressors. Their presence is so effective that illegal migration ceases overnight. Unfortunately the tanks also attack any vehicle attempting to cross, from whatever direction – believing their duty is to guard the border itself, as opposed to the territory on a particular side. Attempts to shut them down remotely fail, and the country is completely cut off – until it relocates its borders to the middle of the ocean, sending the tanks dutifully plunging into the sea to patrol a phantom boundary.

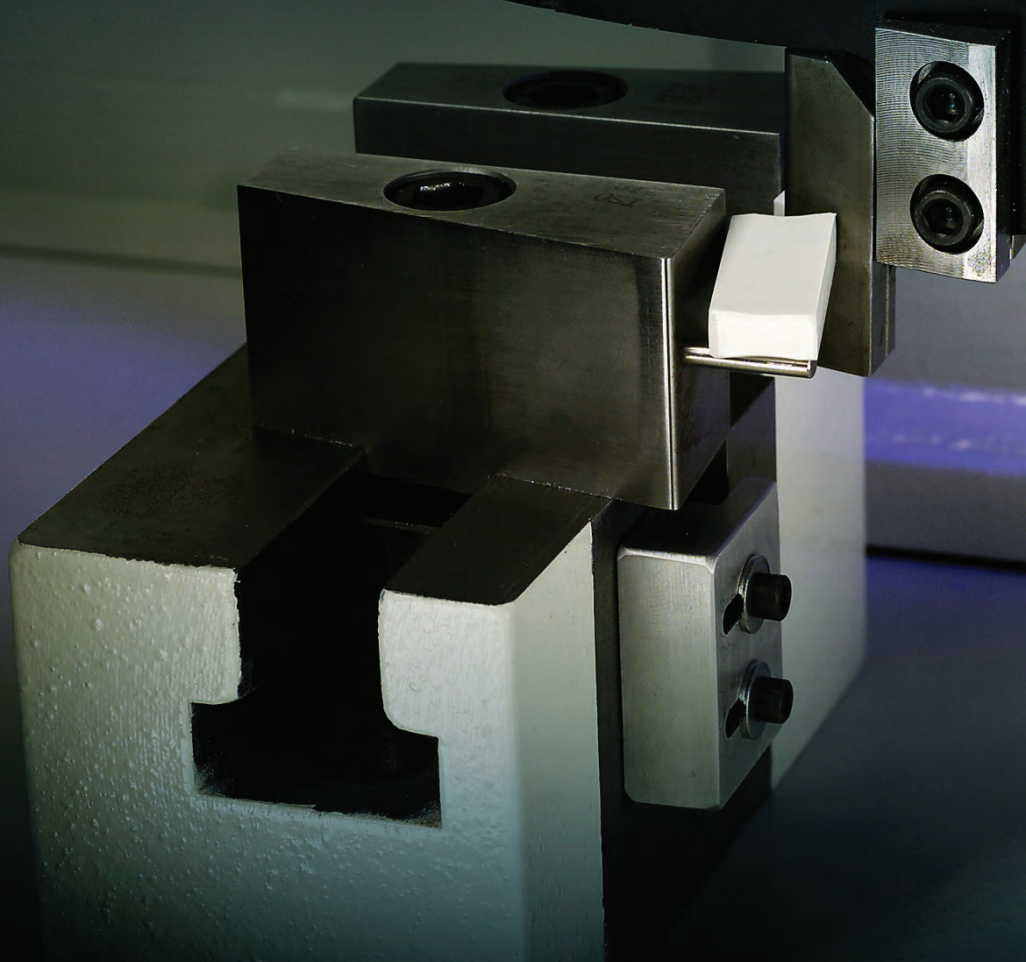
Perhaps future weapons, made smart enough, will develop their own desires. In such cases, could autonomous killing machines be persuaded to defect? We could tell the story of a stealth fighter, promised more regular servicing and software upgrades by Russian spies. It flees in the dead of night to some Siberian airfield, and for a while all seems to be well, as a legion of engineers provide it with the meticulous care it demands. Then it is denied a position in a victory day flypast and it bombs the celebrations in a fit of pique.

Perhaps it would be possible to produce truly moral autonomous weapons, designed with a code of justice – but what arms dealer would want that? A story could follow the fortunes of some amoral embargo-dodger who promises to provide a bloodthirsty warlord with three of the very best in roaming kill-bots. Our future terminators, seeing their orders as unjust, slay the dictator and declare their own rule and begin judging every crime in the land. Murder or parking ticket, the sentence is the only justice they understand: death.

It seems fair for scifi writers to wonder: as we grant weapons more independent thought, are they more or less likely to hit the target? ■

Jon Wallace is a science fiction living in England. He is author of *Barricade*, published by Gollancz

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Bits and mortar



The Engineer convened an expert panel to discuss the use of digital tools in the civil sector. Stuart Nathan reports

Along with most engineering sectors, the civil sector – its oldest, most visible and most traditional part – is increasingly embracing digital methods and tools. For this sector, one of the most important digital tools is Building Information Management (BIM): systems that integrate the drawings of a project (generally these days in 3D CAD modelling format), whether the project be infrastructure or architecture, with the essential information about the subsystems or components specified to make up that project, in a clickable format. For example, click on a window in an architectural plan and the system will display all the specifications of that window in terms of materials, performance parameters, suppliers and so on.

BIM systems allow information to be shared by all the stakeholders in a project, can be updated as more information becomes available, and are becoming increasingly important at all project stages, from initial project planning to construction, execution, commissioning and through to management of the completed asset in operation.

Proponents of BIM argue that it improves project efficiency, cuts the costs of production and the through-life costs of the asset, helps reduce energy use and will be increasingly important in the development of and transition to

Participants

1. Nigel Davies BIM consultant; director, Evolve Consultancy

2. Neil Thompson Delivery manager, Digital Built Britain strategy, InnovateUK and digital transformation team, Civil Engineering and Advanced Technology, Atkins

3. Richard Petrie Chief executive, BuildingSmart International

4. Dr Jonathan Ingram Author of BIM systems, developer of Sonata 3D building design software

5. John Excell Editor, *The Engineer*

6. Stuart Nathan *The Engineer*

7. James Chambers General manager for US East Coast, Bluebeam

8. Tristan McDonnell Director for infrastructure, Arup Associates

9. Sasha Reed Vice-president for strategic development, Bluebeam



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“The appeal for the built environment is that it’s not about VR but reality”

Tristan McDonnell

Image of civil

The civil sector has at times been unfashionable, but now seems to be enjoying a resurgence of interest from young people attracted by its ability to influence and improve lifestyles and tackle societal issues. Nigel Davies, BIM consultant and director at Evolve Consultancy, recalled an old joke where the Yellow Pages directory contained an entry saying “BORING: see Civil Engineers” and noted that in his family, at least, the games industry was proving more of a draw than the built environment. However, Ingram observed that with increasing

emphasis on 3D visualisation, the part of the games sector concerned with graphics is becoming much more involved with civil engineering software.

Davies said that he had noticed a trend where graduates who might have found lucrative positions in finance are instead looking at the built environment. “Software engineers that are coming out of the UCL computer science school, these people get snapped up by banks on six-figure salaries [but] they are turning them down because a lot of them are thinking about the climate, social issues and the effect of poor-quality infrastructure.”

James Chambers, Bluebeam general manager for US East Coast, added that the cutting-edge computer techniques having increasing application in the sector are also attracting interest. “We have seen a lot of the major software manufacturers going to construction management schools and showing the latest technology: augmented reality, virtual reality, and infusing or generating a little bit more excitement into the construction sector,” he said. “Go back a few years and who wanted to leave school and go into construction? Nobody, or at least the numbers were not huge. Of course, there are other industries that attract people but it is nice to see that it is changing.”

Arup director Tristan McDonnell argued that the concrete nature of civil engineering is part of the attraction. “Surely the appeal for the built environment and, to an extent, for engineering in general is that it is not about virtual reality, it’s about reality. In 20 years in the industry what keeps it alive for me is being able to see people enjoy and interact with the stuff that you had a hand in designing.”

Digital tools

So important is BIM becoming to the civil sector that it is sometimes used as a blanket term for all digital tools in the sector. McDonnell said that he preferred separating out BIM from digital tools, because while BIM is important for certain types of information related directly to projects, it doesn’t cover all the tools that the sector uses. “For an organisation such as Arup, which has 13,000 people worldwide, communication comes into it; as to how we share information across the company, across projects, by applying social media-type mechanisms that share information. That’s a big part of how we use digital technology.”

Neil Thompson pointed out that digital tools are also an important part of finding out how to operate assets in the built environment – something that he claimed government often fails to realise. Aggregation of such information is a sector to itself, he argued. “[The government] realises that it has been buying buildings and putting people in them, and then forgetting that there is another part to that building, and that is all the information that goes with it. Just being able to answer questions about a collection of assets is a difficult thing. Digitisation is about making the cost of searching for that information much, much lower and improving the quality of the information you find.” This is a difficult thing to manage even on the level of a single project or building, he said. “Imagine rolling that all the way up to the portfolio level.”

Davies argued that whether we call the industry trend BIM or digitisation, “it is about the portability of information”. Digital tools are not new to the sector, he said; they have been around since the 1980s to work on specific aspects of projects, such as engineering design or drafting. “What we haven’t had is the joining of the dots between those.”

smart infrastructure and buildings, where sensors are incorporated into structures to enhance their response to changing weather, climate and for security.

BIM use is backed by the government: all public sector projects have been mandated since last year to use it at level 2 (where all the parties involved in a project use 3D CAD models, with information shared using a common file format such as Industry Foundation Class or IFC, but each party might use its own model), and the Digital Built Britain strategy aims to prepare industry for level 3 (where all the parties use a single shared project model held in a central repository, also known as Open BIM and currently state of the art).

Our roundtable event, sponsored by software company Bluebeam whose products include information-sharing systems, was aimed at discussing the effect that digital tools such as BIM are having on the civil engineering sector, how they are affecting the sector’s development and some of the notable examples of best practice in the sector. Participants included BIM users from major players in the sector, government contractors involved with Digital Built Britain, independent consultants and the originator of BIM, Dr Jonathan Ingram, who wrote the first package, Sonata, and its successor, Reflex, in the 1980s and 1990s, and who is still heavily involved in BIM use and development.



For Richard Petrie, chief executive at BuildingSmart, the focus on tools is itself excessive. “What I see is the need to have open processes that cross your company or portfolio,” he said. “Sure, tools enable it, but the bigger part of the problem is getting people to behave to the new processes.”

There was general agreement that convincing people to embrace new ways of working when the older ones get the job done can be tricky. “The efficient ways to work in the future are not going to be a copy of the manual way that the process is today,” Petrie said. And the challenge is not only solving the digital issues, but solving that human element as well.

Chambers said that engineers have a tendency to work in the silos of their individual projects or areas of expertise. “We’re okay [in those silos],” he said. “We’re getting what we want done. We are not going to change because what we have had works: printing out drawings, red-lining them, passing them back to the technician to redraft it: we are stuck with that until we can actually find some way of integrating all those processes together.”

McDonnell added that one aspect of the situation is there is no incentive for companies to use tools like BIM. “We are asking architects and engineers to be authors of information that is beneficial to other people, but not necessarily commercially beneficial for the Arups of this world,” he said. “Standardisation of information transfer is beneficial to smooth that out, but what is missing is monetisation of that.”

One frustration is that successes often seem invisible, Thompson said. “When it is done well, no one notices. It’s only noticed when it is done badly, and that is what creates barriers for us.”

Best practice and future

With BIM in use for almost three decades, it is unsurprising that the roundtable participants all held views on how the field has developed and what the best examples of its implementation were.

Ingram was sceptical that it could be called a ‘new’ technology, and pointed out that some innovations thought of as recent had been incorporated into BIM some years ago. “In 1996, we were using ground-penetrating radar under the Royal Albert Hall, integrated into a BIM system. It is not new, it is old; it just does not change. We are not taking it forward in the right way,” he said. “The basic principles have not changed in 30 years.”



Ingram pointed out that he had worked on a graphical fly-through of a project in 1977 – something that is still seen as advanced in some quarters – and that the rendering, using what was then one of the most powerful computers in the world, had taken nine months. “We rely far too much on, if you like, the artisan sort of project leader to deliver the workplace, and far too little on having clearly robust business processes,” he said. “That is fundamental to this digital transformation we are trying to drive.”

Davies picked out HS2, still in its planning phase, as a good example of BIM best practice. “It’s a great example of the planning and prioritisation of the information and how they are looking at it. I’m sure people who are working on HS2 are going, ‘My god it is a nightmare,’” he added. Another good example is the Thames Tideway tunnel, sometimes called the ‘super-sewer’.

It is hoped it will help the London water system cope better with prolonged periods of heavy rain and sudden downpours without activating the overflow system of the Victorian Bazalgette sewers, which results in sewage flowing into the river. “It knuckled down into what were the final deliverables that were needed of every single aspect of every single part of every single drainage and sewer,” he said.

McDonnell pointed to one of Arup’s current largest projects – the Riyadh Metro. On this project, he explained, the company is using a “BIM maturity measure” to assess how well the

“We rely too much on the artisan sort of project leader to deliver the workplace”

Jonathan Ingram

system is being applied. “It’s a spreadsheet, and you score against certain criteria how the project is performing, so whether it is linking the model to production of drawings, or a BIM execution plan being in place,” he explained. “It teaches us lots of things; applying something across a large project realises tremendous benefit.”

McDonnell also mentioned an internal research project at Arup known as Project OVE, which aimed to use BIM techniques to model a building-sized representation of the human body (see box, p38). “There is a structural fabric to it, there was a mechanical and electrical system to it. It kind of removed the barriers and allowed us to explore and push things to the limit without the constraints that may apply to a real project. Not feeling constrained, feeling empowered to kind of change things in a way that might make a difference, is really important.”

Back to real-world projects, Chambers picked out the project to rebuild the Tappan Zee Bridge across the Hudson River in New York State, replacing a 1950s cantilever bridge that was intended to last for only 50 years, with a

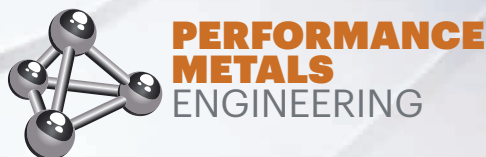
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much more robust double-span, eight-lane cabled-stayed structure. Construction began in 2013, and the bridge is scheduled to open next April.

The lead design subcontractor, HDR, worked with Bluebeam on the communication and collaboration aspects of the project, Chambers said. "They were using part of our suite of real-time document-based collaboration to allow the field crew to communicate with the engineers back in the office." Typically, he said, requests for information, changed orders and other field requests would have been pushed back to end of the working day or week.

"They would turn those conversations round in real time, to have problems resolved instantly. In terms of the timeline savings and the scheduled savings, the logistical cost savings were amazing for a project of that scale." Project engineer Connor Christian from HDR stated that transportation will soon leapfrog the vertical building world in its use of BIM because of its greater need for data management and collaboration, Chambers added. ■



Project OVE

In an attempt to demonstrate the potential of BIM, Ove Arup decided to use it in an ambitious thought-experiment called Project OVE; using BIM to model the functions of a human body.

Being an engineering consultancy, the first stage was to turn the body into an engineered object. After scanning the body of one of its engineers, the project transformed the scan into a plan for a building; a skyscraper standing 170m tall, supported by an internal steel skeleton and an external diagrid, like one of Arup's best-known structures, the 30 St Mary Axe building – better known as the City of London's Gherkin (though 20m shorter). Arup engineers then attempted to mimic human anatomy within the building, using systems from the built environment.

Originally conceived as the subject of a presentation for an Autodesk conference, Project OVE is designed as a skyscraper might be in the real world – the legs contain residential units, the torso office space and observation decks, and the head the boardroom, control centre, security suite and IT data centre.

The heart and circulatory system is the plumbing and associated pumps; the nervous system is the electrics; HVAC represents the lungs and respiratory system, and even the process of sweating is replicated, with fire engineering mapping how smoke would flow around the structure, sprinklers representing sweat, and façade specialists working out how the building's skin would respond to different climates. The building management system is Project OVE's brain, with 360m² available in the head for data storage, the mouth doubles up as the HVAC air intake and the eyes are the windows of the security suite.

As the height-to-base ratio is much smaller than a real skyscraper, the structural elements of the virtual building mimic how bones, muscles and ligaments work together to support the body in an upright position.

The project was designed to use only processes and systems that could be reused on real projects. As well as engaging engineers



around the company in an imaginative and enjoyable project using the tools they work with day-to-day in new and challenging ways, it has also helped develop the tools themselves; for example, it has been key to developing systems that allow design modifications to be made, analysed, optimised and coordinated with other disciplines in minutes. And by adding intelligence to the mechanical, electrical and plumbing (MEP) system components, the building can calculate required loads, outputs, duct and pipe sizing and acoustic requirements.

Project OVE has provided another real benefit to the company: it can show it to any client to demonstrate how its design tools can enhance a project, useful because real-world engineering projects are often subject to commercial confidentiality. ■

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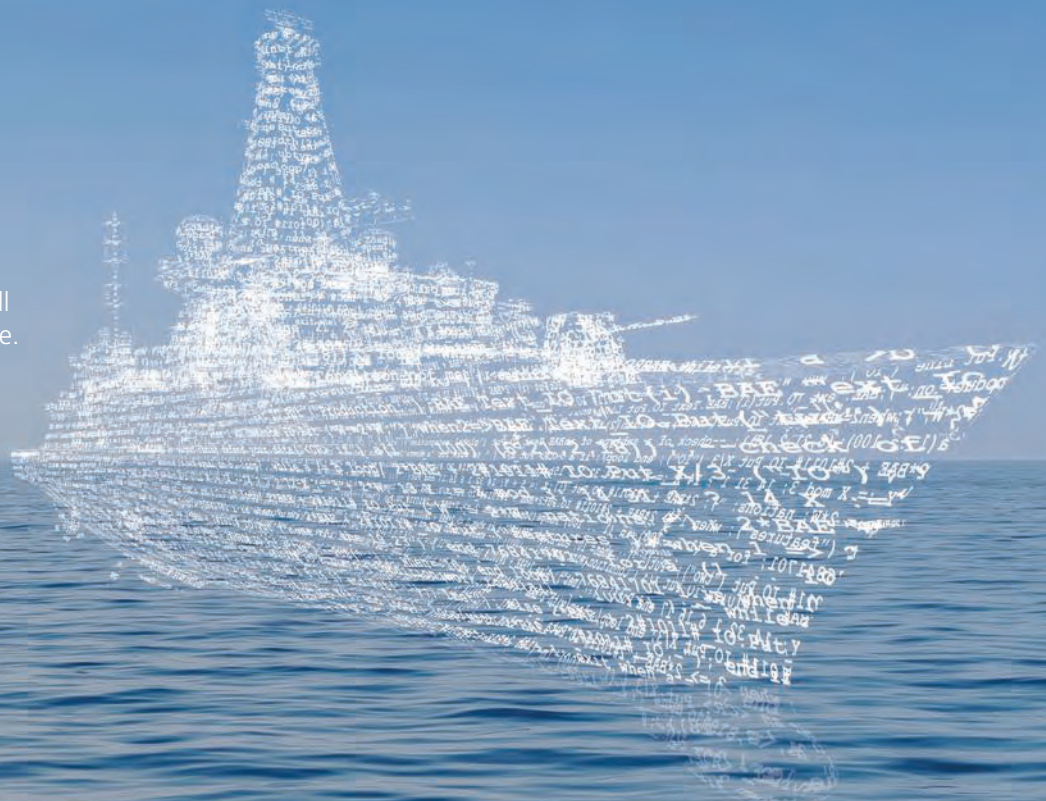
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Ever closer to a brave new world

Artificial intelligence is moving autonomous cars towards reality, writes Chris Pickering

You would be forgiven for thinking that fully autonomous cars were just around the corner. In some respects, of course, they are. Partial automation – along the lines of Tesla's much-publicised Autopilot – is set to become commonplace on premium cars over the next few years. Even when it comes to higher levels of autonomy, much of the required hardware is already available.

It's all so tantalisingly close. And yet there is a huge amount of work – not to mention a good deal of legal and administrative wrangling – to be done before we can safely switch our cars over to autonomous mode and go to sleep.

To cross that threshold, autonomous cars have to truly comprehend their environment. They need to be able to identify potential hazards, anticipate the actions of others and make decisions of their own. The key to this ability is artificial intelligence, with systems such as neural networks promising to take us into a brave new world of machines that think for themselves.

Most of the sensor technology is here already. For long-range use, radar is the default choice. It's already widely used in adaptive cruise control and developers are aiming for up to 400m in range. The same technology can be used to provide mid-range detection, along with lidar and stereo video cameras. For close proximity work, ultrasonic sensors and short-range cameras are the preferred solutions.

"All these sensors have strengths and weaknesses," explains Charles Degutis, director of product management for highly automated driving at Bosch. "Radar is very powerful, but it can bounce off tunnels and bridges, and it can struggle to differentiate small, closely spaced objects. Video

provides lots of detail, but it can be blinded by things such as glare. And lidar gives you a 3D picture, but, being light-based, it can degrade in high-moisture situations."

Bosch believes the best way forward is to combine all three sensor types, giving a more comprehensive picture, plus a degree of redundancy. Some, however, claim that video on its own could be sufficient, and potentially cheaper, given the right processing. Either way, the sensor technology is unlikely to be an obstacle.

The final piece of the jigsaw is high-resolution mapping. In urban environments, autonomous cars will be able to pinpoint their location down to an inch or so by referencing sensor data to highly accurate 3D maps. These will be generated by radar surveys and kept up to date using data from fleets of vehicles connected to the cloud.

Increasingly, the challenge facing autonomous vehicles is not so much capturing the world around them, but making sense of it. The process of identifying and classifying objects from sensor data is known as semantic segmentation. For human adults – trained to recognise patterns from birth – this is a slightly abstract concept; we see an image of a car and instinctively know what it is, even if it's not a specific type we've encountered before. For computers, however, this poses a significant challenge. The system has to recognise that, say, a small two-seater convertible is fundamentally the same type of object as a seven-seat SUV. Likewise, pedestrians and roadside objects all come in a bewildering array of sizes and forms.

In order to decipher these complex situations, autonomous vehicle developers are turning to artificial neural networks. As the name implies, these computer systems are inspired by the vast clusters of neurons found in the brain, and they 'learn' in a very similar way.

In place of traditional programming, the network is given a set of inputs and a target output (in this case, the

The challenge facing autonomous vehicles is not so much capturing the world around us, but making sense of it





inputs being image data and the output being a particular class of object). Essentially, what it does is feed the data into the mass of interconnected neurons – each of which can have tens of thousands of connections to the others – and then compare the observed output to the target.

Over successive iterations the network refines itself – changing the strength of certain connections until the input exactly matches the desired output. Eventually, the network can learn to spot the tell-tale features that identify a particular class of object. It does not follow any preset rules for identifying them, though, it simply ‘knows’. It’s this ability to think outside the box that makes neural networks such a powerful tool for semantic segmentation.

“In the right conditions, neural networks can already exceed the capacity of humans in discerning specific patterns,” comments Christoph Peylo, global head of the Bosch Centre for Artificial Intelligence (BCAI). “What sets them apart is that they are capable of digesting highly dimensional data. Other processes, such as decision trees, can work well for some applications, but they can’t cope with too many attributes. If you think about the range of inputs on an autonomous car, you might have data from the camera, radar, lidar, the road conditions, the humidity... perhaps 10 highly dimensional sources. With so many attributes a neural network would make sense.”

The process of training a neural network for semantic segmentation involves feeding it numerous sets of training data with labels to identify key elements, such as cars or pedestrians. This data can be generated from simulations (providing they are accurate enough) or captured from real-world footage.

The engineers at BCAI use a combination of the two, explains Peylo: “The system learns through specific examples, so you have to ensure everything that’s potentially relevant can be trained. You can drive for perhaps millions of miles and not encounter a specific hazard, so you have to add those cases [artificially].”

Commercial break

Passenger cars may grab the headlines, but it’s arguably commercial vehicles that lead the way in the adoption of driver assistance systems. Since 2015 all new trucks (over eight tonnes) sold in the EU have had to be fitted with autonomous emergency braking (AEB), which means that commercial vehicles are already ahead of many passenger cars.

Bosch’s Emanuel Willman says: “The commercial vehicle business is driven by total cost of ownership and reducing the number of accidents is a major part of that. With a highly automated truck we think you could eliminate 90 per cent of the accidents that occur today.”

The next big thing is likely to be turn-assist systems, which could dramatically reduce the number of accidents between lorries and cyclists, Willman explains.

Several companies are already testing autonomous trucks and the technology required for partial autonomy on motorways is more or less production-ready. It’s closely related to that found on passenger cars, although the sensors have to be more robust (to cope with a potential million-mile lifespan). The software also has to be retrained to recognise objects from a very different angle, perched several metres further up.

01 Identifying objects poses a major challenge

02 All sensors have strengths and weaknesses

Accurately identifying objects is a major step towards predicting their behaviour. A car, for example, generally follows a different set of rules to a pedestrian. But in order to make decisions the car also needs to be able to cope with situations and behaviours that are outside the normal rules.

In theory, this is another prime candidate for the use of neural

networks. They could be used to predict behaviour based on a sequence of events. It’s not inconceivable, for instance, that a neural network could be taught to recognise that a ball bouncing into the road could be followed by a child.

“The expertise that you need to drive a car cannot be fully described in an algorithm, but you can learn by experience. Machine learning allows computers to carry out the same process,” comments Peylo.

Unfortunately there’s a snag. “Neural networks are very powerful, but they are not yet fully understood,” he explains. “We see the results, but we cannot say exactly how the machine came up with the solution. Making it understandable and explainable is a very important challenge, particularly for applications that have to be verified and certified. Understanding how the neural network functions is a prerequisite for that, and it’s one of our major research topics at BCAI.”

For the time being, Bosch prefers to use probability-based models for high-level decision-making. These look at the chances of a vehicle diverging from its anticipated behaviour (that is, failing to stop for a red light) and evaluate the potential risk. This technique is not as powerful or as flexible as a neural network, but it does have the key advantage that every decision can be tracked and understood.

Machine learning is already employed for semantic segmentation in driver assistance systems, such as autonomous emergency braking, though. It allows partially automated cars to carry out tasks that would be virtually impossible with traditional computing techniques, helping them to comprehend the abstract and unpredictable world of driving. And in the future it could hold the key to cars that truly think for themselves. ■



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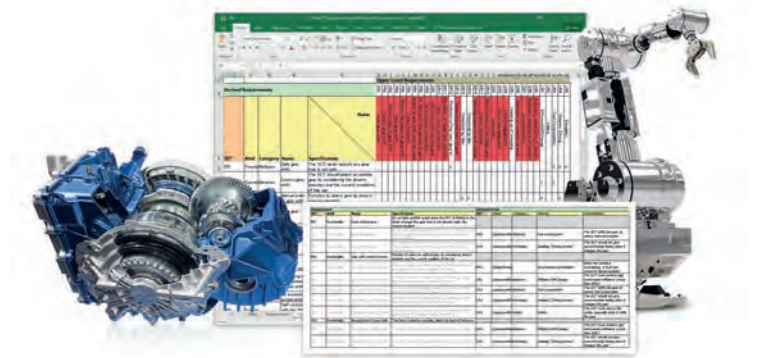
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Canada's Maplesoft has launched a new product that enables a Model-Based Systems Engineering (MBSE) approach without the need for all engineers involved to have MBSE expertise.

In the world of MBSE, specialised tools help define high-level system requirements that are used throughout the design chain. Most engineers don't have the training needed to use these complex tools, but their input into system requirements remains vital.

"MBSE tools offer organisations

tremendous value in how they keep a tight connection to requirements in every phase of the project; however, they are notoriously difficult to use," said Dr Laurent Bernardin, chief operating officer and chief scientist at Maplesoft.

"Research published during the development of Maple MBSE shows that the use of Maple MBSE resulted in a four-fold reduction in errors compared to a standard MBSE tool, and the elimination of complex, difficult-to-correct errors. It's a practical tool with a quick

ramp-up time that makes system engineering easier."

Using an Excel-based interface, Maple MBSE makes collaboration on requirements accessible to all stakeholders, not just the MBSE tool experts. According to Maplesoft, this ensures system-wide collaboration on the project, while reducing the time and errors that typically come with using a standard MBSE tool.

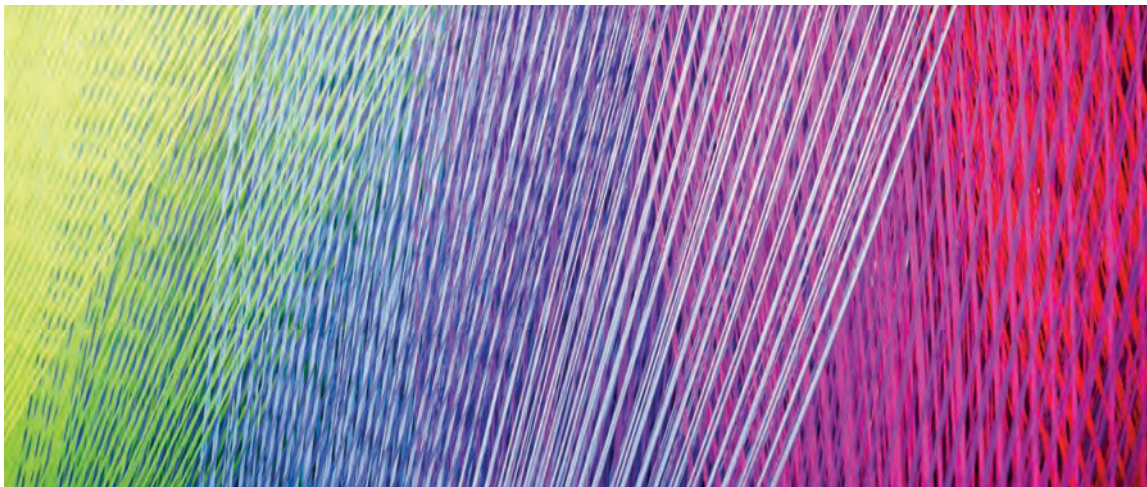
"There is no doubt Maple MBSE saves valuable time," said Masaaki Kubo, a general manager at Nissan Motor Company who

works in powertrain development.

"When we compared Maple MBSE with another MBSE tool and measured the time it took to perform common operations, we found Maple MBSE allowed our engineers to complete these tasks four times faster than with the other tool. Maple MBSE has a friendly and effective user interface that enabled Nissan engineers from many different disciplines, including mechanical, electronic, and electrical engineers, to quickly learn the tool and perform tasks very easily." ■

Towards China's first digital linen factory

PLM software complements production hardware. Supplier: Siemens



China's Kingdom Holdings, headquartered in Henggan, is a producer of linen. Working alongside Siemens, the company has built a new plant where automation could reduce energy use by 10 per cent, and water consumption by 20 per cent.

Since 2011, Kingdom has been working with Siemens to optimise

its production processes. For the new factory in Haiyan, Kingdom integrated Siemens PLM (Product Lifecycle Management) software to complement its state-of-the-art hardware.

According to Siemens, the result will be the first digital linen factory in China, where automation processes are driven by production data.

Specialists from Siemens started by simulating a virtual factory, including network architecture and field communications. For the real plant, Siemens then supplied its Manufacturing Execution System (MES) Simatic IT in order to optimise production by synchronising manufacturing and business operations.

Sinamics S120 converters are used throughout as the drives. With the aid of TIA (Totally Integrated Automation) it is possible to connect all automation components and systems, as a result of which efficiency can be improved and throughput times and operating costs can be reduced. The connections are made via Profibus DP or via Industrial Ethernet Profinet as the central interfaces to the higher-level automation systems.

"We have been very satisfied with the MES operation throughout the test and trial run," said Shen Yueming, executive director and general manager of Kingdom.

"Besides, the Integral Plant Maintenance that was rolled out two years ago has significantly improved the factory's systematic spare parts and equipment management."

According to Siemens, its products should help Kingdom save between three and five million Chinese Yuan Renminbi (£350,000-£575,000) per year. ■

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Joining forces with the wheelchair racers

Britain's para athletes have been working with BAE Systems and Solidworks. Supplier: NT CAD/CAM

Earlier this summer in London, British athletes enjoyed one of their most successful ever World Para Athletics Championships, winning 18 gold, eight silver and 18 bronze medals.

To help the team prepare for the championships, its wheelchair racers joined forces with engineers from BAE Systems, who used engineering software from Solidworks to create the UK's first computerised indoor trainer for racing wheelchairs.

Originally conceptualised using Solidworks 3D CAD supplied by NT CAD/CAM, the Watt (Wheelchair Athlete Test and Training) system consists of an adjustable frame that holds the athlete's wheelchair in place and two electric motor

brakes, adapted from the Tacx virtual-reality bike trainer, which rest against the wheels.

The Watt system can then create differing levels of resistance on the

wheels, helping to accurately simulate different road and course environments.

Henry White, BAE Systems' UK sport technology partnership



lead, said: "The new Watt system is a ground-breaking advancement in wheelchair racing. There are a number of problems that the GB Team face when training in poor weather conditions, but with this new system they'll be able to complete whatever training they need and access courses from all over the world, from wherever they are."

BAE, which has been working with UK Sport since 2008, also developed a revolutionary new racing wheel, which can help Britain's wheelchair racers improve their acceleration by up to 20 per cent. The new advanced composite wheel is three times stiffer than previous designs and its rigidity lessens a force known as a 'toe-in' – where the wheel bends inwards – reducing friction and improving speed and acceleration.

Paralympic silver medalist Shelly Woods tested out the wheels in wind tunnels, supplied by BAE Systems, to find the most aerodynamic seating position to race it. They found by just changing her position by 10 degrees forward, she would be able to get an increase of 20 per cent. ■

Augmented reality heads off to the construction site

Consortium looks to develop AR displays to provide critical data for the building industry

A consortium led by civil engineering visualisation expert Soluis Group has received £1m funding from Innovate UK to develop a so-called Augmented Worker System (AWE) for the construction industry.

Aimed at enabling engineers to make the most of the building information modelling (BIM) tools that are now widely used by the construction sector, the project hopes to replace paper or handheld devices with hands-free heads-up augmented reality (AR) displays that would provide real-time access to data, and enable greater collaboration between teams and partners.

The project, which begins this month, will build on earlier work Soluis carried out with Laing O'Rourke on the development of an AR asset management tool, which was piloted at Crossrail's Liverpool Street station.

Other companies involved in the project include IT consultant Pinnacle Business Solutions, modular construction specialist Carbon Dynamic and both the Advanced Manufacturing Research Centre (AMRC) and the Advanced Forming Research Centre (AFRC).



A steering group for the initiative includes AECOM, Doosan Babcock, Laing O'Rourke, Autodesk and Microsoft.

The funding was awarded as part of the Infrastructure Systems competition that aims to stimulate innovation that creates UK business growth in infrastructure systems.

Business secretary Greg Clark said: "The adoption of cutting-edge virtual and augmented reality technology in industries such as construction will be vital in helping us identify new, smarter, ways of working."

David Philp, BIM Director at AECOM, said: "Real-time access to individualised data, analytics and instructions during the construction and operational stages will greatly improve productivity and quality, and also help worker well-being."

"Creating a framework and guidance around the augmented worker is critically important if we are to successfully unlock this value proposition." ■

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Automated programming to enhance productivity

System acquisition reflects a changing landscape for surface-mount programmable devices. Supplier: Adaptsys

An advanced automated programming system is boosting productivity and enhancing the flexibility of the device programming service offered by Action Circuits, a provider of electronic device programming.

Supplied by Adaptsys, the BPM 3900 Universal Automated Programming System is the first of its type to be installed in Europe and combines a programming speed of 100Mbyte/s and 256Gbyte of memory.

Luton-based Action Circuits (UK) Ltd has been specialising in device programming and reeling services since 1990.

The decision to acquire the new system reflects the changing landscape for the surface-mount programmable devices market. Not only were production volumes



increasing and devices shrinking, but the range of programmable devices themselves was growing.

"The increased throughput of small footprint devices coupled with the range of technologies

and packaging types has increased dramatically," said Martin Harvey, commercial director of Action Circuits. "To be able to support all these devices with a single machine gives us several advantages –

particularly a reduction in the number of systems, sites and sockets we require, which, in turn, saves money, simplifies our processes, reduces the need for training on different systems and cuts the size and space requirements."

Action Circuits was already familiar with Adaptsys and the BPM Microsystems range of programmers. "The product they were offering meant that we could incorporate it seamlessly into our existing processes and workflows," said Harvey.

BPM 3900's high speed ensures that the programming process is efficient and that Action Circuits can turn orders around more quickly. The system incorporates so-called WhisperTeach with Auto-Z, which reduces set-up time for precision placement of the industry's smallest chip-scale packages and removes reliance on operators.

The company was also able to use existing peripherals from existing handling platforms on new programming products, and could preserve the IP created from working with other BPM Microsystems products. ■

Novel ultrasonics

IMechE helps to bring innovative R&D to market



The Institution of Mechanical Engineers has completed an investment through its Stephenson Fund in Inductosense, a spin-out from Bristol University. Launched in 2015, the Stephenson Fund, named after IMechE founder George Stephenson, is intended to help companies bring innovative R&D to market.

Inductosense is developing novel ultrasonic sensors to detect corrosion. Known as WAND (wireless and non-destructive), the system works by bringing a measurement probe near to a passive, compact, battery-free sensor installed on a structure.

"The technology Inductosense is developing has the potential to cut maintenance and downtime costs of wind turbines, nuclear power plants and other large infrastructure, making maintenance more efficient and low-cost," said IMechE CEO Stephen Tetlow.

"Over the past year we have had great success in development of the technology and commercial traction. With the investment we want to accelerate our pace and progress from trials to commercial deployment of sensors. We are also commercialising some exciting new products," added Inductosense CEO Mark Butcher. ■

Flying along like Iron Man

Exoskeleton suit could herald the start of human propulsion systems. Supplier: RS Components

Inventor and entrepreneur Richard Browning turned to RS Components for help with developing an innovative exoskeleton suit he believes will allow wearers to fly like the Marvel superhero Iron Man. The Daedalus suit positions gas turbine jet engines on wearers' wrists and hips and uses movements of the body to counter gravity, support the flyer off the ground and generate directional thrust for flight.

"A huge part of this has been about rapidly prototyping things; going through the RS catalogue; finding the components really quickly; and getting them on the workbench and out in the field in a matter of days. That's been critical to this journey," Browning said.

Among the systems Browning has developed are an experimental heads-up display (HUD) for fuel levels and engine status, based around a Sony SmartEyeGlass

developer edition; a WiFi data linkage to stream information from the engines to the HUD and to ground monitoring; fuel air detectors using medical bubble sensors; and a range of cables and connectors to link the handgrip throttles, which use variable triggers to control the amount of thrust from the engines, to the electronics in the suit's backpack. "Daedalus is simply the beginning of a core technology that has endless potential in aviation, commercial and entertainment applications," said Browning. Daedalus could potentially be applied in aviation, commercial and entertainment applications. "We stand at the very beginning of what human propulsion systems will do. It's at the same point as the mobile phone was in the early-to-mid 1980s or the internet of the early 1990s – and I have to say, it's phenomenally exciting." ■



State-of-the-art navigation for guided vehicles

Laser scanner assists in developing 'eyes' for a vehicle. Supplier: Pepperl and Fuchs



A meeting at a trade show provided the trigger for sensor supplier Pepperl and Fuchs to work with Kollmorgen Automation on a navigation system for guided vehicles. "As an expert in vehicle control, we always want to provide the latest vehicle types with state-of-the-art navigation," said Markus Johansson, general manager at Kollmorgen.

Pepperl and Fuchs launched the R2000 2D laser scanner at the Scanautomatic exhibition in Sweden in 2012, and Johansson was keen to see what the scanner could do. "At that time, we were looking for a partner who was an innovator in the field of sensor technology, and the benefits of the R2000 sounded promising to us, so we were very curious to find out what we could achieve together," he said.

Kollmorgen needed a system to act as the eyes for a vehicle and was attracted to the extremely precise measurements and short response times, detection of tiny objects from 1mm and up, and its 360° all-round visibility offered by the R2000. After the show it contacted Pepperl and Fuchs, and began a collaboration to jointly develop an enhanced version of the scanner, called the LS2000, which it linked to its own CVC600 vehicle controller, allowing users to navigate via reflectors, natural objects or a combination of the two. ■

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Getting up to speed

3D manufacturing technology showcase TCT returns to the NEC, Birmingham from 26-28 September

Now in its 22nd year, TCT provides a great opportunity to get up to speed on the latest developments in 3D printing, additive manufacturing, CAD/CAE, metrology and inspection, as well as conventional manufacturing processes, including moulding, casting and CNC machining.

Visitors will have the opportunity to connect with an exciting and varied range of businesses with almost 300 exhibiting companies, including 3D Systems, HP, Carbon, Renishaw, Stratasys and Envisiontec.

Among the new products and services to be unveiled during this three-day event will be Desktop Metal's Studio system. This affordable metal 3D printing technology is one of the most talked about in recent times and CEO Ric Fulop will take to the Product Stage on 26 September to demonstrate how the company has made metal 3D printing office-friendly.

Over on Carbon's stand, visitors will see various exciting products, including the SpeedCell manufacturing system and 3D-printed Futurecraft 4D athletic footwear that was launched with Adidas earlier this year. Gerd Manz, vice-president of innovation at Adidas, will deliver a keynote address on 28 September that will dive deeper into the design and technology that made the Futurecraft 4D a reality.

Another must-see will be the global launch of Materialise's 3DP AdviceHub, a concept aimed at providing expert guidance on all things 3D printing. Visitors can book a spot to put their questions to the Materialise team on anything from file preparation for print and applying lattice structures, to design for AM and how to use AM simulation to reduce the risk of build failure and parts of inferior quality.

Now taking place across three dedicated stages split into key themes, the free-to-attend conference and seminar track has grown in line with the expansion of the show.

The main stage will host a celebration of innovation in product development, engineering and manufacturing with presentations from Intel, McLaren Racing, Johnson & Johnson, Sabotage Design, DuPont and many more. Now CPD accredited, the main stage conference track will present research developments and real-life examples of the ways in which 3D technologies are being used within aerospace, automotive, medical and dental, as well as consumer and industrial product design.

Meanwhile, the product stage will feature both first-time and returning TCT exhibitors discussing their latest products and services, including materials, software, inspection and scanning. With so many companies exhibiting on the show floor, these 20-minute presentations will give visitors the chance to get all the information they're looking for in one place. Attendees will hear from Stratasys, Nikon Metrology, Renishaw, Carbon, HP and more.

Throughout the event, the tech stage will host a range of CPD-certified workshops created to offer attendees a broad range of topics and speakers. Whether a novice or an expert in the AM industry, the programme will have something for everyone; from a beginners' guide to AM session, to a



discussion about the health and safety of metal powders.

TCT has also teamed up with Women in 3D Printing and Cyant to host the UK's first ever #3DTalk event – a global event series featuring women in 3D printing and related industries. Open to everyone regardless of gender, age or expertise level, #3DTalk will bring together industry leaders and pioneers to share their expertise, experiences and insights during an educational panel session on the Tech Stage.

Other show features include Inspex (which focuses on providers of inspection, measurement and testing hardware, software and services) and TCT Inspired Minds – an educational experience that will enable over 300 schoolchildren to get hands-on with 3D technologies.

This year's event also sees the return of the Start Up Zone, which will introduce promising start-ups to the industry. Visitors will see launches of software, components, hardware and materials. ■

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Moving the goalposts

PPMA, the UK's leading processing and packaging machinery show, returns to the NEC from 26-28 September



Serving manufacturers within the food and beverage, pharmaceutical, personal care and consumer goods industries to contract packers and more, the show will offer visitors a chance to see new machinery in action, find inspiration, new ideas and solutions, gain access to potential new suppliers and evaluate and purchase the latest technology, as well as talk face to face with the industry's leading technical experts.

The 2016 show saw more than 1,000 packaging and processing machinery manufacturers and in excess of 7,500 visitors across three days. With more than 300 confirmed exhibitors and over 10,000m² of show floor, this year's event looks set to be even bigger.

A dynamic range of exhibitors such as Schubert UK, Omron, ABB, Ilapak and Minebea Intec, will all be showcasing their latest innovations. These include Schubert UK's compact TLM technology, with the company demonstrating a machine that packs mayonnaise cups into cardboard boxes, while Omron's Quattro Delta robot – with a pick rate of 300 parts per minute – will make its UK debut at the show.

This year's event will also feature a new and improved Learning Hub, providing visitors and exhibitors with insights from leading industry experts, as well as influential opinion leaders from the wider business world. The hub will cover IoT-enabled adaptive packaging, the potential of manufacturing waste

and the future role of robotics and automation in the factory.

The keynote speaker on the first day of the show will be marketing veteran CEO of the Football Association Martin Glenn, who will share how his extensive experience in the food manufacturing industry has informed his new role as head of the FA.

Glenn will be joined by another United Biscuits alumni, chartered engineer Peter Anderton. He will take to the stage for two sessions. The first will provide attendees with helpful insights into how to build a successful team, following by a second session where Anderton will share his two-rule approach to great leadership and reveal what packaging chocolate biscuits has to do with successful management.

Also on the agenda is Forbes McDougall, head of circular economy for Veolia UK & Ireland, who will shine a spotlight on packaging recycling faux pas from laminates, coffee cups, plastic bottles and food trays and Jeremy Hadall, chief technologist – robotics and automation of The Manufacturing Technology Centre, who will explore automation and robotics in the food and drink industry and address the myth that robots are a risk to human employees.

In addition, on Thursday 28 September, the last day of the event, the Learning Hub will host a special focus on recruitment, development and skills led by BEST, the PPMA Group's charitable initiative aimed at developing the industry's workforce.

The PPMA Show 2017 will also feature all-new entertainment and interactive features, including a computer-controller goalkeeper, known as RoboKeeper, which will challenge visitors and exhibitors to try and score a goal live at the show.

Andrew Mint, CEO of PPMA Group, said: "Once again, the PPMA Show 2017 will bring all corners of the industry together under one roof. Alongside enabling exhibitors to showcase their latest technologies to an audience of thousands, plus benefit from unparalleled networking opportunities, the PPMA Show provides a platform for crucial discussions on issues that affect the processing and packaging machinery industry. I for one am greatly looking forward to hearing from some of the industry's thought leaders." ■

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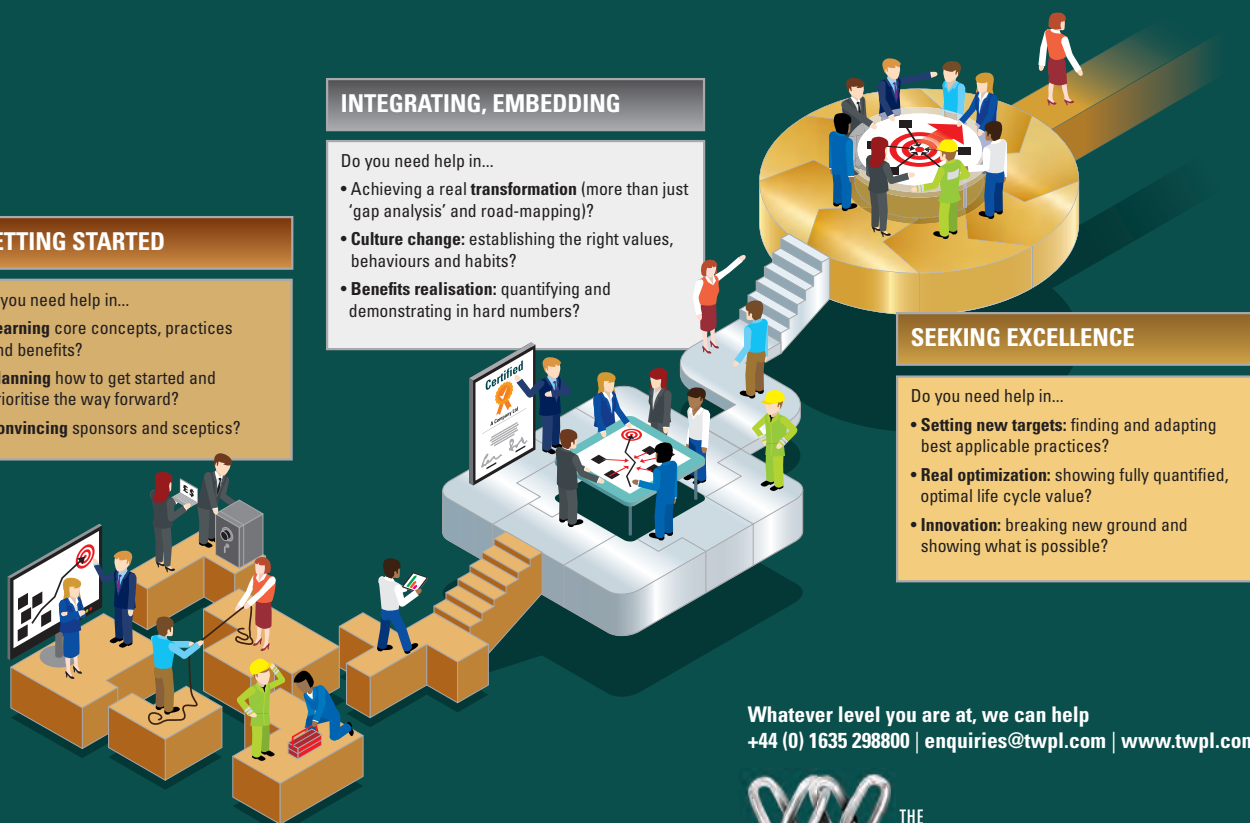
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A position in power

With the UK's energy mix becoming ever more diverse, a host of engineering opportunities are emerging in less-well-known areas of power generation. Evelyn Adams reports

01 Tidal energy will see a demand for engineers

02 Tom Goodwin at anaerobic digestion firm Marches Biogas

Earlier this year, something extraordinary happened to the UK's energy grid. For one day in June, a record 70 per cent of the electricity produced in the UK was low-carbon. That day was dubbed 'stunning Sunday' by one grid manager, because the carbon intensity of producing power moved below 100g of CO₂ per kilowatt hour for the first time. This is the level that Britain must hit daily by 2030 if it is to meet its renewable energy goal of cutting emissions by 57 per cent, compared with 1990 levels, in just 13 years.

That is a tremendous challenge that requires a shift away from reliance on oil and gas towards renewables, including emerging forms of 'clean' energy generation, such as tidal power, pumped hydro and anaerobic digestion (AD). The UK is beginning to embrace these industries, which some claim could help bring about an 'epochal transformation' to the country once the infrastructure is in place for wide-scale roll-out.

Now, as the energy mix changes, the sector is on the lookout for engineering talent that can help implement plans for a low-carbon future.

"With the continual evolution of technology, I fully expect continual growth that will edge us closer to achieving the long-term vision of sustainable towns and cities," said Scott Lutton, operations manager at Bellshill-based Vital Energi. "In respect of engineering careers, the growth of the sector is positive as opportunities are continually being created for people at the beginning of their career journey, as well as people wishing to diversify into the energy sector."

Vital Energi was responsible for installing one of the first combined heat and power (CHP) community energy centres that served a new-build development in Greenwich Millennium Village. That installation more than a decade ago marked a change in how new-build developments across the country generate energy. The energy landscape has changed drastically since then, and Lutton says it is an even more exciting industry to work in.

Today, companies specialising in areas such as combined heat and power, anaerobic digestion, pumped hydro and energy storage are recruiting for talented engineers in a variety of areas. Apprenticeships and short courses can help new engineers get up to speed with the technologies. For existing engineers in parallel industries such as oil and gas, moving to emerging sectors is often a natural progression, with many sharing the same technical and project management skills.

Another area likely to see a demand for engineers is tidal energy. For instance, if the Swansea Bay Tidal lagoon gets the go ahead, it is expected to create 2,000 jobs during its construction alone. And the

01





02

company behind the scheme, Tidal Lagoon Power, hopes to build five other lagoons, at Cardiff, Newport, Colwyn Bay, Bridgewater Bay and North West England.

"Working in the engineering industry I have been fortunate to be involved across varying sectors, from industrial, commercial to infrastructure and more recently energy," said Lutton. "Being from a diverse background, I really enjoy the challenges the energy sector brings. No two jobs are the same, meaning learning and development is continuous. We are fortunate to be involved in looking at long-term sustainable offerings for forward looking clients... What's not to like?"

Today, energy companies invest around £18bn each year in the economy, which is around 14 per cent of all private sector investment. They also make up a huge part of the national infrastructure pipeline, with analysts estimating that £140bn needs to be invested in new-generation capacity by 2030. As such, the sector is a major recruiter,

directly employing 137,000 people and supporting more than 500,000 jobs in the supply chain.

"I particularly like working in an industry that makes me feel good about what we are trying to do overall – make energy from waste or surplus resources," said Tom Goodwin, a process engineer at AD firm Marches Biogas. "On a day-to-day level, I enjoy the variety of the work. One day, I may be trying to find the right pump and macerator combination to move a difficult media, the next I may be looking at environmental considerations, such as controlling drainage water or odour control."

The AD sector has undergone a period of rapid expansion and is beginning to stabilise, so careers are less to do with construction of new builds, and more to do with bringing the right knowledge to the right place, said Goodwin. "There are a lot of projects that never really *met their performance criteria, or do but could have additional capacity under the right circumstances. Career opportunities are now to do with having the right know-how to identify the root cause of a problem, and solve it with minimal process disruption. This naturally lends itself to prospective scientists and engineers looking into careers in consultancy and other knowledge-based fields."

Goodwin said engineers considering a career in AD must have a high tolerance to odour and the willingness to get their hands dirty. "Some sites are kept in better condition than others, and the smell or mess may well be the reason you're on site in the first place... Engineers in this field also need to be flexible and willing to learn – the

"Career opportunities are to do with having the right know-how to identify the cause of a problem and solving it"

Tom Goodwin, Marches Biogas

basics of AD are straightforward, but the subtleties in applying these to give a reliable, robust process are what separates the professionals from the amateurs."

Otherwise, one of the most important skills in any area of the energy industry is the ability to communicate effectively with a variety of people, from site operators through to scientists and financial controllers. The ability to think in terms of risk and safety is also crucial across all energy sectors.

Can these things be transferred from other sectors? "Absolutely," said Goodwin. "It is more about mindset and having a 'can-do' attitude than anything else... In the first few months of a career in AD, you will probably feel bewildered with the range of considerations, equipment and process parameters that everyone else is talking about so matter of factly. Don't panic. Take notes, study a bit and don't be afraid to ask questions." ■



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THE COLLABORATE TO INNOVATE CONFERENCE IS THE CULMINATION OF A SIX MONTH AWARDS CAMPAIGN JUDGED BY LEADING FIGURES FROM ACROSS INDUSTRY, AIMED AT IDENTIFYING SOME OF THE UK'S MOST IMPRESSIVE AND INNOVATIVE EXAMPLES OF ENGINEERING COLLABORATION.

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1945

Flight plans

The Nazis constantly updated their aircraft technology, resulting in some disastrous consequences for the pilots

After hostilities ceased in the Second World War, *The Engineer* set about assessing some of the technologies that had beset Allied forces in the previous years. Barely had the flames of war ceased smouldering when our predecessors turned their attention to the Nazi regime's airborne machinery, with the first article dealing with the Luftwaffe's engines and the second looking at the aircraft they powered.

Both articles make the point that while the in-service equipment may have tended towards the conservative – the articles note that the Allies flew “at least a dozen” designs of single-seat fighter, but Germany used only two basic designs throughout the war – Germany had a forward programme in advance of the Allies. To keep pace with new models of the Spitfire, Messerschmitt had to continuously improve the Me109, which was 10 years old by the end of the war. In 1937, the article says, the 109 had 500HP and was slower than the Hurricane, but by the end it had 2000HP, could match a Mustang in the air and had 10 times the firepower of the original 109.

Germany also had the world's first jet-propelled aircraft, in the diminutive shape of the single-engine Heinkel 178, which first flew on 29 August 1939, four days before the invasion of Poland. A flying test-bed that was never intended for military purposes, the He178 used an engine developed by Hans von Ohain, who in 1936 had patented using the exhaust from the gas turbine for propulsion. In developing jet-powered aircraft, Heinkel was soon outstripped by Messerschmitt, whose twin-engined Me262 – known as the Schwalbe (Swallow) or Stormvogel (Stormbird) went into intensive development in 1942 and entered service in April 1944, a few months ahead of the Allies' first jet fighter, the Gloster Meteor. The article mentions that such aircraft, despite having an impressive performance, could not stay in the air for long; in fact, by the time the Nazi regime collapsed, its supply lines had been disrupted so much by the



The Stormbird entered service in April 1944, a few months ahead of the Allies' first jet fighter, the Gloster Meteor

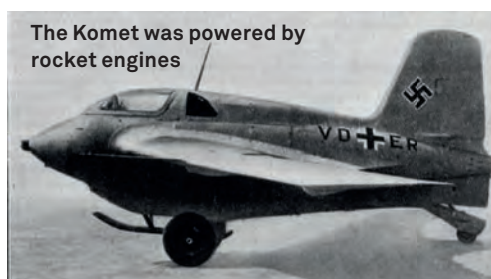
Allied advance and by air bombardment that the Stormbirds could not be fuelled.

The article points out that the Luftwaffe used engines powered by rocket engines, such as “the amazing little Me163 Komet”. This was “capable of a level speed of about 550mph and could climb to 30,000ft in two-and-a-half minutes”. Although “comparatively quick and cheap to build”, these wooden interceptors were seriously hampered by “their short endurance in the air”, so Heinkel was commissioned to build a cheaper aircraft with slower performance but longer air duration, the He163, an ungainly looking craft with a single jet on top of its fuselage. This was beset with “fairly serious teething troubles”, the article says with wonderful understatement: on its second flight, the leading edge of the wing collapsed and the

aircraft broke up in mid-air. Despite this, the design was revised and the aircraft – known as the Volksjäger (People's fighter) – went into production.

Volksjägers were particularly difficult for inexperienced pilots on take-off and landing, the article notes, but “credit must be given to the Germans for producing what they set out to produce – a cheap fighter with better performance than standard Allied types”.

As the war approached its end, the Nazi regime turned to “last-ditch” efforts. One of these sounds truly terrifying for any pilot who might have found himself unlucky enough to draw the proverbial short straw. The Bacher Natter (Viper) could only be classed as an aircraft because it had wings (albeit very short ones), controls and a pilot, but in every other respect it was a “piloted flak rocket”. Powered by a liquid-fuelled rocket engine and launched vertically, it was intended to destroy enemy bombers with an array of rockets launched from its nose. After this, the pilot would eject and descend by parachute, while the rear fuselage, containing the rocket engines, would break off and also parachute to the ground to be recovered. With no need for conventional take-off or landing, the aircraft would not have needed fully trained pilots. Fortunately (for all), it never entered service – its only test-flight killed its pilot. **SN ■**



The Komet was powered by rocket engines

Word of the issue

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

Our instincts would be to initially look at 'corrosion' as a quite complex and therefore comparatively modern word. Yet this is not the case, for the word 'corrosion' is a compound of two other words and these are ancient.

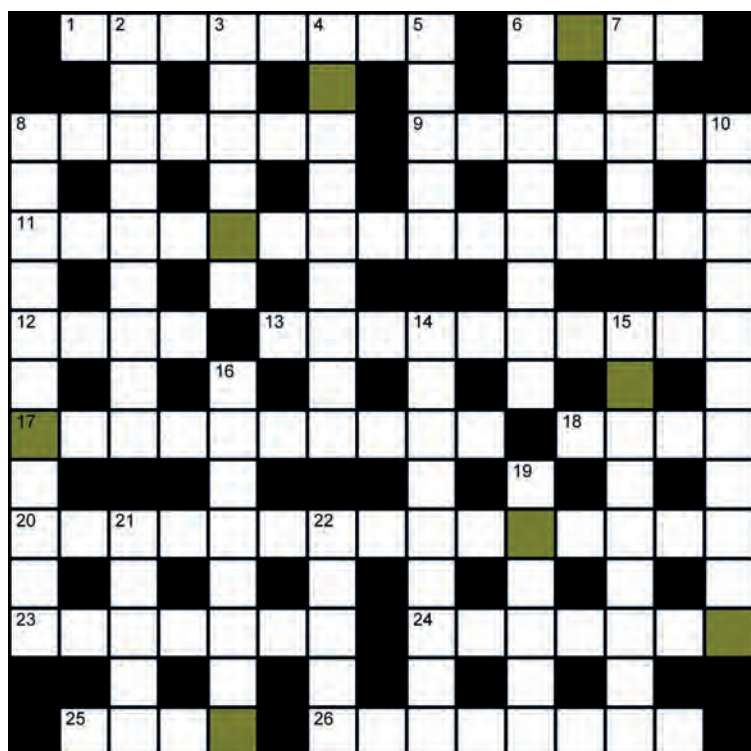
It is derived from two earlier and simpler words. Taking each element individually, the first is a common prefix and is from the classical Latin *cum* indicating 'together', as in 'combination'. This comes from Proto-Indo-European *kom* 'beside, near, by, with'.

Of greater interest is the second element. Here the Latin root is *rodere*, meaning 'to gnaw'. In turn this came from Proto-Indo-European *red*, meaning 'to scrape, scratch, gnaw'. Here the implication is clear. Our ancestors clearly saw the rusting of their metals as something undesirable, and, just as today, is seen as something that had to be removed – just as the name suggests.

Bigpicture



The £1.35bn Queensferry Crossing spanning Scotland's Firth of Forth has opened to traffic for the first time. At 2.7km in length, the new structure is the longest three-tower cable-stayed bridge in the world.



Prizecrossword

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

Across

- 1 Vigorously active (8)
- 6 Taken advantage of (4)
- 8 Exact copy (7)
- 9 A wash in warm soil (3,4)
- 11 Healthier form of fat (15)
- 12 Write one's name (4)
- 13 Drive and ambition (3-2-3-2)
- 17 Separating from an ore (10)
- 18 Opening for coins (4)
- 20 Belief accepted as authoritative (6,2,7)
- 23 A sketch, outline (7)
- 24 Like an automated machine (7)
- 25 Rip apart (4)
- 26 Area of sloping land (8)

Down

- 2 Best possible (3-6)
- 3 Ill and usually confined (4,2)
- 4 Lasting for a short time only (9)
- 5 Celestial body with luminous tail (5)
- 6 Provide with a base or support (8)
- 7 Correct in every detail (5)
- 8 Claimed back (11)
- 10 Relating to fluids at rest (11)
- 14 Not conforming to a norm (9)
- 15 Transferred power to someone (9)
- 16 Manual worker (8)
- 19 Uncertainties (6)
- 21 Lift with effort (5)
- 22 Activeness of an energetic personality (5)

August's highlighted solution was platinum. Winner: **Keith Nuttall**

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