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## inouropinion Still a player



Given his administration's faltering support for renewable energy, it's hard to believe that David Cameron once promised to lead "the greenest government ever".

Just five years ago, the prime minister pledged to put renewables and climate change at the heart of government policy. But, today, falling levels of support for new technologies and cuts to subsidies

for green forms of energy have, some claim, derailed an area of huge potential and put off international investors

According to the International Energy Agency's (IEA's) 2015 renewable energy report, while renewables will account for almost two-thirds of all of the world's new generating capacity over the next couple of years, renewable capacity added in the UK will fall by half between 2015 and 2016.

In spite of this, as we report in this issue's cover story (page 20), which examines some of the disruptive technologies that will shape the renewables sector in the years ahead, the UK is

## most ambitious wind projects

still a major player: home to some of the **The UK still has** world's most ambitious wind energy some of the world's projects and a pioneer in the nascent world of tidal energy technology.

The UK's relationship with wind energy is expanded on in this issue's interview with DONG Energy's Brent

Cheshire (page 40). Interestingly, Cheshire is something of a reformed wind sceptic and his arguments will touch a nerve with both proponents and critics of wind turbines. The article also provides a reminder that while the UK government might not see huge potential in renewables, other governments take a different view. DONG, a state-owned Danish firm, operates most of the UK's largest offshore wind farms. We've arguably missed the boat on wind, but, with the right support, it's not too late to replicate DONG's success in the tidal sector.

Finally, this issue's O&A feature (page 42) takes a look at a concept arguably closer to science fiction than reality: the space elevator. Our expert panel answers your questions and gives a flavour of some of the engineering challenges that will need to be addressed should the concept ever take off.

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The EDM system covers a range of applications

## AUTOMOTIVE **Electric Drive Module** is all torgue for JLR

#### System is designed to fit between engine and transmission

#### BY CHRIS PICKERING

Jaguar Land Rover (JLR) has developed an experimental Electric Drive Module (EDM), which it says is capable of producing up to twice the power and torque of those currently found in high-volume production applications.

Designed to fit between the engine and transmission, the modular EDM system covers a range of different applications. At its core is a radial flux motor packaged inside a short, cylindrical housing, along with a clutch pack and a slave cylinder.

In plug-in hybrid (PHEV) form it uses a copper-wound neodymium synchronous permanent magnet motor running up to 8,000rpm. This produces around 150kW and 400Nm of torque, while comparable production systems are generally in the region of 50 to 70kW and 120 to 200Nm.

JLR has tested the PHEV version of the system in a modified Range Rover Sport fitted with a prototype two-litre four-cylinder turbocharged gasoline engine producing around 300bhp. The engine is packaged longitudinally with an eight-speed automatic gearbox, while the EDM draws its energy from a 320V lithiumion battery back stored in the boot.

We looked at every element of the design to optimise the power within a very small axial space," said Mark McNally, JLR's senior manager, Advanced Research Technology Demonstration. "We worked in collaboration with Motor Design on the electromagnetic performance. Newcastle University worked on the mechanical design and the packaging density, maximising the magnetic flux in the system. All this helped us to deliver a high degree of performance in a confined space."

At the other end of the spectrum, the EDM in the mild-hybrid (MHEV) car uses ferrite magnets and aluminium windings to produce a cheap and exceptionally compact system. It produces 15kW and 50Nm - enough to act as a starter motor generator unit, as well as providing torque-filling and a low-speed creep functionality before the combustion engine kicks in.

Jaguar Land Rover has trialled this version in a development vehicle based on the Range Rover Evoque, where the EDM is fed by a 48V lithium-ion battery pack and coupled to an experimental three-cylinder 90 PS diesel engine, driving through a nine-speed automatic gearbox. Significantly, this engine is mounted transversely in the chassis, placing an even greater emphasis on packaging.

'It's very slim in terms of axial length on the MHEV," according to McNally. "Plus, the mild-hybrid is a more transient system and the aluminium windings present benefits in terms of thermal inertia.

By placing the EDM in between the engine and the transmission and using a clutch pack to control the drive, the system can decouple the combustion engine during regenerative braking to eliminate pumping losses. It also means a coasting function can be integrated.

The EDM work is part of a wider two-year £16.3m research project, involving 12 technology partners and part-funded by Innovate UK.

"We have a wide-ranging low-emissions technology strategy, which has created innovations such as our Ingenium engine range and lighter vehicles. Technologies such as these have already helped us reduce our fleet CO<sub>2</sub> average by 25 per cent in recent years," said Dr Wolfgang Epple, JLR's director of research and technology.

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### inbrief

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#### **Steel storm**

SSI UK is mothballing its Teeside Iron and steelmaking facilities, a move that will lead to the loss of 1,700 jobs. The decision to halt production in Redcar was made in response to poor steel trading conditions and a worldwide deterioration of steel prices. Calling on the government to intervene, David Hulse, GMB national officer, said: "It is not too late for them to do so while the furnaces are still burning."

#### **Innovative call**

A new report from the Royal Academy of Engineering (RAEng) is urging the government to take more decisive action to foster innovation in the UK. Entitled Investing in Innovation, the report calls for a long-term strategic framework that will encourage businesses and other organisations to invest in research and development. According to the academy, innovation was responsible for around half of the UK's productivity growth between 2000 and 2008.

#### Pulling back

UK energy company Drax has pulled out of plans to develop one of the world's first commercial-scale carbon capture and storage coalfired power plants. The company has been a key partner in the White Rose CCS project, which plans to build a new CCS-enabled coal-fired power station next to Drax's existing plant near Selby, North Yorkshire.

#### Arctic reversal

Royal Dutch Shell is to abandon its attempt to extract hydrocarbons from a region in Arctic waters off the Alaskan coast. The company has spent roughly US\$7bn over the past eight years on drilling an exploratory well in the Chukchi Sea, in 300m of water some 150 miles from Barrow, Alaska, but says it did not find sufficient reserves of oil and gas.

## No need for false alarms

#### Scanner can identify presence of hidden explosives in seconds

#### BY HELEN KNIGHT

An X-ray scanner that not only produces an image of an object but can also identify precisely what material it is made of, is being developed for use in airport security.

The scanner, which is being developed by researchers at Nottingham Trent and Cranfield universities, can identify the presence of hidden explosives or illegal drugs in milliseconds.

The conventional X-ray scanners used in airports produce an image of an object and can identify broadly whether it consists of metal or organic material, but they cannot determine definitively what substance it is made from, according to Prof Paul Evans at Nottingham Trent University.

"You therefore have problems discriminating between explosive substances and other substances," said Evans, who developed the technology alongside Prof Keith Rogers at the Cranfield Forensic Institute.

The technology, known as Halo, uses the way an object diffracts, or scatters, X-rays to identify what it is made of in just 100 milliseconds.

X-ray diffraction is used widely in laboratories to identify materials. However, the process traditionally uses a thin-beam, low-power X-ray, which takes a long time to collect information.

Instead, the researchers use high-power but hollow X-ray beams, in the shape of a conical shell. When this hollow beam intersects the object to be scanned, the object itself focuses the scattered X-rays into a pattern inside the shell, where they can be detected, according to Evans. "Our beam intersects the object, and

concentrates the signal, so we can place various



detectors inside the hollow beam, and see these patterns of diffracted radiation," said Evans.

A spin-out company, Halo X-ray Technologies, will commercialise the scanner. The company has produced its first prototype device, suitable for scanning small portable objects such as parcels, envelopes, smartphones and tablets.

## Mobile soars for US aviation

#### Airbus commits to aircraft manufacturing facility in Alabama

#### BY ANDREW WARD

Airbus has reaffirmed its commitment to US aviation at the inauguration of its new US\$600m final assembly line (FAL) manufacturing facility in Mobile, Alabama.

The assembly plant is Airbus's first in the US and will directly employ around 1,000 people.

The factory will receive sections of the company's A320 family from Europe, with these sections fitted together across four different stations in the factory's flow line, then painted, tested and handed over to customers.

"Our commercial aircraft production in Mobile signifies

two things: that Airbus has become the first truly global aircraft manufacturer, and that Airbus is now also a truly American manufacturer," said Airbus president and chief executive Fabrice Brégier.

"With the addition of our US facility to our production network in Europe and Asia, we have strategically expanded our worldwide industrial base."

The A320 range (which includes the A318, A319, A320 and A321) is the world's best-selling single-aisle aircraft, with 6,700 delivered to date, and an order backlog of nearly 5,500. Barry Eccleston, president of Airbus Americas, said that somewhere around the world an A320 takes off or lands every two seconds.

Introduced in 1988, the aircraft can accommodate up to 220 passengers and is widely used for inter-city flights in the US. Over the next 20 years Airbus expects demand in the US single-aisle market to increase significantly. For the foreseeable future, the FAL will deliver aircraft exclusively to US customers, including American, Delta, United, Jet Blue and Spirit.

Airbus also operates an engineering centre in Mobile that was opened in 2007 and currently employs more than 200 engineers.

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Project view

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#### AEROSPACE

## Hitching a ride on a rocket

Small satellites take off

#### BY HELEN KNIGHT

A commercial rocket designed to launch small satellites into orbit is being developed in the UK.

The developer, Space Launch Services (SpaceLS) is hoping to compete with private launch firms such as SpaceX, Virgin Galactic and RocketLab with its rocket, known as Prometheus 1.

The rocket is being designed to place small satellites of around 100kg into low-earth orbit, including the low-cost CubeSats used by educational institutions, according to SpaceLS programme director Jamie Welton.

"There is a shift towards smaller satellites, as the technology improves, so the market for these type of launches is likely to grow," said Welton. "When you look at the bigger companies such as SpaceX, they don't have the capacity to take many of these smaller payloads on board, as a lot of their launches are dedicated to one, larger, satellite, and they won't take secondary payloads."

The rocket will be propelled by a 75,000lb-force, bi-propellant engine called Raptoex, which will be fuelled by hydrogen peroxide and kerosene. The company chose to use a hydrogen peroxide and kerosene propellant, as it is much easier and cheaper to handle than alternatives such as liquid oxygen. "Instead of designing everything from scratch, we have reverse-engineered previous British designs for peroxide-kerosene bi-propellant engines," said Welton.

It expects to take delivery of the first critical components for the engine from its partners before the end of this month, and hopes to begin testing later this year.

Many of the parts for the project are being provided without charge by the company's partners. The project's partners include Sigmatex, a Cheshire-based carbon-fibre developer, which is also working on the Bloodhound SSC land speed record car. Sigmatex is providing complex 3D-woven carbon-fibre parts such as the combined rocket chamber and nozzle unit.

"Instead of going straight for a regeneratively cooled chamber, we are using a test chamber, which will be wound carbon fibre with an ablative heat shield inside," said Welton. "That will verify the turbo pump before we incorporate the regeneratively cooled chamber."

The company is also working with London-based 3D Print UK, and Essex Laser, which is based in Grays.

## Grey matter

#### Funding aids work on white carbon fibre

#### BY CHRIS PICKERING

UK-based materials specialist Hypetex has been awarded £100,000 from Innovate UK to help its development of white carbon fibre.

In its natural state the material always comes in more or less the same shade of dark grey. However, in 2013, Hypetex began work on a process that would allow the company to produce carbon fibre in virtually any colour, without the use of a secondary paint or coating.

"Paint adds weight, which defeats the object of using carbon fibre in the first place," said Marc Cohen, Hypetex's CEO. "Our process has a negligible effect on the overall mass of the part – we're talking fractions of a per cent – and it accentuates the underlying weave structure."

Other benefits are said to

include improved resistance to ageing from heat and UV, plus a small increase in tensile strength. However, the one thing the process can't offer reliably at this stage is the preferred colour for a lot of applications: white.

"At the moment we're getting discolouration issues at certain curing temperatures," explained Cohen. "We've had some very good results, but they're not consistent enough for mass production just yet."

Hypetex can now offer production parts in other colours, although the material is awaiting certification for some industries, such as aerospace. The process itself is a closely guarded secret and the company manufactures all parts in-house to protect its IP.

Cohen said that his team has a solution in mind for the discolouration problems.

## AEROSPACE Weight watchers

Element of EU Clean Sky 2 project seeks to lower weight of aero engines

GKN Aerospace is involved in an initiative to lower the weight of aero engines by up to 30 per cent.

The company's aeroengine centres of excellence in Sweden and Norway will work with project leaders Safran, Rolls-Royce and MTU on the engines element of the EU's €4bn Clean Sky 2 project.

GKN's teams in Scandinavia will design, develop and manufacture complex structural parts, as well as rotating parts for full-scale aero-engine integrated technology demonstrators (ITD).

Robert Lundberg, director EU R&T Programmes at GKN in Trollhättan, said that candidate processes and technologies for the Clean Sky 2 project will include adaptive laser welding, additive manufacturing and the introduction of new Ni-base high-temperature alloys, as well as new automation techniques. "We are responsible

for some of these engines' complex structural parts [such as] inter-compressor structure, rear turbine structure, but also rotating parts, such as the rotating structures for the Open Rotor engine demonstrator," said Lundberg.

"The goal is to reach TRL6, which means that product development can start right after the demonstration/validation," he added. JF/CP

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### news: design



## See for miles

#### Radically enhanced vision for tank crews

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#### BY JON EXCELL

An advanced situational awareness system developed by engineers at BAE Systems enables a tank's crew to see through their vehicle's armour.

The BattleView 360 system combines a head-mounted display with cameras on the outside of the vehicle to give an unobstructed view of the surrounding terrain.

The system then uses communication and digital mapping technologies to augment this view with real-time data on a host of surrounding features of interest.

The system can be accessed via a head-mounted display as well a head-down touch screen display that can be used by commanders to assess information

and view the displays of other crew members, and even other vehicles, such as unmanned drones that may be patrolling the area.

BAE claims that this will enable a vehicle commander to make i also revealed that

vehicle commander to make rapid informed decisions and communicate these decisions to other vehicles.

The technology has been developed by BAE's Swedish subsidiary Hägglunds.

Dan Lindell, one of the engineers behind the system, said it offers considerable advantages over existing technologies. "It's a huge difference," he said, "'You get proper see-through armour and with augmented reality. You get blue forces and red forces tracking and the correct geographical data just by looking through the armour."

Lindell added that by coupling all of the information with 3D map data, the system is able to plot and identify safe routes for vehicles. "For instance", he said, "if you have a high point scout that you want to sneak by, if you have that 3D data the driver would be able to see the route. That has never been seen before."

The system has been designed to be compatible with a range of existing vehicles and communication technologies. According to Lindell, it is currently

under trial with a number of users and the firm is continuing to refine the technology before it enters full production. BAE has

also revealed that engineers in the UK are working on a related "intelligent turret" system. The firm said that this technology is being developed to free up armoured vehicle crews to concentrate on the battlefield.

A spokesperson declined to confirm whether this development will include some form of autonomous driving capability.

## AUTOMOTIVE Cutting back on drive-by noise

#### New tyre design could reduce vibrations

#### BY CHRIS PICKERING

Tyre manufacturer Falken has released a new design that could cut cabin noise levels by as much as four decibels and drive-by noise levels by up to 10 decibels.

The patented Silent Core technology was developed in collaboration with Falken's parent company Sumitomo Rubber Industries (SRI). It uses a layer of ether-polyurethane foam applied to the inner surface of the tyre to damp vibrations and resonance in the air trapped within the carcass.

Left unabated, these vibrations travel up through the suspension and into the cabin, where they're heard as the characteristic tyre drone. Advances in powertrain design and aerodynamics mean this drone is often now the single biggest contribution to cabin noise, so any form of attenuation is useful.

While Falken is not alone in using a foam core to damp these oscillations, the company's successful patent application suggests that its approach differs somewhat from those offered by other manufacturers. The construction is described as a 'double-hump' shape, which may contribute to the acoustic properties it exhibits.

The manufacturing process is now said to be mature enough for series production and the Silent Core tyres are undergoing a pilot phase with a well-known automotive manufacturer.

Falken reports that its testing to date has shown no adverse effects on performance or tyre life.

Silent Core is a very simple yet extremely effective solution to the reduction of drive-by and cabin noise created by the tyre," said Andreas Giese, product planning manager at Falken Tyre Europe. "We've received a significant amount of interest from automotive manufacturers about this new technology, which is cheaper and easier to implement than electronic technologies. Initial reports from the pilot test are positive and we're looking forward to seeing the Silent Core technology progress."

## Well-healed flight

#### Self-healing alloys could really take off

A project is underway to investigate the use of self-healing alloys in aerospace structures.

It will develop alloys suitable for additive manufacturing (AM) processes, followed by the development of a metallic manufacturing process as flexible as AM and as precise as subtractive manufacturing.

UK firm Ilika has been awarded a £466,000 grant for research and technology for its role in the £2.15m, three-year project.

Ilika, which is focussed on accelerating the development of new materials through its patented, high-throughput techniques, said the project would lead to novel components with critical feature tolerances.

By doing so, the project expects to overcome the challenges faced in the design of aerospace components with lower weight, structural integrity and functional performance.

Graeme Purdy, Ilika ĈEO, said that self-healing alloys are metals that respond to stress by changing their grain structure to eliminate micro-cracks.

"They would be used for load-bearing components such as engine mountings on aeroplanes that need to cope with repeat vibrational loads," he added.  $J\!F$ 

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## viewpoint: klaus dieter rennert



W ith congestion suppressing GDP by two per cent, 65.7 million road accidents a year and seven million deaths from air pollution worldwide, there is a huge challenge for organisations looking to effect change in the transport industry. Yet there is also an opportunity for those taking an innovative approach.

How we travel and the transport we choose has a huge impact on society, from congestion and pollution to productivity and well-being. About two per cent of GDP per year is currently suppressed by congestion and in excess of 10,000 deaths per year occur as a result of air pollution exposure in London alone. In the UK, there are around 2.3 million accidents each year. Despite the list of significant challenges that call for 'smart solutions', little headway has been made in the UK to improve people's daily lives.

Social innovation in transport applies technological innovation to travel experiences in order to deliver lifechanging outcomes for people. This could take the form of mitigating the effects of congestion or pollution, or developing new mobility products and services, providing

behaviour change when adopted on a mass scale. The most opportune areas for innovation include reducing congestion and air pollution caused by transport, improving journey time reliability and information on transport.

Mobility needs to offer **by 2025** customers integrated travel options, as opposed to the largely individual modes of transport we have now. We are already witnessing new mobility models such as car sharing and on-demand transport applications, which reduce the reliance on private cars, and are far more sustainable.

In London, just 34 per cent of trips are made by private car, with the remainder by public transport, walking or cycling. We've also seen declining applications for driving licenses among 16–29 year olds in

## Moving on to innovation

Social innovation in transport has potential to transform people's daily lives, says the chief executive for EMEA-CIS, Hitachi

particular over the last decade in the UK (nine per cent), France (four per cent), and Germany (14 per cent), for example.

Those who do use cars are increasingly looking for smarter solutions. We have seen a sharp rise in the market for smart parking, both by installing sensors in the infrastructure, and by linking the supply and demand through mobile applications. Navigating drivers to a secure space improves confidence from the user and reduces congestion. The smart parking market was worth US\$14bn in 2014, and is forecast to grow to US\$56bn by 2025, creating particular opportunity for train stations and transport hubs.

One of the key opportunities to enable social innovation in transport is through connecting public and private transport. While 'connected cars' (i.e. vehicles enabled to communicate with infrastructure through embedded devices) have existed for several years, communication and cooperation between vehicles and connected transport-related infrastructures (such as traffic lights and parking lots) is a relatively new phenomenon. By allowing vehicles to communicate with each other and their

The smart parking market is forecast to grow to \$56bn surroundings, real-time data can help improve road safety, traffic efficiency and passenger comfort.

Hitachi is working as part of a consortium to deliver vehicle-to-vehicle and vehicle-to-infrastructure communications (v2x), initially with pilots for full

electric vehicles, as demonstrated in their role in the EU project eco-FEV. This includes the invention of an electromobility platform that combines information from full electric vehicle (FEVs) related infrastructure systems, with intelligent telematics services. This could generate a whole ecosystem of clean electric vehicles and allow communities to measure congestion and transport use.

In the UK, the HS1 railway has led to a 33 per cent passenger increase on the



Southeastern trains network, and has cut journey times significantly. Alistair Dormer, Global CEO of Hitachi's Rail Systems Business, stated that "people can save time and therefore enjoy having breakfast with their children or getting to the gym – a true social innovation in daily life".

More of us live in and travel through cities for longer periods of time. Without social innovation in transport, economic risks and social costs will increase. Social Innovations in transport, such as those outlined above, could reduce the reducing the number of accidents on the road by 25 per cent, saving the UK £1.2bn.

The building blocks are already in place in many cities and countries. If we can take a more collective fluid approach to transport technology, we can build a reciprocal transport system that will in turn, allow us to live more collective informative lives.

Social innovation in transport and mobility is a global phenomenon, with many different regional opportunities to make a real difference. Whether it's bringing personal mobility to places where infrastructure is limited, or driving economic growth around transport hubs such as train stations, social innovation in transport and mobility is an enabler of a better future.®

Klaus Dieter Rennert is chief executive for EMEA-CIS, Hitachi

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## the<mark>hot</mark>topic

## **Emission omissions**

#### Unsurprisingly, coverage of the Volkswagen emissions scandal generated plenty of discussion.

I suspect that Volkswagen is not the only company to do this sort of thing, and I guess the US will be doing more testing and investigation to see just how much of this has taken place.

But, more fundamentally, it reveals how much software is used (and abused) in a modern vehicle and how little oversight of this is regulated. It isn't just VW cheating on emission tests, there was the 2009-11 Toyota vehicle recalls due to flawed engine management software that led to some deaths; recent Ford cars refusing to shut off the engine; and Jeep having safety-critical systems hackable through the connection to the in-care entertainment system.

It is high time that any software that has any control or connection to safety or regulatory functions should be independently audited. It also needs something like an NCAP star rating given to it, depending on the quality and security of design, testing and on-going maintenance. Paul Crawford

I would be hugely surprised if this turns out to be just Volkswagen

and only that engine type. I'd bet most big manufacturers are doing something along these lines, for obvious reasons. I am sure drive-by noise tests have been manipulated in a similar way for some time. Jonathan Douglas

What did the engineers involved in this think they were doing? In 17 years in the aerospace industry I encountered quite frequently the attitude 'I'm just doing my job/following orders'. Maybe it's time, as is happening now in at least some MBA courses, to start teaching engineering students about ethics and their obligation to blow the whistle on unacceptable behaviour. As we see here, and in so many other activities in the past, keeping quiet only damages the company in the long run. **Mike Hally** 

It's not a surprising situation when you consider that all the figures are produced in house. Having a cleaner vehicle is a good sales pitch and, with insanely high worldwide sales potential, there has to be a little temptation. It's hardly the result of a rogue engineer having a play, it's a corporate decision to deceive. It's a bit of a 'horse-meat' situation on a grand scale and, unfortunately, we'll all forget about it far too quickly again. **Neil Davison** 

This is nothing new. Even at the beginning of emissions regulation, all manufacturers were trying to cheat the



system. It all started when they used to put their exhausts into low-pressure areas and run their engines on sewing machine oil, and remove power-sucking items such as alternators, power-steering pumps and air-conditioning systems. This progressed onto claiming 'elf and safety guv' and having vacuum pipes attached to exhausts, and ended up with hand building engines specifically for fitting into vehicles destined for emissions testing.

This area has merely grown and every car manufacturer breaks the rules. As it has gone unchecked for so long it was inevitable someone would push the envelope further and get caught out. **S Martin** 

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## Our anonymous blogger ponders the irritating rise of the armchair engineer

Recently, there were two news items of such magnitude that they generated repeated headlines

and the consequences are likely to rumble on for much longer. They occurred within days of each other and the response I witnessed on social media seemed to be very telling.

The first was the disaster at the Shoreham air show. In case the details have escaped anyone, this was the largest British air show disaster since Derry went in at Farnborough during the 1950s. At the start of the afternoon's flying on the Saturday, a two-seat Hawker Hunter entered a loop and failed to pull out, crashing onto the A27. Eleven people are confirmed dead with, hopefully, the fears for this number growing proving to be unfounded.

The second was China's stock market crash. The markets operate on an international level so the ramifications are twofold. Foreign investors in China will have had their shares dramatically fall in value and other stock market centres have had their local stocks influenced with these too being devalued. Theoretical money it may have been, but still billions were lost.

So how were these addressed by the public on social media? I can only rely on my 'friends' online but there are a large number of them with a wide range of backgrounds and general outlook.

Therefore, although I make no claims to this being a scientific survey I am confident it can be seen as representative. Broadly speaking, the Shoreham crash generated a high level of response. This varied from those in the aerospace community cautioning against the more lurid coverage in the press and speculation regarding the cause, to people generally ignorant of aircraft operations offering views in a tone of absolute certainty. I have lost count of the number of times I saw comments about banning aerobatics over residential areas (of course, this is already illegal and air shows certainly aren't held over built-up areas.)

People who I wouldn't trust to put oil in their car were suddenly experts gleefully calling for sweeping changes and declaring how it is obviously dangerous to do anything with an old jet except park it permanently in the hanger. By contrast, I have seen absolutely no comment regarding the stock market crash, the closest being one person posting a newspaper article about the Chinese government accusing a journalist of causing it.

There is the fact that fireballs and fatalities have their own sensationalist draw but, on the one hand, we have an accident that, thankfully, directly affects a very few people, and, on the other, an event that (through pensions and the like) affects most people.

In addition, there is a social emphasis on us to take personal control of our finances and to invest for the future; there is no similar drive for the general public to have a knowledge of engineering.

Why then should our field of expertise be the one seen as appropriate for some ill-conceived judgement?

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#### **Realdeal?**

The UK government's £2bn Chinese nuclear guarantee angered many readers.

The money should be going to a UK-led effort. There is enough expertise in the industry but the government does not listen to its own people. When you hear chancellor George Osborne's simplistic take on the deal you really have to wonder what is going on. **Mike** 

Where are the men of vision? Once again, our politicians have sold out our own industry for short-term benefit. For a once world leader to buy in technology displays a chronic lack of

foresight, and from a country whose USP is low-cost manufacturing. When will the London elite realise that wealth is not 'created' by trading shares and that manufacturing matters. **Geoff Kershaw** 

Having worked with Chinese companies I can say that their attitude to health and safety, and the environment, is terrible. If they have little regard for these factors in their own country they will care little about ours. Additionally, the strategic issues of allowing a repressive, totalitarian regime get involved with fissile material in the UK beggars belief. **Neil Frazer** 

■ The reported figure of £2bn is far too cheap. It should be more like £20bn a year payable in advance, tied in with a £100bn bond in case of default at any time. Our nuclear power experts, who know the true value of the deal, should be controlling the negotiation all along the line, not George Osborne. Alan George

■ Foxes and chicken coops come to mind with this deal. All we need now is a deal with Putin to guarantee gas supplies in perpetuity. Stephen Bunch



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**Bloodties** The public unveiling of Bloodhound was debated by our readers.

Of course, one cannot be otherwise than amazed and stimulated to see the results of so much intellectual engineering effort, translated into hardware. I can only offer yet again my 'usual' caveat: yes, nice to get the record, lots of PR puffing but do the two presently most successful 'engineering' nations (the losers in the Second World War) spend their time on projects such as this? Or do they spend their time dealing with the multitude of 'ordinary' engineering projects that citizens and firms require in millions, rather that with such prestige 'one-offs'? **Mike Blamey** 

This is one of the most marvellous things for UK engineering for many years. Mike, stop putting on your usual caveat and get behind our country and our profession. We need the media to give more time to projects of this kind and less to the documentaries that show how good we used to be. We still do things such as this and we are bloody good at it. People just need to be shown this kind of thing on television when they will be watching (in the middle of *EastEnders*). Peter Langridge

Having the air intake at such a high level gives me concern for the dynamic stability of the vehicle if at high speed a slight deviation from the straightahead direction alters the airflow into the duct, possibly leading to turbulence and lateral forces that may lead to loss of control. Just my thinking and I'm happy to be proved wrong. John K

#### **True**steel

The news that SSI was mothballing the Redcar steel plant provoked some strong opinions.

Personally I see steel making as a strategic industry and it should be maintained regardless of short-term fluctuations. The UK does not seem to have this mentality; very little is seen as strategic and that varies depending on which government is in power - none have protected much in recent years. The irony is in a few years time when prices and demand have recovered we will be moaning about having to import steel at vast expense. Personally I would like to see us as a nation decide what we consider to be truly strategic and stick to it for the long term regardless of short-term economic and political considerations. Mike

■ It is a sad decision by a board of highly paid directors, beholden to Wall Street and the stock exchanges. But just remember the basic economic factor: for every person employed, there are three people who support those 1,700 SSI employees being made redundant. Thus, the real figure is 6,800 people being affected, along with the tax base for unemployment and numerous businesses and shops in the immediate surrounding area supplying services. When will industry and government officials realise that the overall effect is not just 1,700 people losing their jobs, but on the whole economic area? Steel is one of a country's prime base industries and should be supported, so the country does not lose its place in the world steel markets. Geoff Daly

The issue behind the closure is electricity prices. Large users in the UK carry a massive over-cost due to our CCL and other subsidies on non-commercial power. If they were fully exempted and the tax-payer carried the full cost (as in most of Europe) at least the competition would be fair. The pain would be felt more by the taxpayer who might then appreciate the massive damage climate-obsessed leaders are causing. Jack Broughton

If it's true that EU rules prevent us from providing the help to keep the Redcar steel plant open, then engineers know what they should be doing in the EU referendum. **Cheerful middle-aged engineer** 

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## the Paul Jackson column

## **Demand outstripping supply**

#### It would be a disaster if a shortage of skills negatively affected the delivery of priority infrastructure projects



#### I welcomed the chancellor's

recent announcement of a National Infrastructure Commission under the leadership of Lord Adonis, "taking the politics out of infrastructure planning" and ensuring a longterm strategic approach to delivering the UK's infrastructure. The chancellor's announcement

of a £5bn infrastructure investment is not to be sniffed at, but, if Lord Adonis and the commission are to deliver on their promise, we need the skills to deliver priority infrastructure projects.

George Osborne said it would be a disaster if inertia were to stop us pushing forward with infrastructure projects. I say it would be a disaster if a lack of skills were to have the same result.



As a country we are great at engineering and we should be proud of our ability to deliver impressive projects such as the redevelopment of Birmingham New Street station. That project created 3,000 new construction jobs and the high-impact projects that this new commission will review will draw on a limited pool of workers with the right skills, at the right level.

Take the rail network, which has seen passenger journeys grow by 50 per cent in the past decade. What the network delivers is pretty impressive given that rise in volume but with projections of a doubling of freight and passenger traffic by 2030, we need a greater and more skilled workforce. The majority of construction workers have level 2 skills, yet often more advanced skills are required. For example, at HS2, 50 per cent of the construction jobs are at level 3 (equivalent to A level/advanced apprenticeship).

More than 85,000 people are currently employed in the rail industry but to deliver what is currently planned on the network for the next five years it requires almost 10,000 more, which the talent pipeline will struggle to produce. If the commission pushes through projects such as ones to improve connections between northern cities, this demand is likely to rise.

This problem is further compounded by the fact that 40 per cent of the rail workforce is over 45, meaning retirement is a major influencing factor in the industry's skills landscape. For each new technician recruited, 2.4 technicians are lost to retirement; and for every three

engineers that retire only two are recruited. One potential solution, of course, lies in delayed retirement, which could mean the retention of up to 180,000 skilled workers.

#### More than 85,000 people are currently employed in the rail industry but to deliver on plans requires almost 10,000 more

With skills in such high demand across the board, the rail sector has some rather stiff competition, including from nuclear with its f48bn investment, the automotive industry which employs more than 700,000 people and 3,000 aerospace companies. Given the promise of a decision on airport expansion by the end of the year we may well see further demand from that front sooner rather than later.

Demand already outstrips supply in engineering and as an industry we have a responsibility to boost the supply of skilled workers, to bring new blood into the industry. I am pleased to say that, among others, Crossrail and Network Rail are committed to the Tomorrow's Engineers programme. Infrastructure isn't just about rail, and engineering isn't just about infrastructure however. We need all sectors to help inspire the next generation of engineers.®

**Paul Jackson** is chief executive of EngineeringUK





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### feature: renewables

## **Power** of nature

Bubble wrap: DONG Energy uses noisereducing bubble screens to install wind turbine foundations

## Stuart Nathan spotlights some of the most promising disruptive technologies in renewables

#### WIND

I n the world of the offshore wind turbine, size matters. Offshore turbines have always been larger than their land-based counterparts, but in recent years they've sprung up faster than a teenager in a growth spurt. From the 3.6MW turbines that were state of the art around 10 years ago, the current installations at offshore windfarms under construction are 8MW units; to give a size comparison, the rotor on a 3.6MW turbine is about the size of the London Eye with the top of the uppermost blade 120m above sea level when it's vertical, while an 8MW turbine is 222m from sea level to blade tip.

an 8MW turbine is 222m from sea level to blade tip. The reason is cost. It's much windier out at sea than on land, even on the windiest day, and the larger the area swept out by the rotating blades, the more of that wind resource the turbine can capture. But cost comes into play because, although large turbines are of course more expensive then smaller ones, the costs for the entire installation don't rise in a linear fashion. Large generators are cheaper per unit of torque than smaller ones, and the cost for the foundations, infrastructure and installation of a large turbine aren't much higher than a smaller one. The feeling in the industry is that if you go to the expense of putting in the foundations for an offshore turbine and all the cabling, then it makes sense to put the biggest turbine you can on top of it to justify that outlay, said Tim Camp, head of turbine engineering at DNV GL, a Norwegian shipping organisation that has now branched out into renewable energy. The smaller the number of turbines a company needs to make up the generating capacity of a windfarm, the more cost-effective it'll be and the lower the resulting cost of power: a very important consideration, as offshore wind is still the most expensive way we have of generating electricity. "We're already talking to people about 10MW turbines and even bigger," said Brent Cheshire, head of UK operations for DONG Energy, the Danish company that has built and operates most of the UK's largest offshore windfarms, and is now installing Vestas's MHI 8MW units at its windfarm extension projects at Walney, off Barrow-in-Furness, and Burbo Bank, in Liverpool Bay. "These really are very big beasts, but they genuinely do drive the cost down." There will be a limit to how much bigger offshore turbines can get.

There will be a limit to how much bigger offshore turbines can get The power a wind turbine can produce is proportional to the square of its linear dimensions, whereas its cost is proportional to the cube; so eventually, the cost of getting bigger will outweigh the increased generation benefit. But the feeling in the wind industry is that the industry is still some way off that, so for the next decade at least turbines will continue to get bigger.

The next goal for the sector is the 10MW turbine, as Cheshire said, and although the engineering task of building these giants is by no means trivial (the blades would be the largest composite structure ever made, much larger even than the wings of the biggest passenger aircraft; and gravity loads, experienced when the blade is not in a vertical position, lead to a need to stiffen the blade to prevent bending, which increases weight) some industry figures, notably Siemens Wind Power's chief technology officer Henrik Stiesdal, think they could be

### feature: renewables

made with current technologies, although DNV's Camp thinks that bearings and main casings are potentially problematic, and that the industry needs more experience with 6 and 8MW units.

The first plans for a commercial 10MW turbine were unveiled in 2012 by a Norwegian firm, Sway Turbines. Often at the forefront of offshore turbine development, Sway pioneered a concept for floating wind turbines that were anchored to the seabed by a cable.

The Sway 10MW concept looks markedly different from a standard turbine; its most distinctive feature is a 25m-diameter open structure, resembling a bicycle wheel, around the hub of its 164m-diameter rotor. This is an open generator, with two rotors sandwiching an iron-free stator, all encapsulated in the rim of the wheel; eschewing iron cuts the weight of the generator (it weighs 162 tonnes compared with 375 tonnes for a conventional direct-drive 10MW generator) and allows cheaper permanent magnets to be used in the rotors, reducing the need for scarce and expensive rare earth metals.

The blades are attached to V-shaped blade support structures, which run from the hub to the generator rim, which adds stiffness and stability to the overall unit, according to chief technical officer Eystein Borgen. The blades are attached directly to the generator rotors through these support structures. This has two main benefits, Borgen explained: "The direct coupling... gives a short load path and leaves the generator air gap unaffected by flapping forward and backward wind loads. Another benefit is the rotor torque and blade gravity loads are distributed and absorbed by the entire structure."



Open up: The Sway 10MW concept includes an open generator

#### SOLAR

One technology has completely dominated the solar photovoltaic sector for almost its entire existence: crystalline silicon. Silicon is extremely abundant and its raw material is very cheap; moreover, silicon's semiconductor properties are fairly easy to exploit in a form that captures the energy of sunlight and converts it into electric current. Moreover, it's the most efficient material at doing this.

But although the processes to make crystalline silicon solar panels are well understood, it's an exacting and expensive business, involving high temperatures and energy usage. Costs have come down in recent years, but this has mainly resulted from economies of scale; and there's a limit to how much can be gained from this.

There is much research going on into alternatives to silicon, but efficiencies for, as an example, organic photovoltaics have not yet approached silicon. However, one particular class of new materials is causing excitement. Called perovskites, these materials have achieved large increases in efficiency in a relatively short time; and most exciting of all is that they could be very much cheaper than crystalline silicon; it's sometimes said they could be more than a thousand times cheaper.

Defining a perovskite is rather tricky. Perovskite itself is a rather unpromising-looking naturally occurring mineral, calcium titanium oxide. But it has lent its name to any substances that have its distinctive structure. They have the general formula ABX3, where A and B are positively charged ions — often metals — of markedly different size, with A bigger than B, and X is a negatively charged ion that binds to both. The structure has the A ion surrounded by 12 X groups at the vertices of a geometrical solid called a cuboctahedron; and the B ion is surrounded by eight X groups at the vertices of an octahedron (two square-based pyramids joined at the base). To avoid confusion, we'll refer to the former as perovskite mineral and the latter as perovskite structures.

The exciting thing about perovskite structures is how the behaviour of electrons in the material can be tailored. PV cells work by exploiting the phenomenon that high-energy ultraviolet waves can knock electrons loose in semiconductor materials and allow them to move through the material. The energy difference between bound electrons and conducting electrons is known as the band gap and, in silicon, it matches the energy of the incident radiation. It's bigger in perovskite structures, but researchers at Los Alamos National Laboratory have found a way to grow perovskite crystals with large areas of high purity; something that is very difficult to do with silicon. In silicon, conducting electrons can easily get trapped at the boundary between a perfect crystal region and a defect, which reduces the efficiency of the material because trapped electrons can't contribute to the current flow. "We're growing crystals with millimetre-scale, defect-free domains," explained Los Alamos researcher Aditya Mohite. In a PV panel, the layer of active material is typically about 500nm thick, which means that it's extremely unlikely that a photoelectron would ever become trapped. "It virtually guarantees that the photoelectrons make it out," Mohite said. This advantage outweighs the drawback of the wider band gap, along with one other exciting factor.

This is that the process to make these high-purity crystals requires low energy. It's called hot-casting, and involves immersing a hot substrate in a solution of a perovskite structure salt. Even though it's a hot process, it's much cooler than the temperature needed for purifying silicon. Moreover, solution processing is simple, fast and easily scalable for industrial producers, and unlike silicon crystals, doesn't need clean rooms.

The Los Alamos perovskites, which are based on the compound CH3NH3PbX (where X is a halide) are producing efficiencies around 15 per cent (that is, they convert 15 per cent of the energy in sunlight into usable current) with a peak efficiency so far of 18 per cent. This is still lower than the 20 per cent record for commercial silicon cells, but one thing that gives the researchers hope is that it took decades to develop silicon cells with that efficiency, while perovskite research has only been going on in earnest for a few years. Mohite's team believes that there are several factors that could be optimised, including the material composition itself, the parameters of the hot casting process and the electrode materials.

A study by Northwestern University and the US Department of Energy published in August found that perovskite PV cells could repay

#### We are growing crystals with millimetre-scale, defect-free domains... it virtually guarantees crystals make it out

Aditya Mohite, Los Alamos National Laboratory



a complex 3D structure

## feature: renewables

their costs 10 times faster than silicon PV cells, with a payback time of about two to three months.

The main drawback still to be overcome with perovskites is their durability. Because the materials usually contain a component that is organic, they degrade in contact with oxygen and humidity so they need to be sealed within shielding materials that tend to reduce the amount of energy that gets to the active material. This is a problem that is also being tackled in the UK, with a team at Imperial College looking at the degradation mechanisms. Led by Saif Haque in the chemistry department, the team has found that when an electron is released from the perovskite crystal, it can react with oxygen in the air, creating highly reactive 'superoxides' that attack the crystal, in turn generating water molecules, which also attack the material. Adding a layer of a material such as titanium dioxide, which can trap electrons in the perovskite rather than allowing them to reach the air, could slow this process down or eliminate it altogether, it suggests.



Grown up: perovskites can be grown as high-quality crystals

#### The main drawback still to be overcome with perovskites is their durability... they degrade in contact with oxygen and humidity

#### TIDAL

Tidal power is the youngest and probably least developed of the three main subsets of renewable energy, but it's already acquired a recognisable form: something like a horizontal axis wind turbine, but installed on a framework that allows it to be immersed in the sea. Sometimes the rotor is open, sometimes within a housing or duct; sometimes it's at the bottom of a shaft that descends from a floating structure on the surface; sometimes it's in some sort of framework that is anchored onto the seabed; yet another form is embedded into a harbour wall or similar structure that sits across the flow of the tide. But in all cases the turbine is in a sturdy piece of engineering that allows it to remain still in relatively deep water in an area where the tides rip through with high water speeds.

This is one reason that tidal power is so difficult. Areas with tides fast enough for power generation are relatively scarce, depending on the presence of some kind of channel between bodies of water that drain into each other (the Orkney Islands are located at just such a point, where the North Atlantic meets the North Sea, and the channels between islands and between the islands and the north coast of Scotland are well suited, which is why the European Marine Energy Centre is located there). Moreover, fast-flowing water is a very difficult environment to operate in, which makes installing and maintaining the turbines a challenging and expensive business.



But a new technology called a tidal fence might change the look, location and engineering surrounding tidal energy considerably. Designed to be installed in much shallower and slower water than conventional tidal turbines,

#### The rotation speed is slow, so marine life would be able to swim straight through the turbine without injury

Peter Dixon, Kepler



tidal fences would represent a cheaper, more accessible alternative that could be used in a tidal estuaries – a far more common location than the fast tide sites needed for other systems.

Tidal fence turbines look rather different from conventional tidal systems. Rather than using a propeller-shaped rotor that sits at right angles to the direction of water flow, they are more like vertical-axis wind turbines laid on their side: barrel-shaped constructions that rotate as the tidal flow runs over and through them. Technically, they are referred to as transverse-horizontal axis water turbines (THAWTs), and they are at their most efficient in shallow water, 20m deep, rather than the 30m depth typically needed for conventional tidal turbines, and in water flowing at about 2-3m/sec, rather than 8-9m/sec as seen regularly off Orkney.

The turbines themselves are made from composites, and have the form of a triangular stressed truss. This has the advantage of not needing to be enclosed in any sort of supporting structure; it just rotates freely between two 'posts', which house the generators and export equipment. The basic generating unit consists of two turbines with a central direct drive generator, with four supporting bearings and three foundation supports.

The turbines are being developed by a company called Kepler Energy, which was set up in 2010 to develop technology invented by three researchers from the University of Oxford's Department of Engineering Science, Ross McAdam, Guy Houlsby and Martin Oldfield, who collaborate with the company on development and testing. They have tested scale-model turbines in controlled conditions.

The simplified structure reduces the cost of the technology considerably, Kepler chairman Peter Dixon told *The Engineer.* "They need very little maintenance and work in either direction, on the in- and out-tide," he said. A typical installation for a single unit would be 10m in diameter and 120m long, consisting of two rotors with a single generator; in a 2m/sec flow this would generate more than 4.4MW, and in 2.5m/sec this would rise to above 5.2MW. "The rotation speed is slow, so marine life would be able to swim straight through the turbine without injury, or just avoid them altogether," Dixon added.

A key factor in the capacity of the generators is that when the area of the turbine is large compared with the flow of the water, the power output is proportional to the head – the difference in height between the top of the tidal flow and the turbine site – rather than the flow velocity. In other words, it extracts potential energy, as well as just kinetic energy, as is the case for conventional tidal turbines

Kepler has big plans for the technology, with a targeted project of a 1km-long fence in the Bristol Channel. With a projected cost of f.143m, this fence would generate 30MW of power, Dixon claimed; a longer fence, 10km long, would have output comparable to a small nuclear power station." The Bristol Channel fence, which would run between Abertawe and Minehead, could be operational by 2020-21, Dixon claimed.®

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## feature: agriculture

# Line in the sand

New technology could transform poor-quality sandy soils into high-yield agricultural land. Andrew Wade reports

hrough a combination of climate change, drought, overgrazing and other human activities, desertification across the world is on the march. It's a process defined by the UN as "land degradation in arid, semi-arid and dry sub-humid regions". Given that around 40 per cent of the Earth's land surface is occupied by drylands – home to around two billion people – the potential for desertification to impact the planet is huge. A recent report from the Economics of Land Degradation Initiative claimed that it's a problem costing the world as much as US\$10.6tn every year – approximately 17 per cent of global gross domestic product.

The refugee crisis in Europe has highlighted the difficulties that arise when large numbers of people migrate. However, the numbers arriving from countries such as Syria, Lebanon and Eritrea pale in comparison to those that could be forced into exile by changing climate conditions. According to the UN's Convention to Combat Desertification (UNCCD), the process could displace as many as 50 million people over the next decade.

But one Norwegian start-up is developing a technology to wage a frontline battle with desertification. Desert Control

is a Norwegian company set up by Kristian and Ole Morten Olesen, alongside chief operating officer Andreas Julseth. It was recently awarded first prize at ClimateLaunchpad, a clean-tech business competition that attracted more than 700 entries from 28 countries across Europe. The product that earned Desert Control top honours was Liquid NanoClay, a mixture of water and clay that is mixed

#### Shifting sands: Desert Control's CEO Ole Morten Olesen says the technology could help reverse desertification

in a patented process and used to transform sandy desert soils into fertile ground.

"The mixing process splits the clay particles into individual flakes and adds air bubbles on both sides of the flakes," Ole Morten Olesen, CEO of Desert Control, told *The Engineer*. "The mix is then spread over the land and allowed to saturate down to root level – about 40-60cm deep. This requires around 40 litres of water and 1kg of clay per square metre."

Olesen explained that his father Kristian, Desert Control's chief technical officer, has been working on the process behind Liquid NanoClay since 2008. The treatment gives sand particles a nanostructured clay coating, completely changing their physical properties and allowing them to bind water. The process, which does not involve any chemical agents, can change poor-quality sandy soils into high-yield agricultural land.

According to Desert Control, virgin desert soils treated with Liquid NanoClay produced a yield four times greater than untreated land, using the same amount of seeds and fertiliser, and less than half the amount of water. It found that Liquid NanoClay acts as a catalyst for Mycorrhizal fungi when nourishment is available, with the fungi responsible for the increased yield. Clay is a fundamental component

of productive arable land, acting as

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Virgin desert soils treated with Liquid NanoClay produced a yield four times greater than untreated land a water-holder, providing elasticity, and allowing non-clay elements to bind to the soil. In the past, adding clay to dry land in order to improve its agricultural value has involved tilling clay into the soil. This requires large volumes of clay and substantial amounts of manual labour. The process of transforming sandy soil into fertile land can take between seven and 15 years. By comparison, Liquid NanoClay takes just seven hours to saturate into the land.

The water and clay is mixed on site using the patented process, then traditional irrigation systems such as sprinklers or water wagons are used to spread it across the sandy soil. The individual clay flakes bind to the surface of the sand particles with a Van der Waals binding, significantly increasing the ability of the soil to hold water and nutrients.

The cost of treatment per hectare is US\$4,800, and requires a 15-20 per cent retreatment after four or five years if the land is tilled. If the soil is untilled, the treatment lasts for longer. Converting a piece of desert the size of a rugby pitch into fertile land for this cost seems like a pretty good deal.

"In just seven hours the soil is totally transformed," said Ole Morten. "We use existing irrigation systems to apply the Liquid



NanoClay, removing the need to till the land and use much greater volumes of water."

The performance data for Liquid NanoClay is based on field tests that were conducted at the Agricultural Research Centre (ARC) in Ismailia in Egypt. White pepper was planted in test fields containing dry sandy soil. Fields treated with Liquid NanoClay gave an additional two months of harvest, compared to the fields that were untreated.

Following the initial harvest, the plants were then left without irrigation over winter and spring, when new plants were due to be sown. However, the original crops were found to be in such good condition that they could be used for another season.

"When we returned the following season, we were surprised that the pepper plants were looking so healthy," said Ole Morten. "We had expected to have to replant, as they had been left over winter and spring without irrigation. But the old plants were in good enough shape that we could use them again in the next season."

Unsurprisingly, some of the most vulnerable areas to desertification are in north and central Africa, around the edges of the Sahara. Other regions under threat include large parts of China and Mongolia, as the Gobi encroaches into the eastern parts of the Eurasian Steppe and the farmland it supports, as well as several regions in Australia.

When pitching Desert Control at ClimateLaunchpad, chief operating officer Andreas Julseth also focused in on the particular business opportunity available in Central Valley, California. Making up around 14 per cent of California's total land area, the valley is one of the world's most productive agricultural regions. Farmers will flock to us when they see they can reduce dependency on water by at least 50 per cent Andreas Julseth

However, since 2011, the state has been in the grip of one of the worst droughts on record.

"In 2014, the agricultural sector in Central Valley lost 165,000 hectares to fallowing," Julseth recently told the ClimateLaunchpad audience. "Fallowing means they ploughed the land but didn't sow any seeds, because there simply wasn't enough water available to sustain the land. They estimate this had a US\$2.2bn impact on the agricultural industry."

In the desperate search for water, farmers in California have been digging ever deeper, employing oil-drilling equipment to reach the disappearing aquifers. Not only is this expensive, it is eradicating an ancient natural resource in a classic tragedy of the commons. Acting out of rational self-interest, the farmers are draining a communal water resource dry. Julseth believes Liquid NanoClay can help avert the impending tragedy.

"I believe that farmers will flock to us as soon as they see that they can reduce their dependency on water by at least 50 per cent," he said. "Put it this way – if they were using our product, the present drought would no longer be a problem. I also believe that land developers will use the opportunity to buy dry land, have us treat it, and then be able to sell it for eight to 10 times the purchasing price. Because that's the reality now – dry land goes for one-tenth what fertile land goes for."

If Desert Control can successfully get Liquid NanoClay to market, the potential of the technology is enormous, with implications for fragile environments around the globe and the populations that inhabit them. Along with the testing that took place in Egypt, additional third-party verification is taking place at the Faculty of Natural Sciences at Imperial College London.

## Spacetherm<sup>®</sup> - Custom-built performance

A supplier of high-performance insulation is being called upon to design and fabricate solutions to meet the demands of a growing and diverse variety of important specialist market sectors. The A. Proctor Group explains how it is harnessing its experience and expertise working with the material to provide precisiondesigned and engineered results for customers.

Invented in the 1930s, aerogels are synthetic materials in which the liquid has been replaced with a gas to provide lightweight but highly insulating products which have been used for everything from NASA astronauts' suits to crude oil and gas pipe applications. Spacetherm Aerogel comprises aerogel converted using nanotechnology into a flexible but robust blanket which provides, by some margin, the most effective solid state insulation available. This product's ultra-low thermal conductivity (as low as 0.016 W/mK) means that it can be specified at substantially thinner dimensions than alternative options, making it space-efficient when used in thickness critical applications.



Having supplied the product for over a decade in the UK, the A. Proctor Group has expertise in not only lamination of the product using specialist adhesives, but also in its custom fabrication which is enabling this advanced material to see use in a growing range of diverse applications beyond construction. The A. Proctor Group has traditionally been recognised as a specialist supplier of advanced breather membranes

and other forms of insulation, so diversifying into aerogel was a natural step which enabled it to combine the product with other materials, and also offer a bespoke design and fabrication service.

Spacetherm Aerogel insulation is available in three varieties, which provide distinct performance levels for different applications, but which all share the product's hydrophobic (water resistant), flexibility, breathability and versatility benefits, in addition to its low weight and thickness. Standard Spacetherm offers ultra-low 0.016 W/mK thermal conductivity, and a maximum operating temperature of 200°C. However the company also supplies a high temperature version, which although not quite offering the same level of thermal performance, provides specifiers a maximum operating temperature of 650°C, making the product suitable for extremely demanding heat sensitive settings. Finally the low temperature version enables the benefits of aerogel insulation to be brought to sub-ambient and cryogenic applications down to -200°C.

However it is the fact that the material can be cut to any size and shape, in addition to its flexibility and other performance benefits, that has really begun to open up new market sectors in the past few years. The A. Proctor Group pioneered the use of aerogel in UK construction applications, but is increasingly employing its expertise to design and fabricate precision thermal solutions to very specific customer needs in other sectors. Sam Proctor, Head of Thermal Solutions at A. Proctor Group explains further: "Some



thermal insulation challenges require a bit more than just a standard specification. With over a decade's experience fabricating and cutting Spacetherm Aerogel blanket, our specialist team can cut to Imm tolerances from CAD details to provide the precise result many customers demand."

Sectors from the oil and gas industry to the space industry are now calling on the A. Proctor Group for its ability to provide 3D modelling and CAD capabilities at the design phase as well as the full cutting facilities, all from its premises in Scotland. Sam comments: "Our R&D team is highly enthusiastic as well as expert, and they really enjoy solving client's often challenging requirements." The flexibility of the Spacetherm product versus more rigid rivals is gaining it fans across many sectors, for its capabilities of being formed around products to provide a tight fit, and therefore optimum performance as well as spaceefficiency.







One recent example saw the Group supplying 5 mm low temperature Spacetherm to the University of Warwick for heat-shielding its CubeSat project, a small cube-shaped satellite orbiting the earth as of April 2015. The precision-cut Spacetherm lining the unit will ensure that the operating temperature inside the satellite, which is packed with sensitive electronics, will be no colder than -40°C. Says Sam: "This is a really exciting example demonstrating how Spacetherm can perform in the most demanding situations, and CubeSat's test missions have shown that its thermal performance is as good as was hoped."

Another niche requirement, this time from the rail sector, was for insulation of point heaters used to defrost frozen points on railway lines more effectively by directing more heat energy to the rail itself. Sam Proctor explains further: "Working in very harsh conditions, rail infrastructure managers need the best equipment which will do the job quickly and reduce the risk of line closures due to extreme winter weather conditions. They approached us to develop Tracktherm, a Point Heat Retaining Strip made of high temperature Spacetherm, which is clipped into place over the rail and heating electrode, and minimises heat loss." Finally, a prestigious client, namely BP, required



a solution to significantly improve the performance of it's insulation on the Bruce oil platform in the North Sea whilst also looking to reduce the risk of potentially catastrophic corrosion under insulation. The A. Proctor Group Ltd were tasked as part of a system solution, with designing and fabricating preformed high temperature Spacetherm due to its hydrophobic as well as breathable properties, to significantly improve thermal performance and reduce the moisture problems. Sam says: "The project for BP really showed how well off site prefabrication of materials including high-performance Aerogel insulation solution could save time and cost in an offshore application. A total of 13 project shutdown days were saved, meaning a 30%-35% project cost reduction, and our attention to detail meant that installation errors were minimised and costly wastage substantially reduced."

Custom fabrication has another key benefit, that of waste minimisation, says Sam. "Because

the team designs each product bespoke for each application with very small tolerances, and fabricates it at the same site, we can ensure that waste is reduced to a minimum. Clients discover that the product fits exactly, if their drawings are correct, meaning they have very little if any trimming to do on site."

Other key applications of Spacetherm's rigorous design and fabrication service include marine, high-performance automotive appliances and the aerospace industry, all areas where the flexibility of the product in addition to its other characteristics make it ideal for incorporating into often confined spaces. Finally, tests have shown that the performance of the product is continuous for 60 years+ adding yet another unique layer to it's remarkable insulation.

This truly space-age product is now seeing a greatly increased range of uses in applications across the globe, and far beyond construction, thanks to the design and fabrication expertise being provided by the A. Proctor Group.

Further information is available from the A.Proctor Group on 01250 872261.

www.proctorgroup.com custom@proctorgroup.com Tel: 01250 872261



## feature: software

# Connect the dots

Recent additive manufacturing advances have created a demand for more fully integrated CAD programs to consider unique parts. Will Stirling reports



S ince additive manufacturing (AM) was invented there has been a disconnect between the design engineer's vision and the physical printed part.

CAD vendors wrote CAD files for conventional manufacturing and AM machines are designed to receive STL files, which translate the design for the printing machine. They do marry, but they require a 'mesh' solution. Companies including Materialise and nettfab then began to offer an STL fixing function, as a translation stage. But it was still two communities working apart, said Danny Weber, vice-president Strategic Alliances at Stratasys. "It was a broken system with no true integration."

Printed parts have big physical differences to machined and cast parts in terms of end of use. For example, metal 3D-printed parts with overhangs require supports, which need removal that can leave a residue. The core AM technology – material deposition – naturally leaves a lumpy or 'rippled' surface in many cases,

which may be fine for applications such as prototypes but not for in-service, hightolerance applications. High amounts of finishing can be required.

Dr James Moultrie, senior lecturer in Design Management at the University of Cambridge, and his team have recently been awarded an EPSRC grant to research design for additive manufacture. This will examine additive manufacturing for series Arburg Freeformer software showing how the soluble or breakable support is designed with the part

production as opposed to prototype, where the underlying assumption is that making the economic case for many AM processes is, today, difficult.

"It is often disappointing for designers when they expect to see the beautiful finished component that they imagine comes straight off the machine. But unless they have experience of this they won't realise the amount of hand finishing [needed] to remove supports and to clean the parts up," said Moultrie. His research aims to help eliminate post-printing processes.

Another problem is that original CAD programs were not built to consider unique features of AM parts such as infills and internal structures.

Several makers of new

technologies are aiming

to give the market a

new standard for fully

integrated CAD for AM

The industry has responded. Several makers of new

technologies are aiming to give the market a new standard for fully integrated CAD for AM, designing for end-use manufacture from screen to machine.

PTC's Creo 3 software platform was launched in June 2015. CAD company PTC partnered with AM machine manufacturer Stratasys to deliver this and a platform called Design for Additive Manufacturing. The joint venture's vision is to provide ->

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## feature: software



#### The yellow material is the support, that can be designed as soluble in a water bath or breakable with built-in weak points

a single environment within PTC Creo to design, optimise, prepare, and validate designs for 3D printing. Stratasys's Danny Weber said it is the only platform that has reached this level of maturity for integrating design and manufacture. "Stratasys believes in collaborative efforts to promote the 3D printing space, and seeks partnerships with CAD vendors to address these issues and promote 3D printing accessibility and development of advanced design and engineering functionality," he added.

Collaboration seems to be key to product development in AM, as companies realise there is safety in numbers in a market developing at light speed. Autodesk has developed Autodesk Spark that tackles the problem of integration in a different way. Spark provides extensible application program interfaces (APIs) for each stage of the 3D printing workflow. These enable companies to add 3D printing functionality to applications. Autodesk claims that Spark can enable any application to prepare, optimise and deliver 3D models for any 3D printer or service bureau.

Nettfab, which Autodesk acquired on 28 September, takes a different approach. It takes in a file from the native format and slices it directly into the printing machine, without converting it to an STL file. "It is still mesh-based, because to turn it into a 3D form we have to turn the raw CAD design file into something that is editable, this is, into 'slices'," said Duann Scott, business development at Autodesk Spark 3D Printing Platform. Nettfab and PTC Creo 3 are still remeshing tools. "Until we can get a format that can go directly from the CAD

software into a printer, we will always have to remesh. It is a matter of how elegantly and intelligently we remesh those files," he added.

The really big initiative is to replace the STL file format with a new format called 3MF.

A consortium of companies, including Autodesk, Stratasys, Dassault Systemes, Materialise, Microsoft and others, is defining a new file format, which will allow better connectivity between authoring tools and printers. "It conveys more information than

Autodesk claims that Spark can enable any application to prepare, optimise and deliver 3D models for any 3D printer or service bureau just the topology in triangulation form," said Scott. "There is still a form of mesh involved – i.e. it is a translation from one language to another – but we think we can improve on this translation."

Many printed parts need external supports and infills, printed simultaneously with the components, especially for metal parts with overhangs. Supports vary a great deal from one solution to another. Supports can be soluble in water or another substrate, suitable for FDM and Stratasys's polyjet systems, for example, or breakable. The material that touches the part itself can be weaker than the primary support, to leave a smaller residue.

"Today, the supports are designed within the interface printer operator software and the user can edit the support material, structure, location and solubility, from the user interface not in the CAD environment," said Weber from Stratasys. But the designer has limited ability to simulate and understand the effect of this type of support on the part, he added.

"Our vision is that the engineering industry will benefit as the integration of CAD design and 3D printing platform progresses as we allow the engineer to simulate the part given the specific printing operation, including the support that he can use."

Several companies and universities, such as 3DSIM, are doing R&D on software and hardware solutions to print metal without supports. Depending on the geometry and the processes used this is now possible, but it's not easy and has not become standard. Arburg, which introduced the Freeformer AM machine to the UK and Ireland in September, has an 'open system' for standard materials that gives greater possibilities to vary certain parameters that might be needed, or helpful, for certain designs. It offers both soluble and breakable supports, the latter is a thinned-out intermediate layer with specifically generated predetermined breaking points. It shows that customisation is an important feature for AM machines across the upper price range.

Defence company BAE Systems is trialling many techniques with AM, software optimisation and supports. Matt Stevens,

BAE's team leader for AM in Warton, said there is a gap in the technology and an element of guesswork.

"CAD packages are set up to enable design for conventional manufacture. There is definitely a gap in between what current CAD software provides and what you need to be able to design optimally for additive manufacture," said Stevens. BAE Systems uses the Magics platform for manipulating STL files and for putting supports on to part designs. "We currently have to go through an illiterative process – trial and error

- where part designs are put into the software to prep them for the build, which includes the supports, analyse different orientations and [we] potentially have to go back to modify the design to then ensure all external and internal supports and surface finish are optimal to

produce the printed part."

Stevens said supports do far more than prop up the component. "For metal powder-bed, the SLM process, there are several aspects to cover and there will always be design concerns around these supports. They not only stop overhands from collapsing but also need to secure the part to reduce distortion and act as a thermal conduction pass, to remove heat from the part."

BAE Systems is making and fitting a range of AM parts onto both ground-based systems and in-flight components.  ${\ensuremath{\scriptstyle \odot}}$ 



### PIONEERING TOMORROW'S TECHNOLOGY FOR TODAY

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feature: pumps & valves

With engineers recovering oil and gas from marginal reserves, flow separators, and the valves that operate them, are becoming increasingly vital. Evelyn Adams reports

A bit special: separating different phases requires special equipment

# Mix masters

For most of the brutal heat of the desert to the unforgiving ice of the Arctic Circle, engineers are venturing into increasingly harsh environments to recover oil and gas from marginal reserves. Much of these energy streams come in the form of 'multiphase flows'. This is where liquid and gas are in the stream at the same time. It also describes liquids in which solid particles, such as sand and silt, are suspended.

Multiphase flows are becoming common with marginal hydrocarbons where engineers need to create mixtures capable of extracting oil and gas in low-pressure environments. Around 70 per cent of the world's remaining oil reserves are believed to be in the high-viscosity, or 'heavy', category. Most are produced and transported as multiphase flows, usually as a mixture of gas, heavy oil and water. In some cases, multiphase flows are created when sand and chemicals are blasted into rock to free oil and gas.

According to NEL, an independent consultancy for onsite oil and gas measurement and evaluation, the components of a multiphase mixture can be difficult to track, because they travel at different speeds. "Generally speaking, the velocity of the gas is much greater than the velocity of the liquid," said a spokesman. "In some production wells it takes the gas a few hours to reach the well head but it can take the liquid days to travel the same distance."

Multiphase flows can cause some significant problems for engineers. For instance, the flow can separate in the pipeline, leaving liquids behind. These liquids can then create backpressure problems. Meanwhile, temporary multiphase outflow changes can cause problems for the connected plant.

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### feature: pumps & valves

Exactly how the material is distributed throughout the pipeline varies, based on velocities and orientation of the pipes, and the monitoring of it requires sophisticated tools.

To help overcome these problems, engineers often separate their flow early on in the process. "To be more realistic, water may be separated from a crude oil stream on offshore oil platforms rather than transported to the onshore facilities," wrote Wuqiang Yang, in a paper for Manchester University. "Because the space on offshore oil platforms is limited and expensive, effective monitoring and control of the crude oil separation process on offshore oil platforms will result in huge savings to oil companies."

Control of the crude oil separation process on offshore oil platforms will result in huge savings

In most production facilities, the first

separation phase of any hydrocarbon production process usually begins once the product has started to flow from the well. Engineers must separate the gas from the liquids and the hydrocarbon liquids from the water. The same process takes place in marginal oil and gas production, such as when trying to extract shale gas. In this case, the hydrocarbon first needs to be separated from the flowback water using a series of sophisticated valves.

While the selection of separator is based on the specific flow mix, they largely work in the same way. The wellhead  $% \left( {{{\rm{A}}_{\rm{B}}}} \right)$ 

pipework sends through a mixture of oil, gas and water, which is controlled by the wellhead chock valve. The vessel then separates this mixture with the help of gravity. Oil floats on top of the water and gas forms above the oil. An extractor is often used to capture additional liquid from the gas. A weir over the oil can flow into a separate chambers. The remaining water is drained from the bottom of the vessel.

This volumetric flow of most separators is controlled by the inlet valve position, which is often a wellhead choke valve. Meanwhile, outflows are regulated by control valves, and the pressure inside

Goes with the flow: flow separation valve

Liquid look: the flows of different liquid phases need to be accurately simulated

the vessel is controlled by a gas outlet control valve. Some are simply on/off switches, while others provide a more continuous and smooth flow of oil and water from the separator allowing downstream production to be far smoother. This technique is known as phase separation. An example is Cameron's 3-Phase Separators - KCC Slug Catchers, NATCO Free Water Knock Outs and **Multi-Phase Separators** - which are typically fitted with effective inlet devices to absorb the momentum of the fluid. This removes gas that rises while the bulk liquid settles into the lower section of the separator through a valve that has horizontal flow. Meanwhile, the heavier water phase settles by gravity beneath the lighter oil phase. "Liquid levels are maintained by weirs and actuated control valves." said Cameron. "Oil can be discharged from the separator through two or more compartments. With the addition of optional externally adjustable weirs, fluid levels can easily be adjusted as needed. Water is discharged from a single outlet located at the bottom of the vessel and gas is discharged through

a separate outlet on the top of the vessel.'

GEA is offering to do the same thing with vertical bowl highspeed centrifuges. These are mainly designed to separate liquids with and without solids content. The maximum particle size that can be separated is 0.5mm with a total solids content of 0.1–3 per cent. "Only the high g-force of our separators can handle the low-density difference between, for example, heavy crude oil and water in a reliable and efficient way," said GEA.

IMI Critical Engineering, a provider of flow-control components, provides bespoke valves for such separators. It recently delivered a series

of choke valves for the Tahiti facility in the Gulf of Mexico.

Choke valves control the rate of flow of liquids and gases. Each valve had to be able to handle multi-phase flow with entrained solids. "Two custom valve designs were provided; an 8in and 6in 11,000 API with solid tungsten carbide trim, capable of withstanding a 2,400 psi drop in pressure," IMI explained.

As engineers venture to increasingly remote regions to find oil and gas, these systems are dealing with a greater variety of multiphase flows. Investing in the right separation technology now, could help save oil and gas operators money further down the line. ®



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## feature: advanced manufacturing





Aerospace manufacturers are increasingly using 3D printing for functional aircraft components. Helen Knight reports

# **Additive** takes off

hen the Flying Test Bed A380 aircraft from Airbus hits the skies later this year, it will mark a major milestone in aerospace manufacturing. That is because the Rolls-Royce Trent XWB-97 engine powering

That is because the Rolls-Royce Trent XWB-97 engine powering the aircraft will be equipped with the largest civil aero-engine component ever built using 3D-printing techniques.

The component, an engine front bearing measuring 1.5m across, contains 48 aerofoil-shaped vane components, each of which was produced by 3D printing, or additive manufacturing as it is also known.

Additive manufacturing is an umbrella term that covers a range of processes designed to build up components layer by layer from powdered materials. The technology was initially used by the industry to rapidly produce prototype parts, but it is increasingly being applied to build in-flight production components for aircraft. Later this year, for example, GE will begin printing fuel nozzles for the LEAP engine it is developing in partnership with Snecma.

The 3D-printed nozzles will be 25 per cent lighter and five times more durable than the existing nozzles they will replace, which have 20 different parts. They will be produced at a US\$50m facility in Alabama, which the company claims will be the first plant in the world to mass-produce 3D-printed aero-engine components.

Boeing, meanwhile, has several hundred types and tens of thousands of 3D-printed parts flying on its aircraft. These include 3D-printed parts on 10 different military and commercial aircraft production programmes, according to Leo Christodoulou, chief engineer for Boeing research and technology, materials and manufacturing technology.

Boeing's suppliers have been using selective laser sintering to make small, polymer parts for environment control system ducts ->



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## feature: advanced manufacturing

(ECS) for military aircraft such as the F/A-18 Super Hornet and EA-18G Growler, as well as the company's commercial aircraft.

"3D printing offers great potential to reduce the cost and weight of aircraft structures and improve the ability of engineers to design parts purely for their eventual function in a vehicle system," said Christodoulou. "It enables the design and production of monolithic structures, which means converting an assembly and several structures into one piece."

The company's metals research is focused on tackling challenges in the supply chain, such as difficult-to-cast or machined parts that are needed in limited quantities.

"We evaluate all categories of additive metals, including large, wire-fed systems, direct metal deposition systems and powder bed systems," said Christodoulou.

Although Rolls-Royce's record-breaking front bearing is a prototype rather than a production component, the project has helped the company to understand the challenges of industrialising additive manufacturing technology, said Neil Mantle, head of the centre of competence for additive layer manufacturing at Rolls-Royce. "Influences from new and recycled powder, operating practices and set-ups, multiple machine to machine variation and differing component geometries were all tested and invaluable knowledge gained," he said.

By using additive layer manufacturing for the front bearing, the team was able to spend more time designing and developing the part without the constraint of having to fix its design too early to allow for the long lead time for tooling, said Mantle. "By avoiding this, we reduced the overall manufacturing lead time of the first parts by approximately 30 per cent, while smaller part development continued in parallel using laser based systems."

GKN Aerospace is also actively investing in additive manufacturing, and is already employing – or will shortly begin employing – a variety of production techniques, according to Dr Rob Sharman, global head of additive manufacturing at GKN Aerospace.



Jet set: the key components of a Trent engine, including (top, centre) Rolls-Royce's prototype 3D-printed front bearing

For example, the company uses electron beam melting – a process by which metal components are built up, layer by layer, using a metal powder that is melted by an electron beam – to produce small- and medium-sized titanium components such as fittings and brackets.

Wire deposition techniques, in contrast, are better suited to tasks such as adding features to engine casings, while blown powder deposition can be used to repair and modify high-value components. "Additive manufacturing is a generic term like casting, with multiple processes underneath, and just like casting

you use each process depending on the component, the material, and the rate of production," said Sharman. "So, generally speaking with small intricate parts with internal channels, I would probably want to use a laser

powder bed (machine), but if I'm making a bracket or other small structural part I would want to use electron beam melting because it builds

#### Flying test bed: Rolls-Royce's Trent XWB engine will feature a 3D-printed front bearing

faster, the powder is cheaper, and there is less residual stress," he added. When it comes to building structural aircraft components using additive manufacturing, much of the focus to date has centred on making titanium parts as a direct replacement for conventionally produced ones, according to Sharman. "Particularly for aero-structure components, a lot of additive manufacturing is about making those parts from a near-net [shape] to make a saving on cost, because there is less waste

so you're not throwing all that material away," he said. However, as the technology develops, manufacturers will increasingly begin adapting the design of components to take advantage of the specific opportunities the new production processes offer, added Sharman.

Indeed, this is already happening in aero-engine manufacture, where companies are integrating multiple parts into a single complex component, such as GE's LEAP engine fuel nozzle.

Materials will also be specifically designed for the process. Existing 3D-printed parts are often made from titanium 6Al-4V powder, a widely used alloy originally developed for forgings, said Sharman. "We believe the next stage is tweaking those alloys for other production processes, to make them more receptive to electron beam melting or wire deposition, for example," he added. "Then you get the full benefits of the process, because you are designing the material for that process."

To this end, the company is leading a £3.1m research programme, backed by the Aerospace Technology Institute and Innovate UK, to develop titanium powders specifically for additive manufacturing. TiPOW (Titanium Powder for net-shape component manufacture) aims to develop powders formulated and blended to meet the needs of additive manufacturing.

Since the material is generated as the component is being built, aerospace manufacturers will begin tailoring the material's properties across different areas of the part, Sharman said.

This 'functional loading' can be used to adapt the microstructure and texture of the component at different points, to meet the varying load across the part. The final step would then be to change the composition of the alloy throughout the part, to meet different loads or requirements, added Sharman.

"Everything we currently make looks the way it does because of the way we make it, but nature doesn't build anything the way we do," said Sharman. "Now we finally have a process that can help us get closer to the way nature designs and builds things, but we are just at the start of it, and we have a long way to go to emulate that efficiency." B

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## interview: brent cheshire

# Wind convert

#### brent cheshire

UK chairman, DONG Energy managing director, DONG Energy wind power



#### Education 1976: Durham University, honours degree in geology

#### Career

1977: Joins Shell International Petroleum as a geologist in exploration and production division.
Fourteen years with Shell, including three years at the training centre in The Hague
1991: Joins Amerada Hess, serving in a number of roles, including senior vicepresident for E&P Worldwide Technology, where he was responsible for all global

technical activities 2004: Becomes DONG Energy's first UK employee, as managing director of UK E&P Company 2014: Takes on managing director role at DONG wind power and chairmanship of UK business

#### The UK chairman of DONG Energy talks to Stuart Nathan about overcoming his initial scepticism to the potential of wind power

rent Cheshire heads up the organisation responsible for building the UK's largest offshore wind installations and running most of them, but he freely admits that he came to the industry from a position of scepticism. "I'm an oil and gas geologist, and I worked in the exploration and production business for 37 years," he told The Engineer. After joining DONG Energy's E&P business, when he transferred over to head up its wind power division, "I thought well, we have a wind resource in the UK and we have to tap into it, but is it ever going to be serious? Gas has to be the thing to do."

Cheshire now declares himself a fan of wind. "Being exposed to the nuts and bolts of the wind business over the past 12 months, the load factors are much higher than I had thought, the uptimes are fantastic and the generation is really very good. We have wind farms on the west of the British coast, the east, and obviously we also have them in Denmark and Germany. And one of the things that you see, with that overview, is that there is a real balance. The wind is blowing well at different places and different times, and we're getting a lot better at predictability.'

This isn't to say that intermittency isn't an issue, he conceded. "There will always be the problem that if you've got high pressure and the wind doesn't blow and it's a cold day and you haven't got any solar, then you have a problem and you're going to need other forms of generation. But in the time I've been UK chairman and we've built more windfarms offshore, that's virtually never happened."

The name DONG Energy is an acronym for Dansk Olie og Naturgas (Danish Oil and Natural Gas, so it works as an acronym in two languages although it's only amusing in one). The company was formed from a merger between an E&P company and a gas pipeline company, and then a number of Danish electricity companies joined the group, and it is majority owned by the Danish state. Wind is not its biggest business, comprising 12 per

#### **L** The wind is blowing well in different places and times, and we're better at predictability

cent of its turnover compared with gas as 18 per cent; specialising in deep drilling, it is a major player in developing gas production in the West of Shetland region. It also operates thermal power stations (which are all fuelled by biomass) in Denmark.

However, it's probably best known in the UK for wind, where it specialises completely in offshore. It was the first major investor in UK offshore wind with the construction of the 30-turbine, 90MW Barrow windfarm in the Irish Sea 7km off the Cumbrian coast, which it built in 2005-6 in partnership with Centrica, and now has 10 operational windfarms around the UK, of which it operates seven; another two, with total capacity of 2.5GW, are under development.

It's often stated that the UK has the best wind resource in Europe, so why did it take a Danish company — and a state-owned one at that to develop that capability? Cheshire puts it down to the company's early start in the sector. "DONG put in its first wind turbines as a company — which is to say one of its constituent companies — about 30 years ago, and they're still actually running."

The Danish government had a policy to develop low-carbon generation, as at the time it was dependent on coal imports. "Denmark building an industry was part and parcel of state-regulated utilities, which sowed the seed," he said, and when it started to expand outside Denmark it looked for a nearby market with a culture its executives felt they understood. Having already developed the world's first large-scale offshore windfarm, the UK was an obvious target for DONG.

The wind industry has been dogged by scepticism and local opposition in its onshore guise, but Cheshire is adamant that the offshore industry is a very different beast. For a start, it's windier, to an extent that he believes most people who aren't familiar with conditions at sea seriously underestimate. "The performance is much better compared to how I would have thought of it in my old sceptical days," he said.





"The reliability of the turbines in mechanical terms is fantastic, and more than 90 per cent of the time these things are ready to go. We're actually generating well in excess of the high 40s, 50 per cent of the time, and those are much higher load factors than people thought."

DONG sinks considerable resources into making sure that its wind farms are located at suitable sites. "We test the seabed and the windspeeds over a long period of time, and we're getting a lot more sophisticated about how we measure those wind resources," said Cheshire.

The way the company approaches siting is evolving, however, as part of a general concern with driving down the cost of wind energy. "Quite a few years ago, we tended to build farms where there was a lot of wind, but we didn't worry too much about distance from shore or seabed conditions because we could engineer our way out of that," he said. "And we did, but that costs."

DONG now uses a model that balances wind speed with distance to shore (the further out, the dearer it is to bring the electricity back) and the seabed conditions, as well as the scale of the windfarm in terms of number and size of turbines. Like much of the wind industry, it is gradually increasing the size of turbine in typical installations, from 3.6MW (about the size of the London Eye) to 6MW units in its new windfarm at Race Bank, 27km

We test the seabed and the windspeeds over a long period and we're getting more sophisticated

## DONG off the UK

DONG Energy's British windfarms

Name	Location	Capacity	Notes
Barrow	East Irish Sea	90MW	
Burbo Bank	7km off North Wirrall	90MW	
Burbo Bank extension as a	258MW	Onstream late 2016	
Gunfleet Sands	7km SE of Clacton	170MW	
Hornsey One	120km off Grimsby	1.2GW	Construction to start 2016
London Array	Thames Estuary	630MW	Dong owns 25 per cent
Race Bank	Off North Norfolk	580MW	Onstream 2018
Walney	Near Barrow	637MW	
Walney Extension	Near Barrow	660MW	Completion 2019
Western Duddon Sands	South of Walney	389MW	
Westermost Rough	8km off Hull	210MW	

north of Blakeney Point on the Norfolk Coast, and 8MW for Burbo Bank 8km offshore in Liverpool Bay, where it is building an extension to an existing facility. An 8MW turbine is 220m tall from sea level to blade tip.

Other cost-reducing measures include standardising windfarm components such as the substations that handle the electricity. "We have a guy called Mats Vikholm working with us; he was previously with Volvo and he's well versed in driving down cost from his time in automotive," said Cheshire, "and he's also a fierce champion of bringing in local content."

Vikholm, DONG's head of procurement and cost of electricity, has instituted a process of considering installations in terms of their essential components: onshore substation, export cabling, offshore substation, including the windfarm control system, array cables, foundations and turbines. Each component is optimised and each successive windfarm has to produce demonstrably cheaper electricity than its predecessor.

For offshore substations, DONG moved from building bespoke systems for each installation to working with WS Atkins to design a standardised unit. "Sometimes it's overengineered for an installation, but on a unit-cost basis it still saves money."

The goal is to for installations specified in 2020 (which would come on-stream in 2023) to produce electricity at a cost of €100/MWhr. "We expect to hit that," he said. "The latest units off East Anglia are coming in at about £119.50 [€160], and we're still reducing that cost."

Cheshire is pleased that the local content on installations is increasing, up to 50 per cent in terms of value, and also that the installations are benefitting local communities in other ways. For communities that once made their living from fishing, wind power is a good fit, he said.

"The maintenance base we're establishing in Grimsby for our Westermost Rough windfarm has been very good for the harbour and the port," he commented. "Centrica and E.on are there as well, and it's giving a real sense of optimism. Westermost Rough will be 20km offshore, and it'll give good jobs on boats with training and a line of sight to good careers." ()

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## O&A: space elevators





As space elevators move from the realm of science fiction to reality, our panel of experts answers your questions. Stuart Nathan reports

Space elevators have been mainstays of science fiction for decades. Arthur C Clarke was particularly fond of the concept, using it in no fewer than five of his novels; other luminaries such as Kim Stanley Robinson, Robert Heinlein and Iain M Banks also used the idea of a tower with its top in a geostationary orbit, allowing payloads to be sent into orbit by hauling them up the tower rather than using chemical rockets to get them there. The idea has a long history, being first proposed long before the first real rockets, in 1895, by the Russian space science and astronautics pioneer Konstantin Tsiolkovsky; but it has gained more currency in recent decades because it's thought that it might be a cheaper way to attain orbit. The practical considerations, such as materials science and the actual mechanics of the elevator system, have been seen as so onerous that it could only be a concept.

But a Canadian company, Thoth Technologies, has been awarded a patent for a partial space elevator concept, with a tower 20km high topped with a runway for space plane-type launch systems to take payloads the rest of the way up to orbit. We sent readers' questions to Thoth, whose chief executive, Caroline Roberts, and the inventor of the system, Brendan Quine, Thoth's chief technology officer, a professor at the Lassonde School of Engineering at York University in Toronto, have provided answers (TT).

The president of the International Space Elevator Consortium, Peter Swan (PAS) has provided answers to questions that were more concerned with the general concept of space elevators than the Thoth concept. Dr Swan is a senior scholar at the NRO Centre for the Study of National Reconnaissance, a retired lieutenant colonel in the USAF and has taught at Delft University and the Stevens Institute of Technology.

#### What is the Thoth structure made from, what is it inflated with, and what is its aspect ratio?

**TT**: The ThothX Tower is made from readily available materials, such as Kevlar and polyethylene, inflated with helium or hydrogen. The patent example structure describes an aspect ratio of 50:1.

#### The ThothX Tower is made from readily available materials, such as Kevlar and polyethylene, inflated with helium or hydrogen

Thoth Technologies

As 90 per cent of the energy required to enter orbit is kinetic, a space elevator would knock around 10 per cent off the potential energy, so less than 1 per cent off the orbital needs. How can less than 1 per cent off energy lead to 30 per cent off cost? TT: As we describe in A free-standing space elevator structure: a practical alternative to the space tether BM Quine, RK Seth, ZH Zhu Acta Astronautica 65 (3), 365-375, 2009, rockets consume approximately 39 per cent of their fuel during the initial ascent phase to 20km. The reduction in fuel usage comes with a corresponding benefit in the number of stages needed to reach orbit (only one stage is required for a launch at 20km versus three or four for conventional launch). The 1 per cent energy estimate claim does not take into account the staging aspect of rocketry (the rocket is extremely heavy with stages and fuel at launch and very light by orbit). Rocketry is extremely energy inefficient with only about 3 per cent of the chemical energy going into raising to payload to orbit. Thus massive amounts of fuel and hardware must be raised initially to have enough left to propel the final injection stage. Electrical elevators are 50 to 60 per cent efficient leading to a significant fuel saving advantage that enables single stage to orbit space planes to fly from the top of the tower. These planes can also be completely reusable such as a passenger jet as opposed to being single use such as current rockets. This reaps a very significant hardware cost advantage that will reduce the cost of space access.

## O&A: space elevators





### Could an electromagnetic launcher be run up the inside of the tower?

TT: Magnetic launch systems hold great promise to launch small compact payloads and might be best deployed at the top of the tower where satellites could be launched directly into orbit.

## For a true space elevator, i.e. with the top in orbit, would construction be from the ground up or from the orbital end down?

PAS: Two points that are important to remember. There is only one point on the 100,000km space elevator that is 'in orbit' and that is at the GEO location. You are only 'in orbit' if you release from the space elevator, which is a permanent attachment to the Earth and rotates with it. When you release from the SE, you go into some type of Keplerian motion – below approximately 24,000km, the ellipse does not miss the Earth on the far side with its perigee. Between 24,000km and GEO the ellipse has apogee at release point and perigee below that. At GEO, approximately 36,000km altitude, you release into a circular orbit maintaining the relationship with the Earth, in the same way as GEO satellites. Beyond GEO, you go into ellipses that have the apogee well above the GEO orbit - at 47,000km altitude release you go into an orbit that has apogee near the Moon, with a 57,000km release point enabling you to go beyond Earth's pull and reach Mars. At the end of the space elevator (roughly 100,000km), a release will enable you to reach the outer planets and then go beyond the solar system with planetary assists. All this motion is due to the kinetic and potential energy provided by the motion and height of the release location. No chemistry is required to start your journey. Rockets are then needed to adapt

your orbit, provide trajectory changes or land on large bodies. Second, The current concept for construction of a 100,000 km space elevator is the following:

**Step one:** lift cable to LEO, raise it to GEO (with the old-fashioned method, rockets).

**Step two:** lower the 'starter' tether from GEO to the surface of the Earth. This initial tether will just be robust enough to support itself and small climbers.

**Step three:** Build up the tether with use of small climbers. These small climbers would leave the surface of the Earth with additional tether to be combined to the starter tether such that the tether would grow in capability.

**TT**: The ThothX tower is built from the ground up. Thoth is also pursuing patents for construction techniques, including an extrusion method. We believe the Japanese are planning a space tether that uses a counter-balance beyond geostationary orbit to hold up the mass of the tether. This likely requires in-space construction (top down). The main challenges of this design are

#### There is only one point on the 100,000km space elevator that is 'in orbit' and that is at the GEO location

#### Peter Swan

materials strength (carbon nano-tubes are not strong enough) and lightning strikes that could sever the tether. If a tether is to be realised then it would be advantageous to mount it on the top of a 20km pneumatic tower to avoid the environment of the lower atmosphere.

Would there be any advantage in using balloons to lift payloads to a platform, using the barge principle of moving large weights slowly rather than small weights fast? TT: We believe balloons have limited utility because of their lift capacity. The inventor has experience in launching heavy-lift balloons to the stratosphere, however, the payload is limited to a few tonnes. A similar effect could be achieved using an evacuated shaft and gas pressure to raise payload. It is also highly likely that a regenerative elevator design would be used to harness the potential energy released during descent.





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## O&A: space elevators

Take it to the top: A 'climber' ascends on an orbital tether



What measures would be taken at design stage to prevent buckling, and what systems would be in place to ensure the integrity of the structure once built?

TT: The problem of structural wrinkling (the onset to buckling) has been addressed by previous research (see 'Experimental investigation of inflatable cylindrical cantilevered beams' ZH Zhu, RK Seth, BM Quine, S Okubo, K Fukui, Q Yang, T Ochi, JP Journal of Solids and Structures 2 (2), 95-110, 2008). The core is not comprised of a single gas cell the diameter of the structure but by many cells arranged in a torus. Consequently, maintenance can occur to repair leaky cells without compromising integrity. The research paper lays out experimentally derived guidelines for pneumatic structures to avoid the onset of wrinkling, which we have adopted in our design. The control system is implemented in a multiply redundant computer system much like that equipping a modern jet

### height would they act? Are there any forces resulting from the rotation of the Earth?

TT: The structure is designed to withstand a Category 5 hurricane with wind speed of 156mph with significant safety margin and so the sheer and turbulent forces of a thunder storm are within this design envelope. The structure's pressurisation would exceed 100 times atmospheric pressure so pressure changes would have limited effect. The large structural mass is leveraged by the design to negate external forcing by steering the structure's centre of gravity. There are forces resulting for Earth rotation but we have estimated these as quite small compared with other forcing factors. There are also thermal stress effects to be countered.

For a 20km tower, space debris would not be a problem as most meteorites burn up before 20km Thoth Technologies



#### View from below: The lower end of an elevator could be at sea

where at least three systems are used in hot redundancy so as to ensure continuous operation. Using external sensor data such as wind velocity and building attitude, the control system would command control responses from actuators that would adjust the structure's stance in order to counter external forces in a harmonic control strategy that is described in the patent.

What's the magnitude of the forces that would act on a structure such as this owing to air pressure, and to what

*Elevator Survivability, Space Debris Mitigation* 2011, www.lulu. com. The bottom line on space debris and space elevators is that it is an operational issue that can be successfully managed with design and procedures.

TT: For a 20km tower, space debris would not be a significant problem as most meteorites burn up before reaching 20km. Like the ISS, the ThothX tower can adjust its position. The main novelty of our patent is in the harmonic control strategy that we describe that continuously monitors and corrects the structures stance in order to control it. The centre of gravity is guided actively over the base in order to null out external forces such as a hurricane. We also anticipate that structural maintenance and repair would be necessary as with any real construction.

altitude would this become an issue for a space elevator? And how could it be designed to deal with this problem? PAS: For the full space elevator, the answer is two fold. For small stuff, that is not tracked, accept the hits and design the tether for it, with repair climbers going up or down once a year. For the 200 to 2,000km altitude region of the space elevator, the tether would be designed to accommodate this threat. The tether would probably be 1m wide, woven to spread the tension and adaptable for any strand penetrations. In addition, the tether would be curved so no single small piece of debris could cut the tether. For trackable debris, the tether would be moved. This requires excellent tracking of space debris (expected by 2030 or so) and the ability to move the tether (there are many ways to do this: reel in, out, move tether climbers up/down faster slower, actually use thrusters at the GEO Node or Apex Anchor, or actually move the Marine Node). The knowledge of each segment of the tether can be simulated and updated with measurements in real time to ensure the knowledge is available for predictive avoidance. The calculations of the threat to space elevators - hits and density of threat - are in the report: Space

The ISS regularly has to

adjust its position to avoid space debris. At what







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## careers: rail

## Rolling forward

## With numerous rail projects underway in the UK, opportunities for skilled engineers are on the rise. Helen Knight reports

www.including London's new East-West rail link, Crossrail, new intercity trains being built for two of the UK's main lines, and plans for High Speed Two (HS2) steaming ahead, the industry is facing a very busy period.

Added to this activity, the government has just announced that 'paused' electrification plans for the Midland Mainline and TransPennine routes will now go ahead.

And with all of these projects either underway or in the pipeline, opportunities for skilled engineers in the sector are on the rise, according to Graham Coombs, spokesman for the Railway Industry Association.

"The railways have a very extensive programme both of new rolling stock and also infrastructure improvements, including signalling," he said. "So there is an enormous workload, which is going to need skilled staff."

Last year, Transport for London awarded Bombardier Transportation the contract to build 65 new trains for its Crossrail line, which is set to open in 2018, linking Reading in the west with Shenfield in Essex in the east.

The Crossrail project is creating 340 new jobs at its manufacturing plant at Derby, where the new trains will be built.

Each of the nine-car Bombardier Aventra trains will be over 200m in length, and be able to carry up to 1,500 passengers. The trains will be fitted with an automated vehicle inspection system and predictive maintenance technology.

Meanwhile, Hitachi Rail was last year awarded the contract to build trains for the government's £5.7bn InterCity Express Programme (IEP), designed to reduce journey times and improve reliability on the Great Western and East Coast Main Lines.

Last month, the company officially opened its £82m Rail Vehicle Manufacturing Facility in Newton Aycliffe, County Durham, which will build the new InterCity Express trains, creating 730 new jobs.

The facility has been purpose-built to supply the new IEP trains, according to Julia Potts, human resources manager for Hitachi Rail at Newton Aycliffe. "Hitachi Rail Europe will provide 122 trains for the programme, a total of 866 vehicles," said Potts. "The new trains will improve reliability, offer more services, provide more seats and reduce journey times." The IEP Class 800 trains, which will enter service on the Great Western Main Line in 2017 and the East Coast Main Line in 2018, will be a combination of fully electric and bi-mode trains with both diesel and electric propulsion. They will be capable of travelling at up to 125 miles per hour.

The Newton Aycliffe facility will also build 70 new AT200 commuter trains for Abellio ScotRail, Potts said.

The company is actively recruiting engineers to help build the new trains. "At the moment the focus is on quality engineers and manufacturing engineers," said Potts. "In terms of graduate recruitment and apprentices we are looking for manufacturing and electrical engineers for the 2016 intake." The company has noticed a shortage of engineers with electrical skills during its recruitment process, she added. Engineers will need to be multiskilled, providing engineering and technical support to the production and maintenance areas, said Potts. "On a daily basis they will focus on improvement activities, carrying out work analysis, method study and labour utilisation analysis to improve efficiencies."

The company is particularly looking for "time-served craftsmen" with a knowledge of lean manufacturing tools and techniques. "We are striving to recruit locally but where there are skills shortages we are keen to encourage people back to the North East," she said.

Engineers working for the company may be expected to travel further afield. Staff from the factory have already spent around 3,000 hours working alongside employees at Hitachi Rail in Kasado, Japan, building the first IEP train, and will pass on their expertise to the UK workforce.

"As we continue to learn from our colleagues in Japan, a willingness to travel is essential," said Potts.

# **6** Overlap of potential projects means there is going to be a massive resource demand in the future Phillip Hodgson



Elsewhere in the rail industry, demand for engineers is just as buoyant, according to Phillip Hodgson, divisional head of rail at recruitment firm Matchtech.

"The overlap of potential projects means there is going to be a massive resource demand in the future," he said. "For a candidate the opportunities are huge right now."

Alongside Crossrail and other projects, including the government's plans for HS2, Network Rail is in the midst of a five-year, £38bn investment programme, known as Control Period 5, designed to upgrade and improve the network. In particular, this is increasing demand for signalling engineers, said Hodgson.

"The number of IRSE [Institution of Railway Signalling Engineers]-licensed engineers out there is well below 1,000," he said. "So there is a huge need for more skilled people across the whole industry."

Although engineering jobs within rail infrastructure have been largely based around London in recent years, as a result of Crossrail, that is likely to change, thanks to projects such as Network Rail's electrification of the Great

### careers: rail



of new rolling stock gathers pace

Western Main Line and the recently confirmed work to electrify lines in the Midlands and North of England, said Hodgson.

"It's no secret that through the main years of the recession Crossrail really underpinned the rail industry, and was also a home to a lot of engineers from other industries who were seeking shelter," he said. "That was very London-focused, but I would suggest that talk of a northern powerhouse, and obviously with the high-speed rail link, we're going to see things move up the country."

Worryingly for the industry though, many of these major new rolling stock, infrastructure and upgrade programmes are set to overlap.

"The rail industry is in a fantastic state right now, but there are a few hurdles the industry needs to overcome; one is the overlap of projects, which is going to be an issue from a skills shortage perspective," said Hodgson.

"Crossrail is here and now, and if you think about the CP5 projects, and then add HS2 on top of that, and perhaps other projects that aren't rail-related but might pull on similar skills that are out there, those skills are going to be tough to find," he said.®



show preview: Advanced Engineering UK

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Random and the NEC, Birmingham, this year's Advanced Engineering UK looks set to be the biggest outing yet for an event that has become a key date in the diary for the UK's advanced engineering communities.

According to the show's organiser, this year's event will bring together more than 700 exhibitors from across the supply chain and is well positioned to showcase the kind of innovative technology the UK is particularly known for, with an emphasis on its commercialisation possibilities.

Typical areas of coverage will include graphene, wearable/printable electronics, smart materials, additive manufacturing, new approaches to design and manufacturing, and much more.

Alongside the exhibition, the conference theatres will host presentations from a variety of industry speakers, including representatives from Boeing, Airbus, Composites UK, and the high-value manufacturing catapult.

Short, sharp deliveries will provide attendees with quickly accessible industry intelligence, application case studies, and technology updates.

One key feature at this year's event is the Enabling Innovation Poster Zone, where ideas and concepts from the UK's up-and-coming innovators are showcased. Hosted by automotive supplier Magna International, with support from the Knowledge Transfer Network, the zone will provide a unique opportunity for early-stage innovators to showcase breakthrough ideas, products and processes to the UK's largest advanced engineering audience. Submissions will come from incubator-level organisations, university students, research-based companies and start-ups. The zone will give the 13,000 visitors attending Advanced Engineering UK the chance to uncover potential technologies, partners and untapped capability.

The Aero Engineering Show; Composites Engineering Show; Automotive Engineering Show; and Performance Metals Engineering are all co-located with this year's event.

The Automotive Engineering Show 2015, will provide a showcase of specialist UK and international engineering services, technology and supply-chain partners supporting the UK's multiple vehicle engineering programmes – from passenger cars to performance vehicles; from



commercial vehicles to motorcycles, specialist low-carbon vehicles and the engine sector.

The Aero Engineering Show will showcase the technology and suppliers supporting the UK's critically important aero engineering supply chain.

The Composites Engineering Show will place the spotlight on the latest

composites materials, processing equipment, and much more.

Finally, the Performance Metals Engineering show has been added to this year's programme in response to increasing demands for higher performance from metallic materials in a range of capabilities vital to tomorrow's engineering world. Protoco

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Candidates will be graduate mechanical engineers, ideally with experience in the design of pneumatic or hydraulic valves or systems. Familiarity with modern design tools, such as SolidWorks, is necessary, and a knowledge of analytical tools would be desirable. Dynamic individuals will have the scope to build on their experience, gain professional qualifications (I.Mech.E. MPDS scheme) and develop their careers in this international organisation.

Please email your CV with covering letter and details of your salary expectations to:

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## news:digest

### october1894

*The Engineer* got all hot under the collar about a large aluminium boat that appeared to defy all preceding norms of military craft design

A visit to *Engineer* Towers 111 years ago would have caught our predecessors in a state of excitement most atypical of the Victorian gentlemen. London was aflap, it seems, over the exhibition of a boat in the Thames that appeared to defy the norms of military craft design. As yet unnamed, this was a torpedo boat that a Poplar-based shipbuilder called Yarrow & Co had built for the French Navy.

"Ten tonnes with steam up and coal in the bunkers; twenty and a half knots speed; 300 horsepower. Ten years ago perhaps five years ago — the man who suggested the possibility of producing a boat which could live in a sea and



satisfy the conditions embodied in the lines above would have been regarded as a lunatic by those who had not watched the progress of events," the journal expounded breathlessly. The boat's secret was that it was made from aluminium;

#### Lt was designed to be carried on the deck of a warship and used at need

indeed, at 60ft long and 9ft 3in across the beam it was not only the largest aluminium ship ever made at that point, it was the largest aluminium structure of any kind.

The vessel was a second-class torpedo boat, designed to be carried on the deck of a larger warship and launched at need, so lightweight construction was a necessity.

The Engineer proclaimed the boat "the best torpedo boat of the size

that has ever been produced". Later reports are patchy; it appears that it was named *La Foudre* and some reports suggest that it suffered from corrosion.

The use of aluminium was adopted by navies worldwide as a superstructure material, but this was relatively shortlived. The metal does not respond well to heat; despite the perception of it as a relatively inert material, it is highly chemically reactive and, in certain circumstances, highly flammable. Moreover, at high temperatures it loses strength rapidly. **SN** 

#### For more on this story visit **www.theengineer.co.uk**

### prizecrossword

When completed rearrange the highlighted squares to spell out a public area set aside as a pedestrian walk. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk



#### ACROSS

- 1 Equipment that delivers a combustible substance to an engine (4,6)
- 6 Tropical talking bird (4)
- 10 Hydrocarbon radical (5)
- **11** Quality of elevation of mind and exaltation of character (9)
- 12 Wooden support in a mine (7)13 Industrial German city on the Elbe River (7)
- **14** American aubergine plant (8,4)
- 18 A rate of increase of velocity (12)
- 21 Makes a logical connection (7)
- **23** So good that you want extra (7)
- 24 Destroy micro-organisms by
- cleansing (9) 25 Any compound of oxygen with another element (5)
- **26** A strong line (4)
- 27 Being in captivity (10)

#### DOWN

- 1 Hanging limply (6)
- **2** Extensive landed property (6)

- 3 Designed to work without intervention (4-10)
- 4 Abrasive sheet (9)
- 5 Fix securely (5)
- 7 Surrenders, as a result of pressure or force (6,2)
- 8 Strong green liqueur (8)9 Entertaining areas in a house
- (9,5)15 Instrument that measures the height above ground (9)
- 16 Mainland part of the province of Newfoundland (8)
- **17** Increases proportionally (6,2)
- 19 Gear with a small number of teeth (6)20 Holized rib going around a ger
- 20 Helical rib going around a screw (6)
- 22 Water at boiling temperature (5)

September's highlighted solution was Citadel. Congratulations to Rachel Bryan who provided the first correct answer.

#### origineering Anthony Poulton-Smith explores the origins of everyday engineering terms

As anyone who has had to drain oil will be aware, the **sump** is the lowest part of an engine and where everything will ultimately drain.

It was not the creation of the sump as part of the engine that created a demand for a word but the undesirable oily sludge collecting there. And, as so often happens, a word already in use was deemed an ideal description and thus the 'sump' in its modern form was born. In fact the word 'sump' had been in use for as long as almost any European word. We can trace 'sump' back through Middle Dutch somp and Low German sump to Proto-Germanic sumpaz and further back to Proto-Indo-European swombho or 'spongy'.

Overall, the meaning has always been 'a marsh, morass', with the original 'spongy' all pointing to the thick muddy texture found, for example, at the bottom of a pit – and as 'a pit to collect water' was how 'sump' first came to English.

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