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Space odyssey

Project Orion: the next giant leap

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this**issue**

Volume 297
Issue No.7871
Established 1856

news

opinion

features

our**opinion**

Past and present

One hundred and sixty years ago this month, in a world very different to the one we inhabit today, the first issue of *The Engineer* rolled off the press.

Launched to document the breakthroughs made during the great Victorian age of innovation, it went on to cover some of the most significant developments of the last two centuries: from the invention of the aircraft and the motor car to the dawn of atomic energy and the Apollo moon landings.

Technology has moved on since those early days. A glance through issues from 1856 reveals an industrial landscape dominated by agricultural innovation, a far cry from the exotic materials and wireless technologies preoccupying modern-day engineers.

But *The Engineer*'s remit – to report on the technologies and trends that are shaping industry and the wider world – is largely unchanged, and it's a tradition we're proud to continue as the publication enters its 160th year.

Throughout 2016, in both the magazine and on our newly revamped website, we will be celebrating the past, present and future of *The Engineer*. We will examine some of the gems from its classic archive, report on the big trends and projects that define the modern world of engineering, and take a look at the emerging technologies that future readers might one day take for granted.

> "A glance through issues from 1856 reveals an industrial landscape being dominated by agricultural innovation"

In this issue, we take a detailed look at the engineering behind project Orion, NASA and ESA's plan to build a spacecraft that will take mankind back to the Moon, to Mars and maybe beyond (p18). Still in the heavens, although a bit closer to Earth, we also examine some of the priorities of the civil aerospace sector in this issue's interview with Airbus technology chief Jean Botti (p26).

Meanwhile, in the first of our new expanded 'From the Archive' features (p53) we take a look at *The Engineer*'s coverage of one of Britain's most iconic aircraft, the Lancaster bomber, which made its maiden flight 75 years ago this month.

Finally, it probably hasn't escaped your notice that, to mark our anniversary, we've had a bit of a design refresh. We hope you like our new look, and we welcome all of your comments on this and any other issues at www.theengineer.co.uk.

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AEROSPACE

Graphene set for show of strength

Aircraft wings could be enhanced by addition of graphene composites

HELEN KNIGHT REPORTS

Graphene can improve the strength of materials by up to 25 per cent

Stronger and lighter aircraft wings could be built by adding graphene to the materials used to construct them.

Through a partnership between Manchester University and the Beijing Institute of Aeronautical Materials (BIAM), researchers will explore the use of graphene composites in aircraft.

Researchers at BIAM and Manchester University's National Graphene Institute will exchange expertise and cooperate on projects to understand and test the structure of graphene-reinforced aluminium matrix nanocomposites.

The projects could result in lighter, stronger and conductive parts for aircraft, high-speed trains and other industrial equipment, replacing traditional materials.

Adding graphene to aluminium alloys could considerably increase their strength, while retaining flexibility, according to Prof Robert Young at Manchester University, who is leading the collaboration. BIAM researchers have been doing a considerable amount of work into incorporating graphene into aluminium in recent years, said Young. While they have already demonstrated that the graphene can improve the strength of the material by up to 25 per cent, they do not yet know how the mechanism works, said Young.

> "One problem with polymers [such as] epoxy resin is that they absorb water and therefore their stiffness and strength drops"
>
> Prof Robert Young
> Manchester University

"So we are going to collaborate with them to try to understand the mechanisms for this particular process," he said.

To complicate matters, adding graphene to molten aluminium typically results in the latter being dissolved. So rather than using conventional melting and casting techniques, the Chinese researchers have developed a ball-milling process in which the aluminium remains in a solid state, below its melting point, to prevent the material dissolving when the graphene is added.

The Manchester team will help develop this technique through their expertise in different forms of graphene, according to Young. "We are going to supply them with some of our very well characterised forms of graphene to help in this process."

The researchers will also investigate the impact of adding graphene to aluminium on how the material corrodes, he said.

In the future, the two parties plan to expand the collaboration on graphene materials beyond reinforced aluminium matrix composites. The researchers also hope to collaborate on the development of graphene energy storage, environmental purification, and information materials.

Researchers at NGI also aim to improve the plastic that holds together carbon fibre in aircraft wings. Adding graphene to the material should help stop water entering the wings, reducing their strength.

"One problem with polymers [such as] epoxy resin is that they absorb water, and therefore their stiffness and strength drops," said Young.

Graphene can act as a plate-like physical barrier, slowing down the diffusion of water into the material, he added.

Graphene could also be used to measure strain in the wings, to assess if any damage has occurred.

The researchers are also planning to explore the use of graphene to prevent ice building up on the wings, as a much lighter replacement for parts such as the copper wiring and copper heating coils currently used. Graphene is conductive, so adding it to the polymer could allow electricity to be passed through the material, heating it up and melting any ice that has built up, said Young.

"The graphene would therefore be acting as a multifunctional material, preventing water absorption and allowing electricity to be conducted to de-ice the wings."

This could reduce the overall weight of the aircraft.

Finally, the researchers in the partnership ultimately hope to try to replace the carbon fibre used to build aircraft wings with graphene. This will be a much longer-term project, however, and is expected to take at least 20 years.

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ELECTRONICS

Device aids heat on the path to power

Nano-rectenna being developed by researchers at Durham and Manchester

HELEN KNIGHT REPORTS

Nano device could light up skyline

A nanoscale device that is capable of converting heat into electricity could help to power homes.

The device, known as a nano-rectenna, is being developed in the UK by researchers at Durham and Manchester universities.

A large array of nano-rectennas could be used in domestic combined heat and power (CHP) systems to convert some of the heat generated by the burner into household electricity, according to Dr Claudio Balocco at Durham University, who is leading the EPSRC-funded project. "If you have a hot body, that body radiates infrared radiation, and it is possible to collect some of that radiation and convert it into electricity," he said.

Existing methods to convert natural gas into electricity in a combined heat and power system are based on complex, bulky devices such as fuel cells or Stirling engines, which require regular maintenance.

Meanwhile, alternative technologies for converting heat into electricity that are more compact and maintenance-free, such as thermoelectric devices, have low efficiency rates and require the use of toxic materials with strict disposal regulations.

In contrast, the nano-rectenna can be built from more environmentally friendly materials, including common metals such as titanium, platinum and gold, plus graphene and non-toxic highly stable organic layers.

The device is known as a rectenna because it combines a rectifier – which converts alternating current (AC) into direct current (DC) – and an antenna.

When used as part of a combined heat and power system, the gas burner would heat water using a conventional heat exchanger.

Infrared radiation given off by the gas burner could then be picked up by the antenna, said Balocco. "The device works just like a mobile phone antenna, collecting the infrared radiation," he said.

This radiation causes the antenna to oscillate, inducing an alternating current in the device. The rectifier then converts this into DC mains electricity. The nano-rectenna can be produced on a flexible sheet of material that can be easily fitted to gas burners.

"We are optimistic we can produce quite a lot of power using the devices," said Balocco.

In a paper published in *Applied Physics Letters*, the researchers demonstrated a proof-of-concept device capable of operating with a source temperature of between 280 to 700°C.

MEDICAL

Navigation for the blind goes underground

Wayfindr uses a network of Bluetooth beacons

ANDREW WADE REPORTS

A digital navigation system for visually impaired people is being trialled at London's Euston underground station.

The Wayfindr project is a non-profit collaboration between the youth forum of the Royal London Society for Blind People (RLSB) and digital studio ustwo. It uses a network of Bluetooth beacons that deliver audio instructions via a smartphone app, guiding people to their destination.

"Bluetooth has a few constraints, but the latest devices, iPhone5 and up, I think the experience is pretty good," said Georgios Maninis, Wayfindr product designer.

"The question is how you configure the beacons. It's not as straightforward as putting them up, having a navigation algorithm, and… go. It has to do with the timings you give, the instructions. It has to do with how far [in advance] you get the instructions. So there is a lot of effort going on in configuring the beacons so that we get these things right."

Wayfindr has been backed from early in its development by London Underground, and has undergone a successful trial at Pimlico station.

"Now, the challenge is how the system will perform in a really busy station," said Maninis. "Also the scope that we have been asked to deliver by TfL is bigger, because it's a full-scale trial."

In 2015 the project was awarded US$1m by Google.org and it's hoped this funding will help accelerate the project, with integration with digital navigation services such as Citymapper and Google Maps via the Wayfindr Standard.

Newsinbrief

On the buses

Around 450 buses in England will be fitted with technology designed to cut emissions by up to 90 per cent, after successful bids for approximately £7m of Department for Transport funding were announced on 3 January 2016. The Clean Bus Technology Fund 2015 is being awarded to 18 local authorities in England to retrofit 439 buses with technology to reduce nitrogen oxide emissions in pollution hotspots.

Infrastructure merger

Infrastructure UK and the Major Projects Authority have merged to create an organisation that will provide expertise, knowledge and skills at managing and delivering major economic projects for the government. The new Infrastructure and Projects Authority brings together financing, delivery and assurance of projects such as Crossrail and the Thames Tideway Tunnel.

Niche assembly

Ricardo's niche engine assembly plant has undergone an expansion that increases its size, provides improved technical capabilities, and facilitates future low-volume, multi-variant engine production. The Shoreham facility has new laboratories and workshops that are capable of supporting prototype engine builds and advanced metrology.

Open-access cure

The Centre for Process Innovation has partnered with NovaCentrix to install a specialist system designed for the high-speed photonic curing of printed electronics inks. The NovaCentrix PulseForge 1300 system is available on an open-access basis.

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ENERGY

Solar power is real force for purity

System could improve access to clean drinking water in the developing world

HELEN KNIGHT REPORTS

A purification system that is portable and solar-powered, and that could provide people in the developing world with access to clean drinking water is under development in the UK.

Around 20 per cent of the world's population, 1.2 billion people, live under constant threat of not having enough drinking water to survive, according to the United Nations.

The Desolenator device, which is being developed by a UK-based company of the same name, purifies and desalinates all forms of water, including seawater.

The system recently won prizes at the Institution of Engineering and Technology's Innovation Awards, winning both the sustainability and start-up categories.

The device, which is the size of a large flat-screen television, is equipped with all-terrain wheels for moving around in rugged areas, and can produce around 15 litres of drinking water per day. That is enough for both drinking and cooking, according to Desolenator's CEO William Janssen.

The device is based on a solar panel that directly converts sunlight into electricity, while any excess heat generated by the process is captured and stored thanks to double-glazing covering the panels. This allows the device to harness both the electrical and heat energy produced by sunlight, said Janssen.

A thin layer of contaminated or salt water flows over the photovoltaic surface so it absorbs the heat from the panels, reaching close to boiling point. In the process, the water cools the panels and improves their efficiency.

"We then take the water off the collector and put it into a separate boiler, where we use the electrical output of the solar panels to accelerate the boiling of the water using a simple spiral heater," he said.

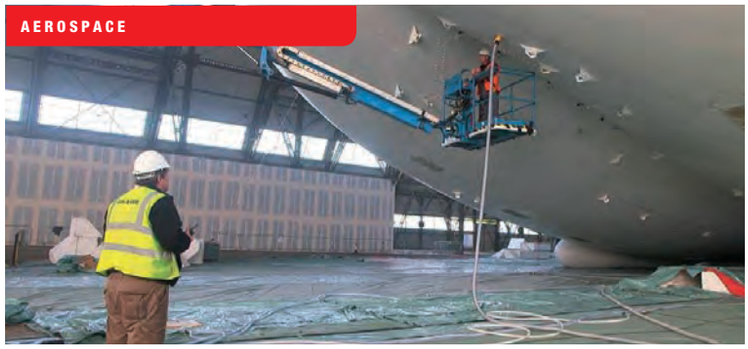
> "We are able to regain the latent energy in the vapour by heat exchanging it against the water"
>
> William Janssen
> Desolenator

The vapour is then fed back into the solar collector where it is distilled. "We are able to regain the latent energy in the vapour by heat exchanging it against the water that is warming up in the solar collector, so we have effectively created a circular system," said Janssen.

A small 'brine line' then filters out any salt to avoid build-up and keep the device running smoothly.

Desolenator will produce clean drinking water

AEROSPACE



Airlander 10 is being readied for flight

Airlander 10 prepares for return for flight

Engines on world's largest aircraft will allow it to enjoy non-stop flight for five days

Hybrid Air Vehicles (HAV) has said that Airlander 10 will have its engines, fins and mission module attached in January 2016, as the world's largest aircraft prepares for a return to flight this year.

The 92m airship has recently had its aft carbon composite battens added, which will provide structural support to the rear engines. Other components attached in the final weeks of 2015 include the port tailcone, as well as the first engine pylon. In addition, Airlander's flight simulator is now operational, and engine testing is underway.

Airlander's four 325hp, 4l V8 direct injection turbocharged diesel engines will enable the aircraft to fly non-stop for five days. Two engines will be mounted forward on the hull and two on the stern for cruise operation. All four are configured in ducts with blown vanes to allow vectored thrust for take-off and landing.

Airlander has the ability to land on almost any surface without the need for airport infrastructure. **AW**

AUTOMOTIVE

Noise reduction makes marque for Ford Europe

Company makes foray into luxury vehicle market

JASON FORD REPORTS

The Vignale promises a quiet ride with its Active Noise Control unit

Ford is introducing noise-cancelling technology into the Vignale, a new marque that is its first foray into Europe's luxury vehicle market.

According to Dr John Cartwright, chief medical officer, Ford of Britain, noise can be intrusive, reducing a driver's mental processing power and exacerbating distraction and stress.

To counter this, the Vignale's Active Noise Control unit uses three microphones in the cabin to detect undesirable noises from the engine and transmission and then counteract those noises with opposing sound waves from the audio system without affecting volume levels of music and conversation. Driver and vehicle behaviour is recorded and anticipated, for example, when a driver is accelerating in a lower gear.

Further measures to cut out noise include windows and windscreens embedded with an acoustic layer to reduce the sound of wind, and foam rather than fibreglass to insulate the engine bay, reducing the noise from the powertrain by up to two decibels.

The company said that sound proofing within the underbody shields, wheel arch liners and front and rear doors block tyre noise, and the new integral link rear suspension also contributes to a reduction in road noise of up to three decibels.

Dr Ralf Heinrichs, supervisor, noise vibration harshness, Ford of Europe, said the technology itself is over 20 years old but advances in integration have brought it into the automotive market with Honda introducing the concept in the 2013 Accord.

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MATERIALS

Water bounces off Lotus-leaf mimic

New superhydrophobic nanomaterials are simple to manufacture

HELEN KNIGHT REPORTS

A low-cost class of materials that mimic properties of the lotus leaf could be used as a water-repellent coating, reducing the use of hazardous chemicals.

Superhydrophobic nanomaterials, developed in the US and UK, are non-toxic, simple to manufacture, and can be applied to surfaces through spray or spincoating.

They could replace the expensive and hazardous fluorocarbons often used to protect surfaces from water, according to Prof Julian Eastoe at Bristol University, a member of the research team. "The big problem with fluorocarbon is its persistence, as it is very difficult to get rid of from the body, unlike hydrocarbons, Here we have a material that does not contain fluorine, but performs in an identical way."

The coating mimics the microscopic and nanoscopic structure of the lotus-leaf surface, which gives the plant its ability to repel water.

A combination of papillae within their epidermis – or outer layer of cells – and a coating known as an epicuticular wax on top, minimise the adhesion of water droplets to the surface.

To mimic this arrangement, the researchers used aluminium oxide nanoparticles to act as the papillae. They then coated these with modified carboxylic acids with highly branched hydrocarbon chains.

These chains are spiky, resulting in a rough surface that traps a layer of air on top. This minimises the contact between the water droplets and the surface, causing the beads of water to simply slide off.

The ability of a material to repel water is measured by its contact angle. This is the angle where the surface of the water meets that of the material, and the greater the beading of the droplet, the higher this angle will be.

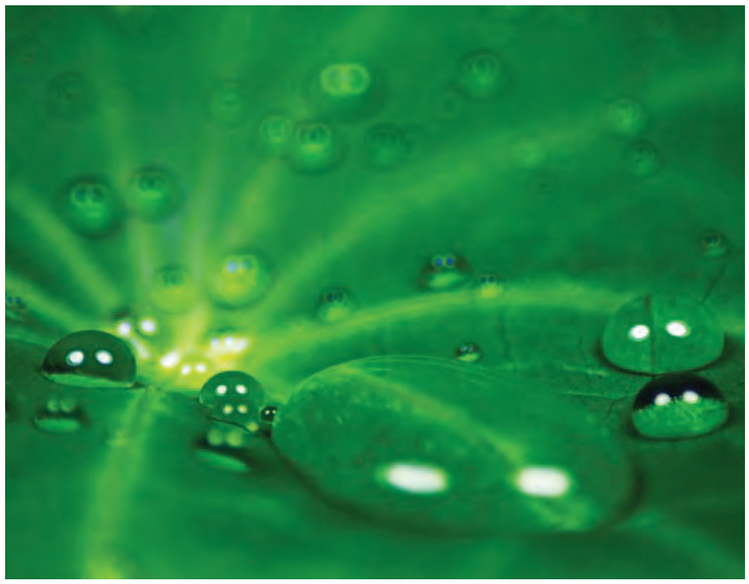
> "Here we have a material that does not contain fluorine but performs in an identical way"
>
> Prof Julian Eastoe
> Bristol University

To qualify as superhydrophobic, a material must have a contact angle of 150° or above.

The new material – a branched hydrocarbon low-surface energy material (LSEM) – has an angle of 155°, a figure that is similar to those that are found in the best fluorocarbon coatings.

The team, which was led by Prof Andrew Barron at Rice University, also included researchers from Swansea University and the University of Nice Sophia Antipolis.

The researchers are now hoping to improve the material's adhesion to a range of surfaces.



New materials will protect surfaces

AUTOMOTIVE

Systematic street knowledge

Researchers work on systems to provide assistance with autonomous driving

A team of researchers from Cambridge University has developed two new systems in order to aid autonomous driving, which use a combination of simple smartphone technology and machine learning.

The first system, known as SegNet, takes an image of a street scene and sorts the components into 12 different categories, such as roads, street signs, pedestrians, buildings and cyclists.

Using a base set of 5,000 images in which every pixel was labelled by a team of Cambridge undergraduates, SegNet learns by example. According to the researchers, the system currently has a 90 per cent accuracy rate.

The second system uses a single colour image taken from the vehicle to determine location and orientation. It does this by analysing the geometry of the scene and comparing it against an online database. According to the Cambridge team, the technology is more accurate than GPS and functions indoors. **AW**

PROCESS

Project works on alternative to palm oil

Yeast-based oil can be grown on food wastes

ANDREW WADE REPORTS

Researchers from the universities of Bath and York are working on a yeast-based alternative to palm oil, which they hope to be able to produce in the future on an industrial scale.

Palm oil has numerous uses in biofuel, cosmetics and as a food ingredient but the farming of palm is associated with widespread deforestation, particularly in parts of Southeast Asia.

Previous work at Bath University involved the production of a thick oil that was nearly identical to palm oil using Metschnikowia pulcherrima, a yeast that can be grown under non-sterile conditions on agricultural and food wastes.

"This project is an exciting opportunity for us to develop a renewable alternative to palm oil, while developing further sustainable technologies that could have a significant impact on many other UK sectors," said lead researcher Dr Chris Chuck, from Bath University's Department of Chemical Engineering.

"The yeast is naturally oleaginous, which means that certain strains can accumulate triglyceride oils within the cell. If you culture the yeast under the right conditions we can get up to 50 per cent of the cell weight to be oil. Certain conditions, different strains and growing methods will change the composition of the oil, but it is possible to match the composition exactly to palm oil."

The team has been awarded a £4.4m grant via BBSRC, EPSRC and Innovate UK.

To commercialise the process, production must be scaled-up and Chuck said that one of the biggest challenges will be to develop cost-effective methods to depolymerise the feedstock.

This needs to be done to release mono and oligo saccharides that the yeast can be grown on, but requires microwave heating.

The University of York will use its share of the grant to investigate ways of scaling this up.

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Paris puts CCS back into focus

Despite government deferment, CCS is still a vital cog in meeting the UK's carbon targets, says the managing director of 42 Technology

December's widely celebrated COP21 Paris agreement has the objective to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century".

Balancing sources and sinks is certainly a more pragmatic approach than trying to eliminate the use of fossil fuel entirely. However, observed CO_2 concentrations have been rising for decades, and although natural sinks can help, they work very slowly and in isolation are unlikely to make the impact required.

Timing matters because the second, more fundamental goal is to "limit the temperature rise to 1.5°C", and certainly "well below 2°C".

Temperature rise is related to cumulative global net emissions, with trillionthtonne.org reminding us that to keep global warming under two 2°C, cumulative global emissions must not exceed 1tn tonnes of carbon equivalent. Around 600bn tonnes have already been emitted and at current progress we will probably have emitted the remaining 400bn tonnes within the next 30 years or so. At that point the damage is done no matter how balanced we are in the second half of the century. Indeed, burning even half of known reserves (as estimated by the *BP Statistical Review of World Energy*) will take cumulative emissions to more than 1tn tonnes, irrespective of how much we try to dilute this with nuclear and renewables.

So the planet has to either leave fossil-fuel reserves in the ground or sink some carbon – or both – in the next 30 years. Permanently resisting extraction of valuable fossil fuels is difficult and strongly opposed by developing and transition economies still experiencing poverty. These are economies that believe they deserve to use those resources to create wealth.

The leading large-scale CO_2 sink option is probably carbon capture and storage (CCS); a technology that is already in operation in a handful sites around the world.

The UK has for some time been (almost) a global champion for CCS. And certainly we have done more front-end engineering design (FEED) studies than most. There have been at least five major FEEDs completed on commercial scale end-to-end CCS projects in the UK.

The 2007 BP DF1 pre-combustion gas CCS project at Peterhead was abandoned after the (self-funded) FEED study had been completed, and the then Labour government announced it would only fund coal CCS. In 2011 the Longannet and Kingsnorth FEEDs were completed but failed to reach agreement with the Coalition government to fund their construction. And, in November 2015, weeks before the conclusion of a four-year process, the Conservative government stealthily scrapped a long-promised £1bn capital grant fund for CCS, a decision that will lead directly to the almost certain cancellation of both the White Rose IGCC project and the Shell/SSE Peterhead post-combustion gas projects, just as those FEEDs reached completion.

UK investment in CCS research is rational and defensible. As a relatively small power island, the UK will feel the need for CCS earlier than larger or more connected decarbonising economies. UK carbon-reduction obligations are set by the Climate Change Act, then through 'carbon budgets'. The fifth carbon budget (drafted with 2°C, rather than 1.5 in mind) is available in draft, ready for legislation in June 2016 and contains a glide path for electricity generation carbon reduction; reducing to around 10 per cent of today's value (50g/kWhr) by 2030.

The cleanest non-CCS fossil plant is a combined cycle gas turbine (CCGT) emitting perhaps 350g/kWhr. Consequently, no more that 15 per cent of annual generation could be CCGT to meet the 50g/kWhr 2030 target. Unfortunately, this is almost certainly impossible as the UK power grid must ensure a continuous, instantaneous and exact match of supply with hugely variable demand. Only fossil generation has the capacity to provide this flexibility and much of which will need to be equipped with CCS to meet the UK's own carbon targets.

Tomorrow's opportunities for CCS will be huge. The long-term need for CCS was amplified by COP21: we need to create new carbon sinks so the planet needs CCS. Furthermore, the COP21 process made it clear that emission reduction burdens need to be equitably distributed.

In addition to the high-profile FEEDs, there has been a wealth of world-class academic research and industrial studies in the UK that have built knowledge and understanding. The government took a difficult decision to defer UK CCS development. However, with the demise of White Rose and Peterhead, this knowledge will be lost unless there is urgent action to ensure that we are ready for the opportunities, indeed the necessities, that will arise tomorrow.

Jeremy Carey
Managing director of 42 Technology

> "As a relatively small power island, the UK will feel the need for CCS earlier than larger or more connected economies"
>
> Jeremy Carey

Funding for the Peterhead CCS project was withdrawn

SAVE THE DATES

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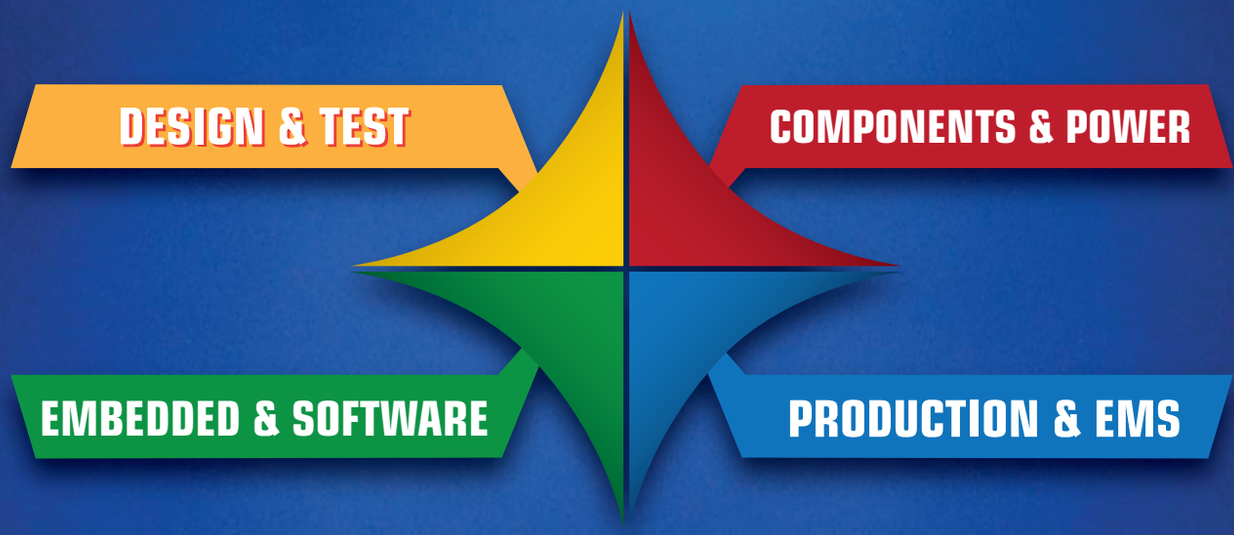

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Thehottopic

Paris — what's the catch?

Our article on the UK's response to December's Paris climate talks provoked a lively response

COP21 should prompt a UK energy policy rethink. However, the UK government's stance gives very little cause for optimism that it will do so and provide the nation with a coherent policy that both reduces our GHG emissions rapidly and encourages economic growth by stimulating innovation and engineering excellence in the renewable and associated sectors. The failure of leadership shown by this government will leave a legacy – environmental, economic and societal – that will be felt by future generations long after Cameron and Osborne have gone.
Keith Binding

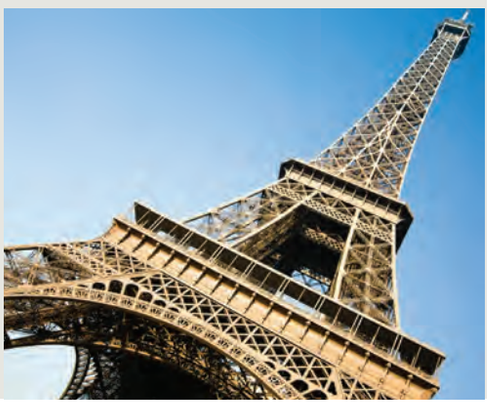
While it's a laudable ambition to be at the forefront of global change, I can't for the life of me think why we would want to be. The UK already has very expensive energy that penalises our industry and hence our economy. CCS does not need to be supported by tax payers' money if there is a legitimate business case – particularly for UK taxpayers if we are going to close down coal-fired power stations (I don't believe there is any valid reason to believe that India would buy it from us). While we should fulfil our obligations we should not aspire to take a 'leadership position'.
Edward

We know the Paris climate meeting was a charade. How much of the US$100bn per year will the UK contribute? Who will 'really' lead, with action and not just words? And how many would 'really' follow? The real question nobody is asking is if this is so important, then enforcement is needed, and what would enforcement entail? Sanctions? Military action? I presume no enforcement, and therefore, not much action worldwide. After another decade, we will have more temperature measurement data and likely controversy. Meanwhile, the subsidised industries will take advantage of the opportunity that a real marketplace would not offer.
onnasinkinship

We need to lead by example and reduce our energy consumption and carbon footprint by building all new houses, commercial and industrial buildings to the highest insulation class, insulating all current properties and replacing current fossil-fuel generation systems with renewable sources, coupled to efficient storage systems on a planned basis until we are self-sufficient in our supply and use of energy. This requires a long-term energy strategy that no government has yet committed. Yet the costs of not doing so will be paid for by all generations that follow.
Anonymous

I am so bored by all this. Two-thousand high-paid expense-account politicians and officials spend weeks in five-star luxury having flown first class at huge cost in both cash and carbon, and, at the end, produce weasel words that they know they will not deliver on. Politicians will not commit to long-term investment that may impact on their chances of re-election. Opposition parties will not support long-term investment for the same reasons, and anyway 'it's not their job to help the government'. Witness Heathrow's third runway. Energy investment is too important to the stability of the country to be left to the markets, but governments pretend their pipe dreams will make a difference. Time they all stopped puffing themselves up and got on with actually solving the issues coherently; and stopped conning the public with computer models designed to 'prove' climate change so they can apply yet more stealth taxes to industry. Until they do, I'm bored.
Steve

Although all the flying and five-star hotels once every few years is visibly wasteful, especially when it only results in weasel words, it pales into insignificance compared to the numbers who fly thousands of miles every week to various far-off cities for a weekend's shopping.
Malcolm



Inyouropinion

Responsible robots

Our online comment piece on the ethical questions raised by the rise of AI prompted a heated debate

● It is quite clear that the politicians will have to deal with this, starting now if robotics is coming as quickly as the pundits insist. The present government is obsessed by the concept of work paying, even though it doesn't for far too many people. What in the future if there is no work? It is quite clear that the standard economic and monetary system we live by at present has no answer to this, but governments throughout the world appear to be doing nothing. We need a new way.
Brian Tucker

Virtues are good and noble, and would make a fine basis for society. Unfortunately, our actual intelligences are able to choose not to follow these and more often than not do exactly that. Unless a degree of freedom of will isn't integral to a full AI then I see no reason why one would observe these virtues any more vigorously than we do. Moreover if post-modernism has taught us anything then everything we do, even reading a book, is in part an expression of ourselves. Programming a mind would be no different. Thus, I cannot see how given the fallibility of humanity and our preponderances to do wrong and act unvirtuously this mind would not embody those very same character flaws. Moreover any mind raised in the world is subject to its corruption, as well as its nobilities. If humanity is so easily corrupted and learning seems to have no effect in this why should a synthetic intelligence be any less prone to crime than our organic ones? A strong AI is dangerous, because we would be both its creator and educator – we should refrain from making one.
Anonymous

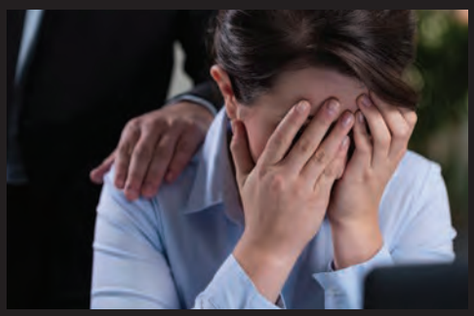
Flood tide

Readers commented on the nature of the engineering response to the UK's recent flooding

● Following the recent floods in the important historic city of York, it is necessary to utilise the agricultural areas north and south of York, as spill lakes to take the excessive flood water away from the city centre. Furthermore, I believe it would be cost effective to also use the spill lake south of York as a 'top lake' for a futuristic underground pumped storage scheme integrated with the disused underground workings of the prematurely redundant Selby coalfield. The excavation of a spill lake between York and Cawood (i.e. the area above the deep-mine Selby coalfield) as an overspill sink for flood water from the river Ouse and top lake for an underground pumped storage scheme would be a long-term asset for the country. As a short-term spin-off, the excavated material from the quarry may be of value. The existing deep mine

Thesecretengineer

Our anonymous blogger considers the business impact of the workplace bully



In my time I have worked for senior managers who have been thought of as a bully, but who actually weren't. Such misconceptions are generally founded in the manager having little social empathy. They have a focus that makes them oblivious to slights and hurtful comments (whether intended or not) and so have little concept of how others may need some kind of emotional consideration. I have no problem with working for such folk as there is no malicious intent behind their approach. True, one has to recognise this and be able to make such allowances, but the knowledge that it is a mere by-product of a particular mindset (to me) makes it acceptable.

However, in my last place of employ I came up against the true bully. Being a fellow at the very top of the tree he could get away with it, which is the first problem with creatures of this ilk. Whether through aptitude or wealth they can rise to such lofty heights while still having this fatal flaw in their character. Either way they are difficult to deal with, certainly if us mere mortals are to consider challenging them then we are stuck between a rock and a hard place. If we succeed there is the spectre of the 'trouble maker' label being permanently attached. If unsuccessful (and given their influence this has to be the most likely option) then what future is there within the company or further afield? Bullying brings the all-important and pervasive maliciousness with it, your whole career path is possibly at risk.

The second problem is that these bullies cannot be challenged, their problem lies in an arrogance that must see their opinion as being paramount. So long as they keep generally making the right decisions, or at least their wrong decisions are able to be passed off as ill fortune, then they can get away with it.

You may wonder if this is a problem so long as the company makes a profit but how much better could it do if the opinions of others are listened to? In my situation there was a layer of very capable senior staff, but at the meetings a general shuffling of feet and murmured comments showed their overarching desire to appease the 'big man' rather than bring their own individual expertise to bear. How much lost value and lost opportunities for the company has this brought about over the years I wonder? The 'yes man' is of no use apart from the flattery of those who need them to prop up a fragile ego.

When it became obvious that unquestioning obeisance was not my style, and I could not be browbeaten into it, my days were numbered. So I left. I maintain extremely good relations with my immediate boss from those days and am now somewhere that is far better, for a lot of reasons. Their loss I'd say – again.

workings could be enlarged to house the 'turbine hall' and the 'bottom lake' of the pumped storage scheme, similar to the one at Dinorwig, in North Wales and an additional benefit of the pumped storage scheme would be the reduction in the amount of imported coal and gas; instead 'green energy' from wind, solar and sea power would be utilised to return the spill water back to the river when levels had sufficiently receded to avoid down-stream flooding. I believe that an integrated scheme of the type described is urgently required to eliminate the possibility of damaging floods and potential brown-outs. It appears, however, that Victorian-type planning has now been replaced with crisis-type COBRA meetings, suggesting to the public that nothing can be done to deal with the biblical scale of events. Instead of peddling a false perception of overwhelming crisis, wouldn't it be better for the government to invest in some bold engineering schemes to eliminate the possibility of future floods and brown-outs?

Clive Broadhead

Green focus

A piece on using 'green' technology in troubled times garnered this response

● Using lower resources and energy will lead to more savings, especially when the prices rise again. I used to employ new people when other companies were firing them. Then I had enough time to train them in our way of doing things, and when the business shot up again, I had a full team busy serving customers and didn't need to waste time and money for interviews and training.

Ralf Mueller

Join the debate theengineer.co.uk

Looking for the new careers captains

Volunteers have a central role in the inspiration of the next generation of engineers and securing a strong future for our industry

"With 27 per cent of students in higher education taking courses related to STEM, we need to include engineering in careers messages"

Paul Jackson

Away from slogans on skills, education and businesses need to combine to ensure those entering the workforce have not only technical knowledge but also skills such as communication, leadership and problem-solving.

Late last year at a parliamentary round table on graduate skills linked to the launch of the Universities UK report *Supply and demand for high-level skills* we discussed this issue and the continued shortages of highly qualified workers in technical industries. That research showed that a lack of "core and employability skills" saw many graduates in non-graduate level jobs meaning they are not fulfilling their potential and employers may be missing out on their technical skills and knowledge.

Engineering needs more qualified workers at a range of levels and the inclusion of a recommendation to address problems in the STEM talent pipeline is welcome. The more education, industry and government can work together to solve the problem the closer we will get to meeting employer demand.

Fewer graduates from non-engineering courses are entering the industry. With as many as 27 per cent of students currently in higher education taking courses related to STEM, we need to do more to include engineering in the broader careers messaging to those students. And, of course, those graduates need to be more 'work ready'. Universities and industry can work together to support students by facilitating work placements, work experience, internships and volunteering opportunities.

Individual engineers are also needed to get more young people excited about what the industry has to offer. Could you be a careers captain at The Big Bang Fair or an advocate for the profession by sharing your story at a local school? Could you help students building and programming robots or judge a robotics challenge? Or could you help steer our overall direction?

As our chair Dr Paul Golby CBE completes his term later this year we are looking to appoint a new chair to work with fellow board members, stakeholders and me to provide strong governance and strategic direction for the organisation. This voluntary role is ideal for a high-profile leader with the credibility and contacts to promote the vital importance of engineering, acting as a catalyst for real change.

The chair of the board needs the determination, energy and enthusiasm to drive change in public perceptions and to attract more young people into engineering and technology.

Could you help students to build and program robots?

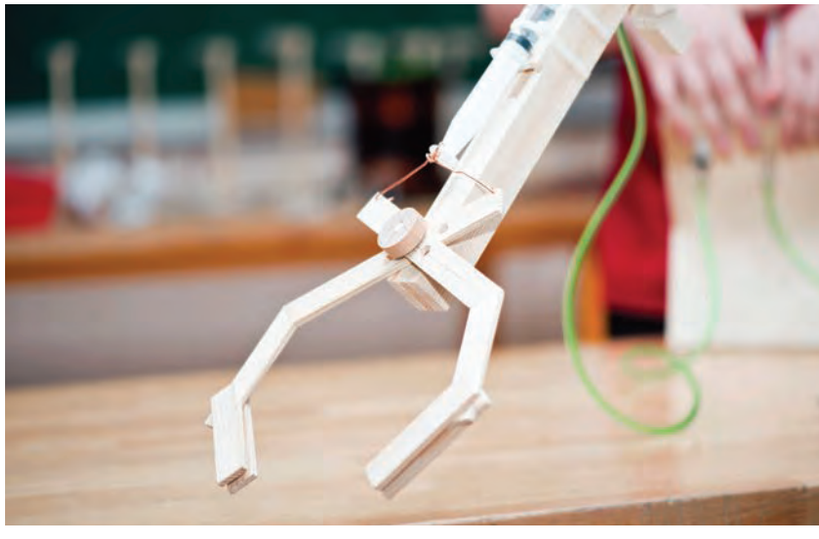
In fact, that also sums up what we look for in the engineers who support our work with young people.

Volunteers are key to making The Big Bang Fair an informative and rewarding experience for the tens of thousands of visitors to the NEC each March. They also play a strong role in Tomorrow's Engineers activities by communicating real-world examples of engineering.

We need ambassadors to bring to life the possible engineering and STEM career opportunities available to young people. Could you do that? Could your team?

If you have started the new year determined to make a positive contribution or to give something back to your community, join us to inspire the next generation of engineers. In return for your time and enthusiasm, we can offer you a hugely rewarding role helping to transform young lives and secure a strong future for our industry.

Paul Jackson
Chief executive, EngineeringUK



Orion takes heed of Apollo spirit

NASA's next crewed spacecraft is now under development and represents a return to the design philosophy of the Apollo era.

Stuart Nathan reports

Since the last flight of the Space Shuttle in 2011, there has only been one way to get humans into space: the Soyuz system, using the capsule design that has been in operation since 1968 with only minor changes; the most recent was in 2010 and that module was intended to go out of service the following year. It's a highly reliable system, but a Soyuz is nobody's idea of a comfortable place. As those who have visited the Cosmonauts exhibition at London's Science Museum will know, it's so cramped that its crew can't even sit with their legs extended during launch and re-entry. And it can't get beyond low-Earth orbit.

NASA's next crewed spacecraft, Orion, is under development, and has passed one major milestone in 2015 with the first flight of a functional model of its crew capsule into Earth orbit and its successful return, and has reached a second with the start of testing of structural test models of its major components, the crew module and service module.

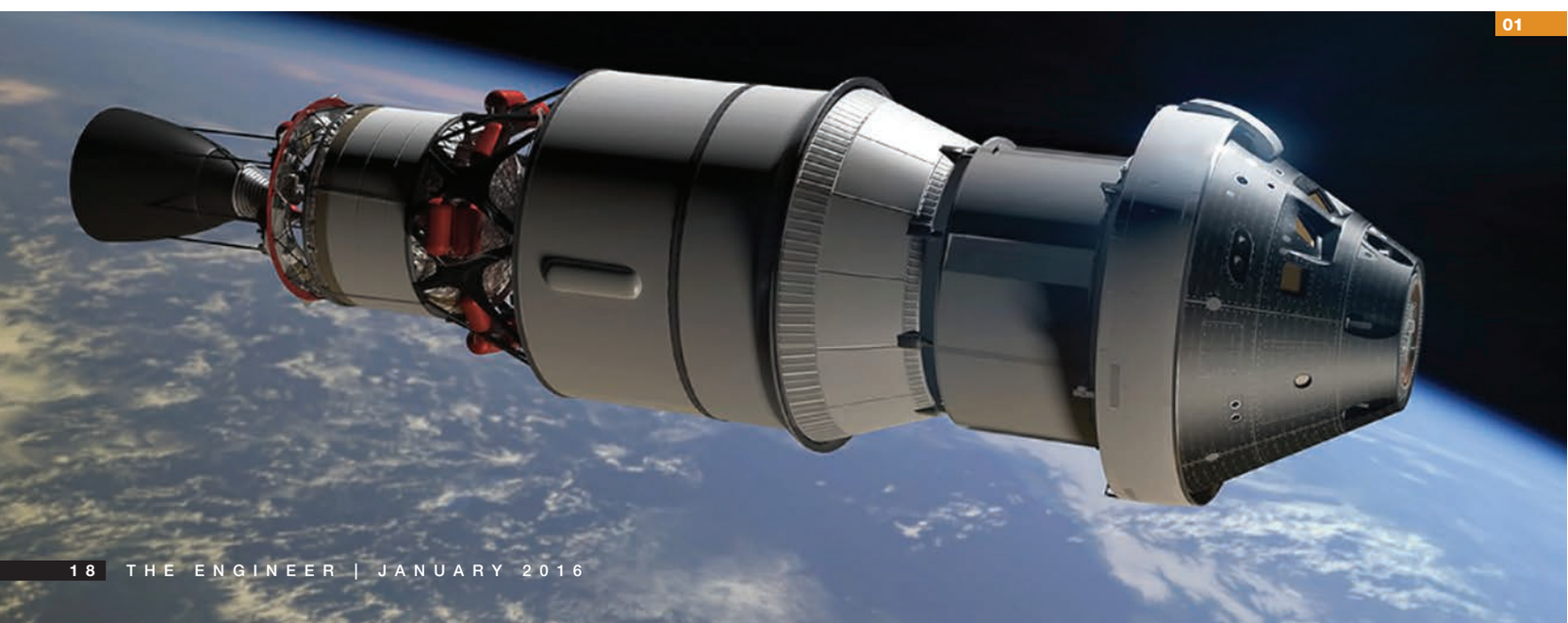
As this implies, Orion represents a return to the design philosophy of the Apollo era. Rather than design another fully reusable system such as the Shuttle, NASA has opted to save money by going for the older, less complex design. Like Apollo, Orion consists of a cylindrical service module that houses the craft's propulsion system, along with air and water for up to four crew, who will sit in a command module in a frustum (truncated cone) shape whose base is a heat shield to protect the crew during re-entry. "This is a design and a shape that we can be completely confident will work," said Mike Kirasich, NASA's programme manager for Orion at the agency's Johnson Space Centre in Houston at an event to welcome the structural model of the service module to NASA's test site in Sandusky, Ohio.

The Service Module is being supplied by the European Space Agency; the first time NASA has collaborated with the outside agency on a crew-carrying spacecraft. The collaboration is part of the agreement covering the International Space Station, to which ESA contributes 'in kind' rather than by financial payments. The European Service Module (ESM) is based on the Automated Transfer Vehicle (ATV) or 'Space Truck', the unmanned craft developed by ESA to resupply the ISS, of which five were built; originally ESA hoped to develop this directly into a crewed craft – the agency's first – but abandoned this plan when the opportunity arose to become part of the Orion project. This, explained Oliver Junkenhöfel, ESM project manager at Airbus Defence and Space, which is building the module at its Bremen plant, made financial and operational sense. "When the Constellation programme [the forerunner to Orion] was cancelled in 2009 and NASA abandoned the idea of building the entire spacecraft itself, we had a system that had all the component functions. It makes much more sense for a project with this scope to be a collaboration with different nations, and we've already proved with the ISS that such multi-agency projects with equipment made in different places that has to interface together not only work, but can flourish."

The scope Junkenhöfel referred to is that Orion is intended for the first time since Apollo to take humans beyond the nursery slopes of low-Earth orbit. Its ultimate goal is to take humans to Mars, but it will also be a vital component of plans to return to the Moon and to send humans to an asteroid that NASA hopes to capture, bring back from the Asteroid belt to within the orbit of Mars and ultimately

01 Orion crew and support modules with upper stage of SLS

02 Different configurations of SLS



01

Indepth Space Launch System is new workhorse for Orion

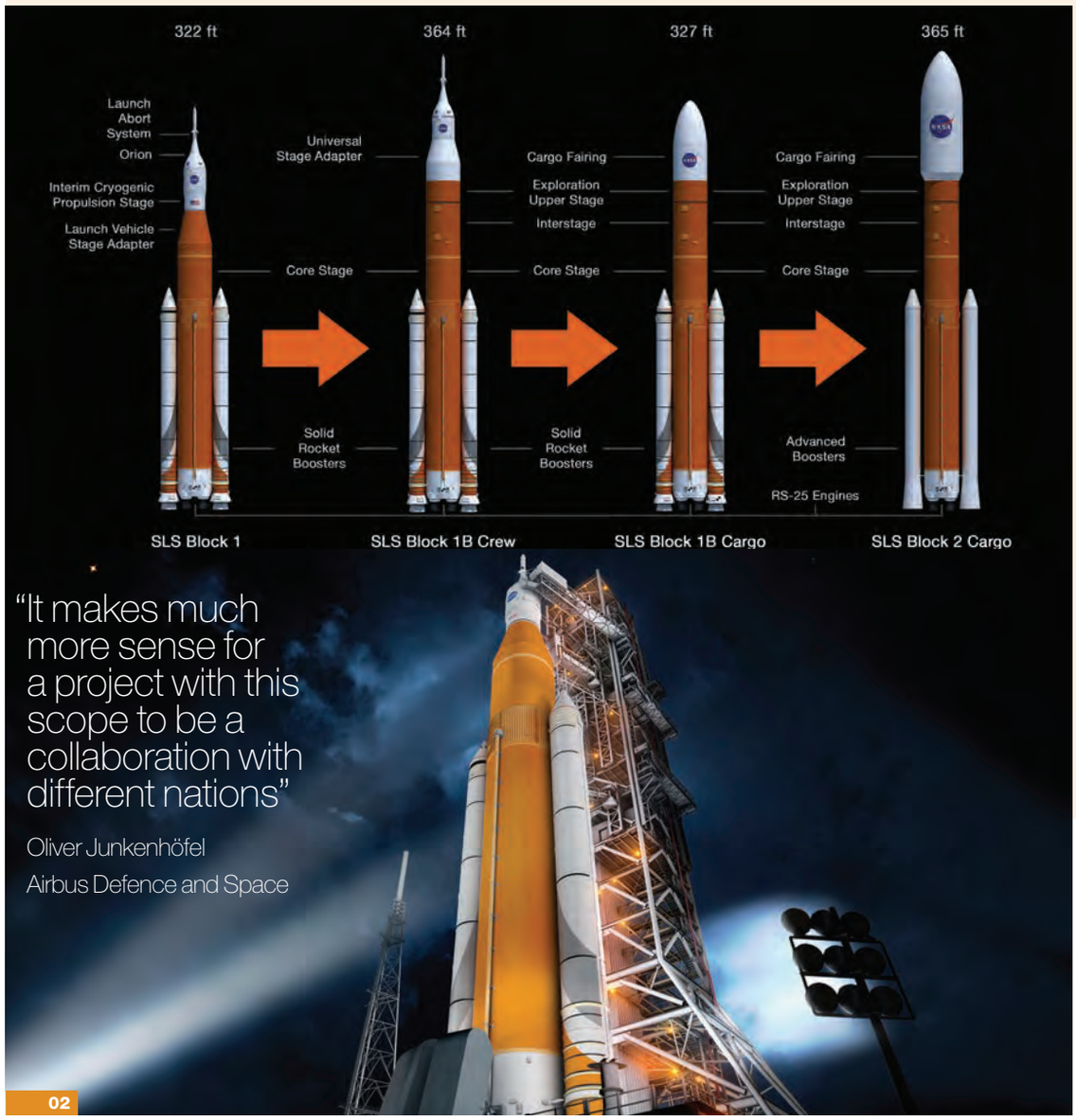
No spacecraft makes it into space without a launcher and for Orion NASA is pulling out all the stops. The first test mission saw the craft sent into space on the agency's biggest current workhorse, the Delta IV heavy rocket, but subsequent launches will use a brand-new giant, the Space Launch System (SLS). Designed to be modular and expandable, SLS will have a variety of configurations, ranging in size and power from sufficient to get the capsule to the low-Earth orbit of the International Space Station to a Saturn V-matching version to get it to the Moon, and a truly enormous version earmarked for Mars missions (although the size and power here is to get the large components of habitation pods into space; not to get them all the way to the Red Planet, of course).

And like Orion, SLS is a mix of Apollo-era experience and Space Shuttle-derived technologies. Rather than carrying all the rocket power needed to escape Earth gravity inside the first stage, SLS will use solid-fuel boosters attached to the sides of the launcher like the Shuttle, which will be jettisoned early in the flight (and unlike Shuttle boosters, not recovered for reuse).

For the 'block one' SLS configurations, that are designed for missions to lunar space, these will be derived directly from Shuttle boosters, although NASA plans to develop a new system for the largest configurations, to fly after the late 2020s. And again, like Orion, Shuttle propulsion is being used; SLS's four main engines will, for its first four flights, be the 16 left over and reconditioned RS-25D Shuttle main engines (the three large engines on the back of the Spaceplane that fired on launch), with later flights shifting to a simplified, purpose-built design not capable of being reused (and the first 16 engines, which have already been used several times, will be discarded after use on SLS).

NASA awarded a contract to Aerojet Rocketdyne (see box on p17) last November to restart production of RS-25D engines, with the contract running up to 2024. It will take five to six years to build and certify the first of the new engines under this contract.

Shuttle heritage doesn't stop with propulsion; the first stage of early versions of SLS will in fact be made from the left over external fuel tanks from the Shuttle programme. The upper-stage engines will be the type used as main engines in Delta IV launchers, of which there will be four. This version of the rocket is set to make its first flight in 2021.



"It makes much more sense for a project with this scope to be a collaboration with different nations"

Oliver Junkenhöfel
Airbus Defence and Space

02

'park' in lunar orbit in the coming decades. In size terms it's been compared with a limousine in comparison to the 'sub-compact' scale of Soyuz; the crew module is 5m in diameter with almost 9m^3 of habitable volume; by comparison Soyuz has 5m^3 of volume (with only 2.5m^3 in the re-entry and launch module) and Apollo was 3.9m in diameter with 6.2m^3 of usable volume. Even so, crew would not be expected to remain in such a small space during the 16-month journey to Mars. The current mission profile envisions a habitation module, based on units of the ISS and equipped with a cargo module and its own liquid-fuelled propulsion system, to be assembled in space and to dock onto an Orion module to form the spacecraft that would visit the Red Planet in a 500-day mission. "We would also locate any electronic equipment that needed shielding in these areas. Orion is essentially a 'space taxi' to take crew to such missions and then return them to Earth," Junkenhöfel explained. "In that sense, it's rather fitting that it's partly based on the Space Truck." The habitation module would contain 'refuges' where crew would be shielded from the high radiation fluxes that exist beyond the Earth's magnetosphere and through which the craft would travel on the way to Mars. "It makes more sense to build these radiation-hardened areas than to shield the whole structure, which would add too much mass," explained Kirasich. "We haven't determined yet what materials we would use," he added; it has been proposed that part of the craft's water supply could be used, as water is good at absorbing radiation.

The Orion crew capsule is designed to be reusable to reduce the costs of crewed space missions, and, as such, it incorporates several elements of Space Shuttle technology, notably in its heat shield. Apollo's was partially destroyed during re-entry and could not be replaced. Orion's is ablative but replaceable; the largest ever built, it is over 5m in diameter and made from a single piece of a material >>

Indepth Rocketdyne uses 3D printing for Orion capsule engines

Space science is a necessarily conservative business when it comes to technology. It's almost always seen as preferable to use materials, technologies and processes that are well known for space missions, as the rigours of launch and the environment in space are extreme and the most important thing is to be sure that everything will work. Naturally, this is even more the case where the safety and survival of human beings is concerned.

But in Orion, a new technology is being used for key components. Perhaps unsurprisingly, it's the most prominent of the 21st century's newest production methods: additive manufacturing. Aerojet Rocketdyne, which has specialised in making the rocket engines that have propelled NASA's space missions, is using 3D printing to make engines for the Orion capsule.

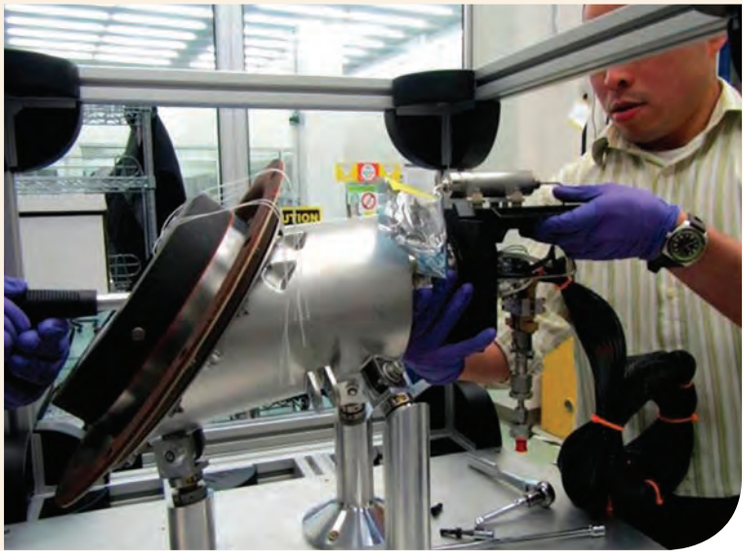
These aren't the main engines for the spacecraft, which, as detailed above, come from the tried-and-tested bracket; but the small manoeuvring engines that stud the surface of the crew capsule. Although small (providing just over 700N of thrust each), these serve a vital purpose: their main task is to move and rotate the capsule after it separates from the service module, ensuring it is in the correct orientation for re-entry into the Earth's atmosphere; give it its final nudge out of orbit and into descent; and keep its orientation stable during re-entry so that parachutes can be deployed safely and effectively. They keep firing even when the parachutes are open to stabilise the capsule so that it's in the right orientation for splashdown.

The components in question are rocket nozzle extensions, and the reason to use additive manufacturing was to save time, according to Jay Littles, director of Advanced Launch Vehicle Propulsion. The 12 nozzles for a single Orion capsule were all produced on one additive manufacturing machine in three weeks, which is about 40 per cent quicker than using conventional casting methods.

Rocketdyne has been using this technology for some 20 years, said Littles, working on projects with both NASA and the USAF. "What sets us apart from someone just buying a 3D printer is that we understand the process from start to finish, from feed powders, to the optimised machine process parameters, to the resulting material microstructures and material properties," he said.

The company's 3D-printed engines have already successfully passed test milestones, with the MPS-120 CubeSat engine, incorporating additively produced titanium pistons and propellant and pressuriser tanks, completing hot-firing tests at the end of 2014.

The new Orion nozzles can't go straight onto a crewed capsule. In the coming two years, they will undergo numerous rigorous inspections and hot-firing tests, before being installed on the capsule for Exploration Mission-1. The system will therefore have a full work-out on the re-entry of an unscrewed capsule returning from lunar space before human lives are entrusted to it.



03

03 Orion crew capsule that was tested in 2015

04 Underside of support module

04

>> called Avcoat, composed of silica fibres in an epoxy resin that fills voids in a fibreglass-phenolic honeycomb structure. A new heat shield will be manufactured and fitted for each Orion mission. The heat shield was tested during Orion's 2015 flight and its manufacture has since been streamlined and simplified, as has the construction of the crew capsule itself, which now requires fewer welds.

Shuttle technology is also being used for the ESM, in the shape of its main engine, which is an orbital manoeuvring engine left over from the Shuttle programme. This wasn't one of the three big main engines from the orbiter, explained ESA development department head Nico Dettmann, but was one of the engines coated in pods on either side of the Shuttle's tail and burned to help the craft into orbit once the launch boosters had detached, positioned the Shuttle in its mission orbit and kicked it out of orbit at the end. The other engines on the module, located around its circumference, are mainly for manoeuvring and have a combined thrust equivalent to the main engine; an example of design redundancy for safety, according to Junkenhöfel.

A major and visible change from Apollo-era technology is the presence of solar panels on the ESM, which will power all the electrical systems on Orion, including all the pumps for fuel, air and water and the electronics in the crew module. Apollo used fuel cells for electrical power.

Orion's next flight will be in 2018. Called Exploration Mission-1 (EM-1), the craft will be sent without a crew on a trip out of low-Earth orbit, though cislunar space, into orbit around the Moon and then back to Earth. This will provide the programme team with an opportunity to test all the systems aboard without endangering any people and qualify the comparatively few new technologies used in the space cart systems (see box above). ESA's contract to produce the service module only covers this mission, but NASA has invited the agency to continue on the programme and, although a final decision on this will not be taken until the next ministerial meeting of ESA's governing body, as Dettmann said it expects and is planning to be involved well into the future. Junkenhöfel thinks ESA's involvement could expand, possibly to include building the habitation modules for a Mars mission. "This should be a goal for all mankind," he said. "And we know this sort of collaboration works. If India, China, Japan or other nations want to be involved, we should welcome that and there's no practical reason why they shouldn't play a part."

Digging the new image

The next generation of imaging techniques could be a game changer for archaeology.

Jason Ford reports

Why would we preserve something if we can't understand it? This question is being asked by Dr Chris Gaffney, an archaeologist whose work has helped to provide fresh insights into one of the world's most intriguing archaeological sites.

Gaffney is head of Archaeological Sciences at Bradford University and part of the Stonehenge Hidden Landscape Project (SHLP), which last year announced the discovery of a major new prehistoric stone monument less than 3km from Stonehenge.

Using a combination of remote sensing and non-invasive geophysical prospection techniques, the project team found evidence for a row of up to 90 standing stones, a discovery that prompted one commentator to suggest that everything written about the Stonehenge landscape and ancient monuments within it be re-written.

"As archaeologists… we instantly turn towards the [Stonehenge] monument because we see that as the focal point in the landscape, which of course it is. But actually it's the focal point of quite a complex landscape, and one that we now know is even more complex thanks to remote sensing."

SHLP's revelation that a large stone monument lay beneath the bank of the so-called Durrington Walls 'super-henge' was preceded in August 2015 with an announcement from the FBI that 'industrial-level' looting was taking place at archaeological sites in Syria and Iraq.

The FBI produced evidence of looting in the form of satellite imagery taken between 2011 and 2014 at three sites over Syria, a method of investigation used by Sarah Parcak, an associate professor of anthropology at the University of Alabama.

01

01 Mounted UAVs are proving increasingly useful

Like the FBI, Parcak has used repeatable, high-resolution satellite imagery from DigitalGlobe's WorldView-2 in a project to identify and quantify looting sites in Egypt following the overthrow of the nation's government in 2011.

According to Parcak, the project revealed a 400 to 500 per cent increase in looting in since 2011, and she believes that there is a 20- to 25-year window until many of the world's archaeological sites are lost to looters, all of which detracts from the work of archaeologists whose efforts have been aided by aerial imagery since 1906 when Stonehenge was photographed from a balloon and is now helped by airborne platforms carrying a myriad of imaging techniques.

Parcak is the 2016 winner of the US$1m TED Award for work that used infrared satellite data to find the ancient Egyptian city of Itjtawy, and the 2014 launch of DigitalGlobe's WorldView-3 satellite is expected to facilitate further discoveries with Short-Wave Infrared (SWIR) capabilities that have added spectral coverage to the invisible range to help identify minerals and specific vegetation, a function that will help archaeologists detect sites of interest more easily.

Benoit Duverneuil, founder of Aerial Digital Archaeology & Preservation (ADAP), said that satellite imaging helps archaeologists understand subtle geophysical changes on a large scale over a short or long period of time and Gaffney believes archaeology would be "in a pretty poor place" without Earth observation satellite technology. He has used imagery from NASA's Landsat program to identify archaeologically significant data at the UNESCO World Heritage Site of Cyrene in Libya.

"Archaeologists are real predators when it comes to other people's data," said Gaffney. "As soon as people have started to provide new data sets archaeologists have been very keen to grab hold of them to see if they can use them for their own purposes."

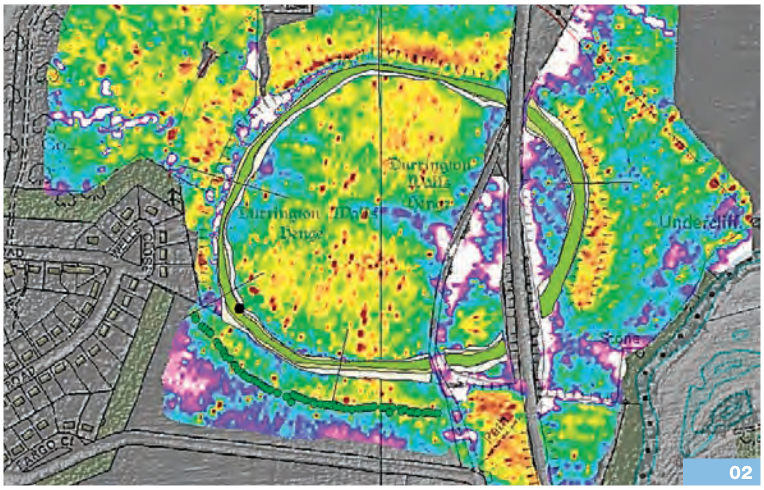
However, despite the repeatability brought about by orbiting Earth, issues arise around the timing of data acquisition, ownership of what is captured, and costs.

"One of the problems with satellite data [is] you either collect data from flights that have passed over at a given time, or pay huge, huge amounts of money for newly collected data, which is well out of reach, certainly for people in archaeology," said Dr Adrian Evans, a post-doctoral research fellow at Bradford's Department of Archaeological Sciences, who is working on Fossil Finder, a project using a customised UAV to capture surface imagery of fossil-bearing areas around the Turkana Basin in Kenya. Images from flights are uploaded onto the project's website where members of the public are encouraged to help in the identification of fossil fragments.

> "As archaeologists we instantly turn to Stonehenge but it is actually the focal point of quite a complex landscape, and one that we know is even more complex thanks to remote sensing"
>
> Dr Chris Gaffney, SHLP

According to Evans, the team has been working with a DJiS1000 multi-rotor UAV fitted with a Pixhawk auto-pilot system, which is based on open-source software that is one-tenth of the cost of commercial autopilot systems.

To achieve a resolution of three pixels per millimetre on the ground without motion blur the team fitted the UAV >>



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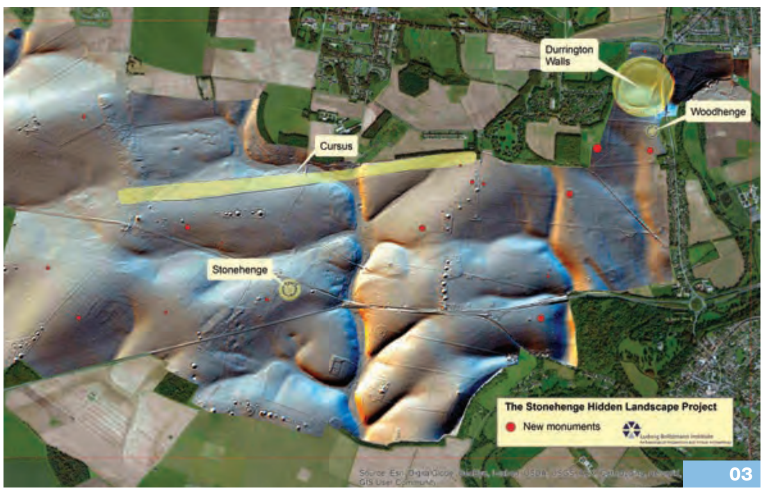

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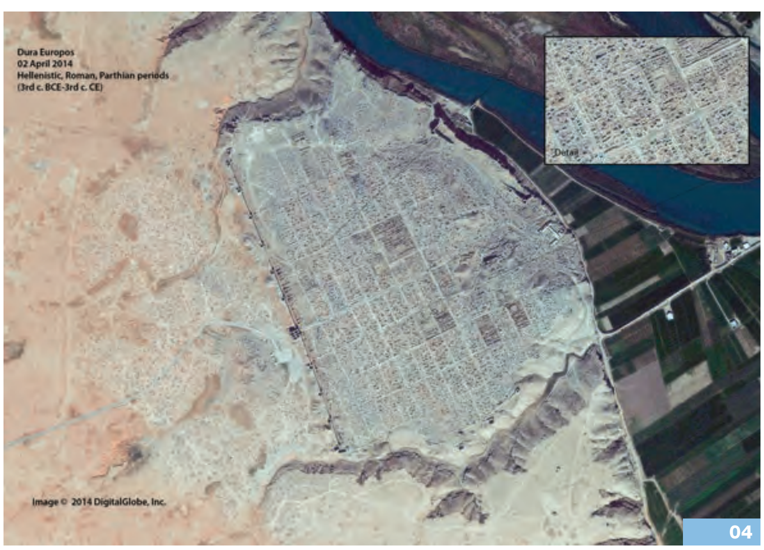


04

>> with a Sony A7R series camera, which was superseded by an A7R MKII to take advantage of the camera's CMOS sensor.

"It's the highest resolution you can get," said Evans. "Even though it's really bright in Africa we're shooting at such high shutter speeds that we're actually dealing with low-light situations so we needed a really good-quality sensor."

While Parcak's work in Itjtawy required satellite coverage from a zone measuring four miles by three miles, the Fossil Finder project is using its flight capability to cover more modest areas, starting with a sector measuring 100 x 40m to establish a raster pattern, although Evans anticipates this to rise to 10km a day from March when the UAV will fly 1km sorties. He added that images collected are extracted from the on-board camera's SD card after each flight.

Gaffney is involved in a project based around cultural transformations in Iron Age Slovenia and Croatia, the former country being one of the most densely wooded in Europe. By using LiDAR (Light Detection And Ranging) mounted on commercial aircraft, the team is able to ascertain complete landscapes that are preserved beneath the tree canopy.

LiDAR, which uses light sensors to measure the distance between the sensor and the target object in order to build a 3D image, is slowly making it onto unmanned systems, notably on board the Riegl RiCopter fitted with a VUX-1UAV LiDAR sensor.

Duverneuil, whose Miami-based research group facilitates non-invasive prospecting through remote sensing, believes LiDAR is becoming more affordable, lighter and compatible with UAVs but will remain out of reach for many archaeological projects for the time being, a point endorsed by Gaffney.

"In the next decade or so we're probably going to see quite a diversification whereby we'll get more standard, miniaturised sensors onto drones and some very specific things onto satellites," said Gaffney. "The satellites will perhaps be very much more focusing more on particular spectra, whereas we'll see the more general data collection being done on drones."

In the interim, Evans is convinced that plummeting prices for UAVs will see greater uptake of the technology by

> "The use of UAVs doesn't really dismiss the role of satellite imagery. In fact, archaeologists have now the possibility to use a multi-scale approach for their project… they can rely on different technologies"
>
> Benoit Duverneuil, ADAP

02/ 03 Last year, archaeologists used imaging technology to make a major new discovery at the Stonehenge site

04 The FBI has used similar technology to monitor looting in Syria

archaeologists, as does Duverneuil who believes that with a budget of less than US$2,000, professional aerial photogrammetry will be something of a game changer for archaeologists.

"With the help of software such as Pix4D Mapper Capture or Drone Deploy (freemium), flight planning, execution, data capture and processing is all done automatically," he said. "We can even preview the results in real time, which is a major improvement for archaeologists."

Duverneuil also sees no reason why satellite and drone data cannot be used in tandem for archaeological projects.

"The use of UAVs doesn't really dismiss the role of satellite imagery," he said. "In fact, archaeologists have now the possibility to use a multi-scale approach for their project. Depending on the stage of their research, the type of data they want to collect, the area they need to cover and their budget, they [archaeologists] can rely on different technologies. UAVs are usually more efficient to survey a small area at a lower elevation even though modern v-wing UAVs can produce hi-definition images for quite large areas."

Ultimately, while satellite imagery and UAVs have a part to play in discovering and recording archaeological sites and landscapes, they are only tools in an arsenal of techniques that should be deployed together.

"The actual concept of archaeological prospection is not just about techniques," said Gaffney. "It's about process, [and] it's sometimes about serendipity. You might spend a year looking through satellite imagery and only finding what you already know. But ultimately, on that extra day that you look, you might find something extraordinary and I always think you have to have that little bit of luck in what we do, no matter how robust our strategies are."

Flying towards an electric future

Airbus's technology chief talks to Stuart Nathan **about the clean, green aircraft of the future**

01

Barely any engineering sector depends as much on the development of new technology as aerospace; and although it's often defence that's seen as the part of the sector where most development takes place, recent years have seen civil aerospace also being the cradle of much new development. The tightening of regulations on the environmental profile of flying, along with new materials and processes, have all driven R&D in the sector; and for Airbus, the world's second-largest aircraft manufacturer, it's taken the technologies of flight in some unexpected directions.

As befits a chief technology officer, Jean Botti is very keen to talk about the forward-looking development projects that Airbus is currently undertaking. Closest to his heart seems to be the electric aircraft project E-Fan, which earlier this year saw the company fly a small two-seater aircraft across the English Channel in a conscious echo of Louis Blériot's famous feat in 1909 – although this time, without the spur of a cash prize from the *Daily Mail*.

The small size of the E-Fan aircraft has led some to dismiss the project as a sideshow, but Botti insists that it represents a serious long-term goal for Airbus. The ultimate aim of the project is to develop an electric airliner, initially with around 100 seats, which the company is currently calling E-Thrust. "This is a learning curve for us. We have to start with the small aircraft with power in kilovolts, and work up to megavolts. We couldn't possibly do it in one go."

Part of the goal of the E-Thrust project – but only part – is environmental. When the aircraft's engines run on battery power, the aircraft produces no emissions. "If you look at where the world trends are heading by the 2030s, with increased numbers of people in cities and the rise of megacities, there will inevitably be more and more congestion and pollution," Botti said. "And if you look at where the most polluted part of the city is, in general it's around the airport; I'm not only talking about CO_2 and NOx here, but also about noise pollution. It has to be better to take off and land with very quiet electric engines." He added that aircraft could arrive and depart later at night and in the early hours without disturbing the neighbours.

As this implies, these electric airliners are likely to be hybrids, with an on-board generator charging the batteries and feeding the motors. This also allows the option of charging the batteries via 'windmilling' the propellers when the aircraft is slowing down; precisely analogous to recovering energy during braking in a hybrid car. "This does mean that you emit greenhouse gases when the aircraft is in cruise," Botti admitted, "but certainly no more than a standard aircraft does; with windmilling, probably less."

Airbus has for some years been investigating the use of biofuels to power aircraft, flying a test using a fuel derived from algae in 2010; Botti pointed out that the fuel proved to

be more efficient than conventional kerosene. He feels that biofuels are the future for air transport. "We chair a German consortium called Aireg [Aviation Initiative for Renewable Energy in Germany], which Boeing's also associated with which is aimed at exploiting and understanding the impact of biofuels," he said. "The main problem with biofuels today is making a justifiable business case, which with today's oil prices is very difficult. The technical aspects are really not that worrisome." However, he isn't prescriptive. "I don't think there will be single biofuel technology that fits all applications. The most important thing is to establish common specification and regulations: that's our job."

In formal terms, E-Thrust and its family won't even be Airbus products; the company has created a new subsidiary called Voltair to commercialise the technology; symbolic of the clean break it represents from its more-established turbojet-powered aircraft families. "We didn't want to mix the message," Botti said. Voltair operates out of new premises in Toulouse: "When I created the plant that will make E-Fan, I had the objective that young engineers will start up and become the experts that we need in the future to make larger electric aircraft; that's knowledge that currently doesn't exist," he added. Technology development is looking at new batteries and motors using high-temperature superconductors; Botti even mentioned the possibility of nuclear fusion to power such aircraft. "We are not looking at next year or even next decade with this project, and we want to keep such possibilities in mind, even if they seem very far-fetched now," he said.

Besides exploring environmental advantages, the other goal for the Voltair project is to investigate new aircraft architecture. Changing the current look of most large civil airliners – wings at the bottom of the fuselage, single vertical fin, two tailplanes, engines under the wings – is known in the aerospace business as 'breaking the paradigm', and it's a paradigm that has held firm for several decades. But along with others, Botti can see the end of the paradigm.

One of the limiting factors for the current paradigm is engines. Turbines are getting wider, because makers are exploiting efficiency improvements that come from increasing the bypass ratio (the ratio of the air volume compressed by the engine's fans to the volume that actually goes through the engine's combustion stage). Eventually, the engines will be too wide to fit under the wing and allow the aircraft to taxi without scraping the ground.

In electric aircraft, it will be vital to make sure as little of the energy output of the engines is wasted in overcoming drag, and Botti said they will have to break the paradigm. "They are going to look very different from the aircraft we are used to," he said. "I think it's inevitable that we'll see a lot more integration of the engines into the airframe, in particular." This design experience, he added, will then inform the design of conventional aircraft into the future.

Indeed, the current E-Thrust concept rendering shows engines integrated into the roots of wings and the rear fuselage: a partial return to the design of the 1950s that gave rise to aircraft such as the de Havilland Comet.

Airbus's other long-term projects are, perhaps surprisingly, outside of the civil aviation sector. Perlan, for example, is an atmospheric research project involving the development of a glider designed to fly at an altitude of 90,000ft. "We are looking at the prospect for supersonic passenger flight, and those aircraft will certainly fly at that altitude," Botti said. The goal of Perlan – which was started in 2006 by the late adventurer Steve Fossett – is to investigate a phenomenon called giant mountain waves, which are 'stationary' changing regions of atmospheric pressure caused by air forced to rise over mountains, escarpments or even masses of cold air; the waves then rise in the lee. They have been implicated in phenomena such as cloud formation, atmospheric mixing at the poles, and sudden changes in weather that affect air traffic in regions such as South America. "The programme stopped in 2007 after Fossett died," Botti said, "but we decided we had to get involved and fund it because it's such a fantastic programme: to understand what's happening with giant mountain waves, how they contribute to rapid changes in weather and to the climate." Currently, the schedule for Perlan includes the building of a pressurised glider based on Fossett's design, to break the world glider altitude record in 2016, beating the mark of 50,671ft (15,460m) achieved by Fossett and co-pilot Einar Enevoldson in 2006.

> "When I created the plant that will make E-Fan, I had the objective that young engineers will start up and become the experts that we need in the future"

Another long-running project is Zephyr, which aims to make a solar-powered electric aircraft capable of remaining aloft for long periods. Intended to act as a 'high-altitude pseudo-satellite (HAPS)' and provide long-term surveillance or services such as telecommunications or internet coverage for the area in which it is deployed, Zephyr's seventh iteration broke the UAV endurance record in 2014 with an 11-day flight, particularly significant as it was during winter conditions with short daylight in which its solar cells could charge its batteries.


02


02

01 The E-Fan electric aircraft is a long-term goal for Botti and his team at Airbus

02 The long-running Zephyr project broke the UAV endurance record in 2014

03 A concept sketch of the E-Thrust

CareerCV

Jean Botti
Chief Technology Officer, Airbus

Education

1986 MEng in mechanical engineering, National Institute of Applied Sciences, University of Toulouse
1991 MBA, Central Michigan University degree in R&D Management, Massachusetts Institute of Technology
1995 PhD in mechanical engineering, National University of Arts and Trades, Paris (in association with Central Michigan University)

Dr Botti also holds honorary degrees from the universities of Bath and Cardiff, and from the University of South Alabama

Career

1978 Joins Renault as an apprentice
1989 Joins chassis division of General Motors in the US
1999 Returns to France as GM's director of European engineering for chassis components
2002 Chief technical officer at Delphi, managing corporate Dynamics, Propulsion and Thermal Innovation Centre
2004 Business Line Executive, Powertrain Line at Delphi
2006 Joins Airbus as chief technology officer

Other positions

2011 Joins National Academy of Technologies of France
2013 Joins French National Air and Space Academy
2014 Becomes a Senator at German Academy of Science and Engineering

Dr Botti is also the representative for aeronautics and space to the European Research Area Board

All dressed up with nowhere to go

In the first of a new series, novelist Jon Wallace considers the scifi implications of engineering stories that have caught his eye. This month: the dystopian world of 'smart' dressings

For many science fiction writers the human form, and man's attempt to alter or augment it, offers a rich seam of stories. We like to ask: how far do skin and bone define our humanity? Living beyond corporeal concerns of sex, age, pain and emotion, what will be left of us, and what else might we discover about ourselves? Imaginations transport us into worlds where humanity has engineered an 'improved' homo sapiens design (*Star Trek*'s Khan Noonien Singh), or even rendered the body into a disposable shell (Richard Morgan's *Altered Carbon*).

Such stories tend towards gloomy visions, where future engineers' hubristic tweaking has created repression, division, or threatened the very existence of the species. Still, there is something inherently optimistic in these ideas: these are futures where, whatever the repercussions, human ingenuity has achieved an evolutionary leap; transforming the very way we experience life.

Yet sometimes, reading *The Engineer*'s news feed, the scifi author's imagination can be excited by a more immediate future, one that will come before such 'Brave New Worlds'; an epoch where science, rather than transforming our bodies (or taking us out of them altogether) will instead refine the way we preserve our plain, 'mark one' human structure.

In December, *The Engineer* reported on DermaTrax, a smart dressing capable of monitoring chronic wounds and transmitting data wirelessly to a nurse station. The intentions are honourable enough: using a range of sensors, the dressing removes the need for nurses to constantly replace bandaging, freeing them up for other work and easing the patients' discomfort. However, much of the meat of the researchers' pitch hinges on cost: the new dressings, we're told, will "potentially make care… more cost effective for healthcare organisations."

That kind of language sets the dystopia sense a-tingling: science fiction has rarely if ever had a good thing to say about the impact that monolithic corporations will have on our future – they make easy targets – and few come more monolithic than certain healthcare organisations.

How soon, we might ask, before insurance companies require chronically wounded clients to wear DermaTrax patches as a precondition of policies? How soon before the dressings are used for all forms of injury, the sensors spreading even to the hospital sheets themselves? How could insurers, constantly striving for reduced risk and maximised profit, resist the chance to monitor their clients' health with such inescapable, 'real-time' data? An account of some ambitious compliance officer's ascent through the ranks of such an Orwellian future firm makes for a promising story.

The scifi author might also explore the perspective of the patient: how would the bandaged of the future cope with technology that documents every twist and turn of a healing wound? Dressing manufacturers might discover a new income stream from people who wish to monitor their own wounds' status. What effect, we might ask, would such an intimate relationship with one's afflictions have on the mind?

A story might see a character housebound by an injury, constantly accessing her sensor data via a phone app, growing obsessed, and seeking out miracle cures online. Here, her story twists into a scifi horror, as she goes slowly mad in pursuit of improvement, self-medicating with crackpot cures that only inflict new and more terrible wounds until there is nothing left of her but a mass of twitching bandages, keeping a meticulous record of the barely human creature expiring within.

What kind of artificial intelligence (AI), we might well ask, would be created in the primordial soup of medical data created by smart dressings? Could it be a hypochondriac intelligence, born convinced that it is sick, yet without a body to cure; a story where humanity is learning to augment or discard its body, while AI longs to inherit it.

And who would be more human then? Our wounds, science fiction constantly reminds us, are part of what defines us.

Jon Wallace is a science fiction author living and working in England. His first novel, *Barricade*, was published in 2014. Check out his website jonwallace.co

> "Dressing makers might discover a new income stream from people who wish to monitor their own wounds' status"
>
> Jon Wallace

'Smart' dressings are awash with scifi potential

Speed is united with metrology

Infiniti Red Bull Racing is finding new ways to turn measurement to its advantage.

Stuart Nathan reports

> "In a fast-moving industry, things that are slower tend not to happen. We use this equipment to speed up the process and give us confidence in results"
>
> Alan Peasland, Red Bull

It's probably fair to say that few people would associate metrology with speed. Even the age-old proverb 'measure twice, cut once' carries the implication that the measurement part of the equation is the time-consuming bit, but that the time is vital to the job.

For the precision manufacturing industry, metrology is part of the price you pay for precision. Knowing the dimensions of the articles you're making is vital, and, more importantly, it's part of what customers are paying for.

Infiniti Red Bull Racing is finding new ways to turn measurement to its advantage. One of the most competitive presences on the Formula One grid, winning one in every four races it has entered in its 11-year history, it is using measurement equipment from its supplier Hexagon Metrology, to help shave invaluable time off the laps its cars perform in practice and during races, and also to reduce its costs in shipping its equipment around the world.

For Formula One, metrology fulfils two functions above and beyond the need to make sure everything in the car is the right shape and size to fit together. First, it's part of the rules: the dimensions of the cars are specified by the sport's governing body, the FIA, and need to be ascertained and confirmed before each race. Second, its part of the competitive advantage; the set-up of the car, including details such as ride height and the position of the aerodynamic components of the car are determined to suit both the individual styles of the team's drivers and the demands of each circuit.

Hexagon Manufacturing Intelligence chief executive Norbert Hanke said Red Bull is his company's most demanding client because of its need for speed. It uses 100 per cent dimensional verification for every component it makes or buys in to go onto its cars; and it can't hang around. During a typical season, over 30,000 changes are made to the Grand Prix car, most of which involve the design and fabrication of new parts. The effect of each change is tiny, but over the course of the season the cumulative effect amounts to several seconds off lap times: the equivalent of podium places, points in the drivers' and constructors' championships and sometimes even between winning and losing.

These changes have to be completed in the time between races: in other words, within a fortnight. "Working nights and weekends becomes the rule," said Chris Charnley, quality manager at Red Bull Technology, the manufacturing and design part of the Infiniti Red Bull organisation. Incorporating the metrology into this extremely rapid design-and-manufacture cycle drives innovation at Hexagon. "Red Bull is constantly pushing the limits of the capabilities of our products and demanding new functionality," said Hanke.

In the factory, Red Bull uses four laser trackers from Hexagon subsidiary Leica Geosystems to check the dimensional integrity of its components.

But Red Bull's use of metrology equipment continues at the circuit. A portable AT960 Leica Absolute Tracker is an essential piece of equipment in the pit-lane garage where the cars are prepared to go out onto the circuit. It helps the team both to verify the dimensional aspects of the car that are necessary for FIA compliance, and also to complete the set-up of the car. "Conventionally, we'd machine special tooling to help us do the set-up and jogs to check it, and then we'd have to ship them to each race with our garage equipment," said Charnley. "Using the Tracker instead, we only have to ship the one piece of equipment which has several functions, rather than several things that only do one job, and we pay by weight for shipping, so it helps reduce our bill." It also, incidentally, shaves a small amount off the team's carbon emissions profile, he added.

Setting-up using the Tracker rather than jigs does not add any time to the process, added Alan Peasland, Red Bull's head of technical partnerships. "In a fast-moving industry, things that are slower tend not to happen," he said. "We use this equipment to speed up the process and give us confidence in the results."

01 Red Bull has won 25 per cent of all F1 races

02 Key to this success is measuring

Speed is key as productivity drives metrology product development

The metrology equipment market continues to produce more and better engineered products to measure components quickly and accurately. Non-contact, optical systems are a strong theme as speed becomes more important. We measure up a selection of 2015's top products with applications.

20 minutes to 20 seconds

Video measuring system helps to rapidly increase productivity at UK subcontractor. Supplier: Nikon

What does an orbiting telescope that is mapping the Milky Way have in common with the first all-English wristwatch to be produced in half a century?

UK subcontractor Microtec EDM in Basildon has supplied prototypes and components for both of them, as well as for many other innovative and high-profile projects. The company recently raised the capability of its metrology department by purchasing a CNC video measuring system, an iNEXIV VMA-4540 from Nikon Metrology.

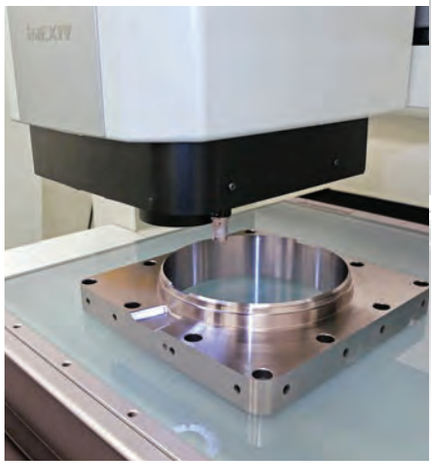
Before the machine was installed, Microtec relied on manual video measuring using another make of instrument. "We are currently seven years into an 18-year contract involving electro-discharge machining [EDM] and centreless grinding of nickel-copper alloy tube to produce a decoy missile component," said owner and managing director Graham Cranfield. "A complete inspection of the part using our manual video measuring system used to take 20 minutes. Now that the job has been programmed on our Nikon, the same inspection cycle is completed automatically in just 20 seconds. We find that time savings of this scale are typical and have revolutionised our productivity."

The iNexiv is an optical based, multi-sensor measuring system that is lightweight and compact enough to be used on the factory bench top, with several fast, fully automatic and high accuracy features. Unlike a touch-probe-only system, iNexiv can be much quicker to measure multiple points. "A standard touch probe has to measure four points and physically touch the part and is relatively slow," said business development manager, video measurement systems at Nikon UK, Paul Gough. "With an optical system it will measure the part in less time if it is within the field of view."

For applications, Gough said that there is no vertical industry sector it does not suit but highlights some that are especially suited for micro-scale measurements. "Medical devices is a strong business sector, inhalers, stents and others, especially in Ireland," he added. "And the electronics industry where products are getting smaller.

"On one of these optical systems we can go up to 4,000x magnification. That allows us to see track widths on silicon wafers of one or two microns, which is being done at a company in Scotland."

> "On one of these optical systems we can go up to 4,000x magnification. That allows us to see track widths of one micron"
>
> Paul Gough, Nikon UK



Getting the hole story

Vision measurement probe can inspect holes as small as 0.5mm. Supplier: Renishaw

Uk metrology specialist Renishaw has launched a new vision measurement probe, called RVP, for use with its REVO five-axis measurement system on co-ordinate measuring machines (CMMs).

Some applications require fast, repeatable measurements, for example, to measure multiple holes where contact probing is not suitable. RVP increases the multi-sensor capability of REVO by adding non-contact inspection to the existing touch trigger, high-speed tactile scanning and surface finish measurement capability of the system.

Thin sheet-metal parts or components with large numbers of holes as small as 0.5mm, and parts that are not suited to tactile measurement, can be fully inspected with the RVP system.

RVP also gives big improvements in throughput and CMM capability by utilising the five-axis motion and infinite positioning provided by the REVO head.

The RVP system comprises a probe and a range of modules that are automatically interchangeable with all other probe options available for the REVO platform. Data from multiple sensors is automatically referenced to a common datum. This flexibility means that the optimum tool can be selected to inspect a wide range of features, all on one CMM platform.

"RVP provides fully automated inspection of aerospace engine combustor cases, measuring hundreds of holes repeatably in a fraction of the time that current methods allow," according to Dave Wallace, director and general manager, CMM Products Division at Renishaw.

When using RVP, part illumination is provided by integrated and programmable LED lighting inside each module. Feature enhancement for the RVP probe is also available using backlighting combined with bespoke part fixturing.

The RVP system is managed by the same I++ DME compliant interface as REVO, and full user functionality is provided by Renishaw's MODUS metrology software.

The new MODUS vision software capability includes RVP configuration, image processing with application specific options and automatic image storage for review and further analysis.

> "The system can measure hundreds of holes repeatably in a fraction of the time of other methods"
>
> Dave Wallace, Renishaw

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NATIONAL INSTRUMENTS

High-speed intricacy

ScanArm offers high-speed, high-accuracy scanning of composites. Supplier: FARO

Scanning time in an engineering environment that is assembling large structures of different materials with harsh delivery schedules poses problems. The Edge ScanArm HD and its Laser Line Probe HD is manufacturer FARO's response to the market need to scan intricate composite materials quickly.

The Edge ScanArm HD combines the various advantages of a hard probing system with the capabilities of FARO's Laser Line Probe HD to provide rapid point-cloud collection with high-definition resolution and precise accuracy.

The FARO Edge ScanArm HD is suitable for product development, inspection and quality control, and offers capabilities such as point-cloud comparison with CAD, rapid prototyping, reverse engineering, and 3D modelling of free-form surfaces.

Shane Dover, Metrology Business Manager, FARO Technologies UK said, "The use of the FARO ScanArm HD has proven its worth within the 3D modelling market, many more components are being produced with this technology in aerospace and automotive sectors and the ability to inspect these quickly and accurately back to a CAD model vastly speeds up the engineering process."

The FARO Edge ScanArm HD provides rapid point-cloud collection with extreme resolution and high accuracy without any special coatings or target placement. The extra-wide scan stripe and fast frame rate boosts productivity by increasing coverage and reducing scanning time. Intricate components can be captured in fine detail as a result of the 2,000 actual points per scanline and the new blue laser featuring noise reduction technology.

Users can also reduce required training time with the new crosshair feature and existing LED Rangefinder functionality, which provides real-time scanning feedback. ScanArm's hard probe and the Laser Line Probe are able to digitise interchangeably without the need to remove either component allowing operators to perform 3D inspections with ease.

"The ability to scan reflected surfaces especially in the medical sector has always been a concern, with the HD blue laser technology this reduces much of the noise taken from the scan data to dramatically improve the information that is being gathered from Laser line probe," said Dover.

"The ability to inspect these composite components quickly and accurately back to a CAD model vastly speeds up the engineering process"

Shane Dover, FARO Technologies

Compact projections

Projector for functional, cost-effective measurement and inspection. Supplier: Starrett

In a business environment that is uncertain, competitive price with all-round functionality is what many precision engineering firms want.

US company Starrett recently launched a compact profile projector, the Starrett VB300, that has been designed to offer an accurate, cost-effective method of measuring small components.

The vertical bench top optical system features a 300mm diameter screen that can be viewed to the edge, with crosshairs, calibrations marks and overlay clips making it suitable for the rapid inspection of small components.

"Vertical systems such as the VB300 are suitable for applications where the parts to be measured are flexible or soft," according to Brian McLay, Starrett Precision Optical Metrology business manager. "As the component rests in a neutral state on the workstage, and no deformation forces are applied during the measuring and inspection process, any data gathered is unaffected by the measurement system."

Flat parts up to 5kg can be measured on the 225 x 225mm precision workstage top, which features a 155 x 155mm toughened glass insert and 100 x 100mm of high-resolution measurement travel. A manual focus range of 100mm delivers sharp of the component being measured remains in sharp relief.

The VB300 has been designed to 'plug and play', coming as standard with an integral DRO system that allows X and Y linear axis measurements and angular measurements to be made on the screen and read off the LED display located just below.

Linear positional feedback comes from precision glass scales with a resolution of 0.001mm, while the digital protractor provides a resolution of one minute.

The device has a quick-action bayonet fitting single lens mount that can accept a variety of optional precision ground magnification lenses, including 10x, 20x, 25x, 50x and 100x, that take just seconds to change over.

Surface and profile illumination comes from Starrett's own LED source. This improves the level and quality of lighting available, as well as reducing the heat soak created by traditional tungsten halogen lamps.

The solid-state LED source also has a predicted service life of more than five years.

"Vertical systems such as the VB300 are suitable for applications where the parts to be measured are flexible or soft"

Brian McLay, Starrett

Reach for the skyscraper

Revolutionary, tower-style computer chips could boost performance a thousandfold

Andrew Wade reports

In the age of big data, the cloud and the internet of things, our thirst for computing power has never been greater. Readers may be familiar with Moore's law, which predicts a doubling of computing capability every two years as integrated circuits are packed ever more densely with increasingly smaller transistors. This general rule of thumb has held firm for a number of decades, but the pace of progress is beginning to slow, with Intel's CEO noting last year that the rate is slipping closer to two-and-a-half years.

As we push against the limits of nanotechnology and chip fabrication, this slowdown is inevitable, and likely to get worse over time. How, then, will the next great leap forward be achieved? Rather than relying on increasing the raw computing power of integrated circuits, the answer could potentially be found through a reimagining of microchip architecture.

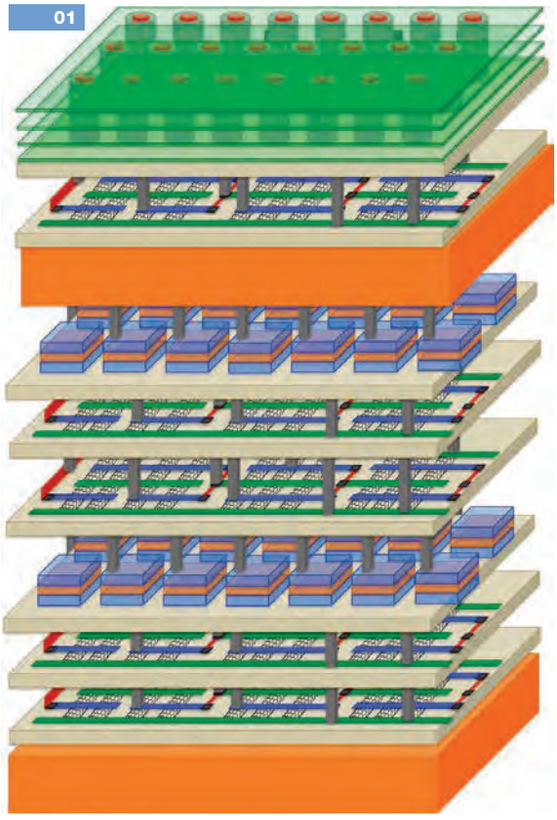
A Stanford-led project recently published its work on a skyscraper-style chip design, where layers of memory and transistors are stacked one on top of the other. The approach has been labelled Nano-Engineered Computing Systems Technology, or N3XT. According to research co-lead Subhasish Mitra, the technology could herald a new era of computational power.

"The reason we are trying to do this is because the question is how to get the next 1,000x of computing performance," says Mitra, an associate professor of electrical engineering and computer science at Stanford. "Clearly, the way things are going now, you're not going to get a 1,000x (leap) in computing performance.

"You have to look at what are the driving applications for computing, and those are what I call abundant data computing. That is, computing on lots of data, both in the cloud and from other sources."

In today's computers, processors and memory are laid out side-by-side, comparable to a suburban sprawl. Moving data around this configuration takes time and energy in the same way that physically getting from A to B in a suburb does when walking or driving.

"If you really look at where the energy is spent, it's spent sending the data back and forth from memory to compute," Mitra explains. "So to get the next 1,000x of benefit, one has to think about not only the transistor, but also think about how to get better memory access.



01 N3XT, or Nano-Engineered Computing Systems Technology

02 Stanford University's research co-lead, Subhasish Mitra

> "There are huge volumes of data that sit within our reach, but we lack the computational horsepower to bring this data to light and use it"
>
> Chris Ré, Stanford University

"To be able to do that, you have to have memory that is very close to computing. People have talked about this for a very long time. You hear people talking about computing in memory, memory in compute and so on. The real question is how do you realise the next-gen architecture that can accomplish that."

The simple answer is to build upwards. Naturally, Mitra and his colleagues are not the first to contemplate this straightforward solution, but traditional chip manufacturing methods have made it difficult in practice.

Fabricating a silicon chip requires temperatures close to 1,000°C, and this makes it extremely challenging to build one layer on another without damaging the chip below. Current methods rely on constructing two chips separately, then stacking and joining them with thousands of tiny wires. However, these 3D chips are susceptible to data traffic jams due to the relatively low number of connecting wires compared to the number of transistors.

The Stanford team's N3XT architecture relies upon a different technique. Instead of silicon, it uses carbon nanotubes (CNTs), which are faster and more energy-efficient than silicon processors and, more importantly, allow for layers of transistors and memory to be stacked. The different 'floors' of the high-rise chip are connected by millions of minute pathways known as 'vias', which are integrated into the build process.

"The carbon nanotube transistors and the kinds of materials that we use for memory, you can actually fabricate the transistors and the memory at a very low temperature, at around 300°C," says Mitra. "That's why you can build the ideal architecture for computation next to memory."

Along with Mitra, the N3XT consortium is co-led by fellow Stanford professor H-S Philip Wong. The pair have so far been joined by colleagues from several US universities, as well as numerous academics from within Stanford. Those academics include paper co-author Chris Ré, who says he joined the collaboration to make sure that computing doesn't enter what some refer to as a 'dark data' era.

"There are huge volumes of data that sit within our reach and are relevant to some of society's most pressing problems, from healthcare to climate change, but we lack the computational horsepower to bring this data to light and use it," says Ré. "As we all hope in the N3XT project, we may have to boost horsepower to solve some of these pressing challenges."

More bang for your buck

Electronics device manufacturers are packing multiple features into the same-sized packages, especially in the sensor sector. Big steps have been made in video-based monitoring and in environmental, low-power devices and wireless-testing technology.

The BLIP detection service

New Blackfin vision platform senses motion, vehicles and faces, indoors and out. Supplier: Analog Devices

"The Blackfin family of DSPs has proven to be a firm favourite"

Simon Duggleby, RS Components

Much of the industry news in recent months has focused on smart cities where, for example, intelligent buildings reduce energy consumption by 'talking' to each other.

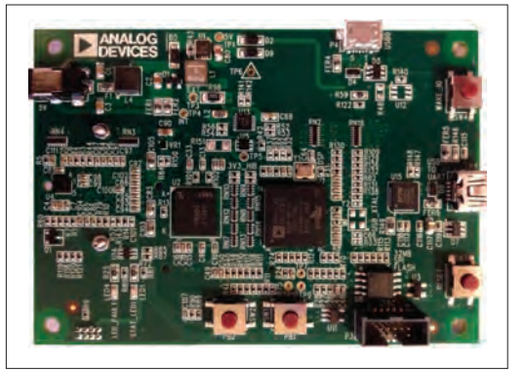
In a similar vein, Analog Devices' new ADZS-BF707 Blackfin Low-power Imaging Platform (BLIP) evaluation hardware provides a low-cost product for real-time security, environmental control and building automation applications.

The BLIP is a computer vision platform with multiple functional profiles. These cover intelligent motion sensing, people counting, vehicle detection and face detection. In addition, the product can be deployed in and out of doors.

The BLIP includes an intuitive configuration graphical user interface and enables real-time analysis of captured video, as well as video output/display through an onboard USB port, making it a highly useful tool for product development.

One notable aspect of the system is its improved home and business security. The BLIP hardware platform is delivered with a pre-loaded occupancy software module, optimised to detect the presence and behaviour of humans or vehicles in indoor and outdoor environments.

This advanced detection operation provides significantly improved performance compared to single-pixel PIR sensor solutions targeting lighting control, climate control, and access control applications.



"The Blackfin family of DSPs has proven itself to be a firm favourite with customers in real-time audio, video and control applications for many years, combining a unique blend of processing performance and power efficiency," said Simon Duggleby, semiconductor category marketing manager at RS Components in Milton Keynes.

"RS customers purchasing any product from the BF70x family and, in particular, the BLIP board, will benefit from this blend of capabilities.

"For adding greater intelligence to existing occupancy sensing, asset tracking or vision-based control systems the BLIP board comes across as a great solution."

The BLIP platform is also suitable for asset counting and tracking.

"I can't help but be amazed at the ever-growing list of features that are built into PLC platforms"

Mike Finseth, Digi-Key

Thanks for the memory

Panasonic's latest PLC boasts more functions and faster execution times. Supplier: Panasonic via Digi-Key

Machine builders and operators today have an impressive choice of programmable logic controllers (PLCs), some of which pack hundreds of features into a small box. One driver is low-cost but high-volume memory.

"With Panasonic's latest programmable logic controller release, I can't help but be amazed at the ever-growing list of features that are built into today's PLC platforms," said Mike Finseth, I&E product manager at Digi-Key. "You can think of a PLC as a small industrialised computer that is specialised for a particular programmed function. These may include motion control, logic and mathematical functioning, vision or hundreds of other functions. The new PLC has input lines where sensors are connected to read conditions of temperature, levels of volume or object detection."

In the past, PLCs were separated and classified by programme execution speed and available memory. Adequate memory has not been an issue with today's PLCs, given the low cost of high-density memory available.

Programme execution speed has been one of the more misunderstood advances, said Finseth.

"Total programme execution time is the total time to scan the PLC inputs (a millisecond or more), the time to execute program instructions and finally the time to turn on or off the outputs," he explained.

"Panasonic's latest FP7 platform allows for 234,000 programme steps, with each step executing in 11ns/step, which is up to 20 times faster than past models."

When it comes to execution times, operators need to consider how they write their instructions, the number of call-ups used and whether they are using library modules such as timer and counter function blocks.

In the past, PLCs have not been so good at storing, transferring data or exchanging data with other devices. Now, according to Finseth, "Ethernet communications have pulled the PLC on to system networks with full accounting and analytics capabilities. Today's PLC needs to communicate via human-machine interface (HMI) displays while not slowing down execution speeds."

With packaging machines for the plastics, paper and textile industries, these PLC units excel due to the complex movements and multiple sequences needed, maintaining a process that is interruption-free.

A safe charge for Europe

The DRF is one of the most compact DIN rail power supplies on the market. Supplier: TDK-Lambda

Wherever power conversion takes place, it is a constant challenge to protect equipment from explosive environments that can form.

Power supplies are used to provide regulated voltages to motors, relays and electronic controls. However, gases, vapours, mists and dusts can all form explosive atmospheres with air.

As power supplies produce heat and contain high voltages or currents that can cause sparks, it is important that operators select products that are appropriately certified for use in these environments.

ATEX was introduced in the EU to facilitate the free movement of goods and services of equipment used in hazardous environments. It includes a harmonised standard that is applicable to electronic power supplies; the ATEX 95 equipment directive 94/9/EC. In Europe, compliance is mandatory and is indicated through the CE mark and distinctive ATEX symbol.

Non-electrical equipment in category 2 and all equipment in category 3 can be self-certified by manufacturers, although it is normal practice to support compliance through third-party testing of products to the EN60079 series of standards.

Electronics manufacturer TDK-Lambda recently gained 'Hazloc' certifications for the DRF series of DIN rail-mounted power supplies, as the previous generation products did not address the European market demands. "A premium medium-power family, the DRF series combines careful thermal design and excellent efficiency," said Martin Southam, EMEA-based director of marketing at TDK-Lambda.

"This series is perfect for customers working to eco-design guidelines and seeking compact high-efficiency products"

Martin Southam, TDK-Lambda

"With an average active efficiency of over 87 per cent and market-leading low standby power consumption, this series is perfect for customers working to eco-design guidelines and seeking compact high-efficiency products."

Efficiency values of up to 94 per cent minimise internal waste heat. This allows the DRF to be one of the most compact DIN rail power supplies on the market, while maintaining conservatively rated component temperatures for long field lifetimes.

Accelerate the processing

Combining technologies leads to pacier wireless manufacturing tests. Supplier: National Instruments

In the car infotainment sphere, automotive safety regulations such as eCall in the EU and the growing number of vehicles with network access devices are creating a growing need for cellular and wireless module testing.

The result is a requirement for shorter test times per device under test (DUT) combined with higher throughput. This entails using RF instruments more efficiently through instrument-sharing or multi-DUT testing.

National Instruments' Wireless Test System (WTS) was recently introduced to speed up testing and reduce costs. Built on PXI, multicore and FPGA technologies, it offers high measurement speed to help improve test throughput.

Infotainment specialist Harman had been using a simple sequential test system for their recalled products that tested one at a time with no parallel testing ability.

"The Wireless Test System gave them the ability to take a pre-build system with multi-protocol and multi-device under test capability, and deploy it into their production lines to test multiple DUTs in parallel much faster," said Jeremy Twaits, NI's senior marketing engineer, RF and communications, Northern Europe.

"As WTS is built on the platform that NI has created for modular instrumentation, known as PXI, you can pick and choose the instrumentation that is required, combined with very powerful processing units, to perform the measurements that are required very quickly."

NI has selected the fastest and latest processors, including Intel optical modules, to speed up the processing.

Within the WTS unit, NI uses a vector signal transceiver, which is an RF generator and RF analyser within a single module, with an FPGA on board for performing inline processing. "The system also has smart switching to allow any signals being generated by the vector signal transceiver to be broadcast to all of the devices under test at once, where multiple responses from the devices are read in order to calculate whether the device is responding correctly to any RF stimuli," said Twaits.

Harman created a '4-UP' four-device system in parallel, reducing the test time of these devices by 25 per cent. "And because they required fewer test systems to meet product demand, Harman could use fewer test systems on the production floor, which saved them space and meant they could reduce labour costs," said Twaits.

More recently, an NI customer has developed an 8-UP device in parallel test platform.

"You can pick and choose the instrumentation, combined with very powerful processing units, to perform the measurements that are required very quickly"

Jeremy Twaits, National Instruments

Manufacturers take centre stage

Southern Manufacturing & Electronics is set to offer a broad selection of firms, from major international manufacturers to smaller, specialist SMEs

With more than 800 exhibitors crowded into its 18,000m², purpose-built venue, this year's Southern Manufacturing & Electronics show, looks set to be one of the biggest yet.

Running from 9–11 February at FIVE, Farnborough, the show is divided into three main areas: Manufacturing, Electronics and a specialist aerospace/automotive precision engineering area named AutoAero.

These main areas are further subdivided into zones such as Machinery and Tooling, Subcontracting, Electronics Production and Test which help to make the event more navigable.

The exhibition features a broad selection of firms from major international manufacturers to much smaller specialist SMEs.

As the first major show of the season, Southern is traditionally the place where those looking to invest in new hardware come to scout the offerings of the major vendors.

Exhibitors include a number of major manufacturers of machinery and production systems. Companies such as Amada, Bystronic, Haas Automation, Matsuura, Yamazaki Mazak and Unison are regular exhibitors, and all return with live demonstrations for 2016, alongside other important machinery vendors such as XYZ Machine Tools, Dugard and JHP Machine Sales.

Other notable names exhibiting are: Nikon Metrology, Faro Technologies, Bowers Group, Olympus, Renishaw and Mitutoyo, to name but a few.

Around these giants circle a galaxy of other star names in tooling and production, such as Quickgrind, ITC, Heidenhain GB, Roemheld and Q8 Oils. There are welding systems from TPS Weldtech, aqueous cleaning and component preparation machines from MecWash and Guyson International.

The show is also a major market for engineering services, which range from precision engineering, to electronics production, fabrication, casting, laser cutting and specialist finishing. There are also a number of firms involved in advanced manufacturing techniques and high-tech materials such as engineering plastics and composites. Examples are Renishaw, igus UK, Brownell and IPF.

Automation and robotics solutions on show include offerings from Fanuc, Panasonic, Mycronic and RNA Automation. There is linear motion, drives and controls from Swiss firm Delta Line and HepcoMotion among many others.

Many of the exhibitors, whether providing services or components, share particular expertise in areas such as aerospace or medical technology. Many of these firms are organised into Technology Trails, which help guide visitors across the many different aspects of the show, from engineering services, to tooling, to components. Pre-registered visitors get a Show Guide booklet containing details of the various trails and their constituent members.

Away from the exhibition floor a free technical seminar programme will run in two theatres over all three days of the show. Highlights of the 2016 programme include the return of Stefan Knox of Bang Creations with his hugely popular look at Good Design and Simple tips to Generate Good Ideas. Nick Statham of Fasturns UK will talk about the Automation of Flexible Manufacturing. 3D printing comes under the spotlight when Sav Jeyendran of Canon UK talks about the options of the rapidly emerging technology. Robin Zhang looks at meeting the legislative requirements for exporting globally, while further advanced manufacturing techniques and materials are examined in An Introduction to 3D Print and Future Applications of Advanced Materials. Ailsa Kaye returns with her popular look at the current thinking in Best Practice for World Class Manufacturing, and numerous other topics are addressed, such as lean, CE marking, supply-chain analytics, the ERP Directive and many more.

Admission to Southern Manufacturing is free and FIVE Farnborough offers plentiful free parking and easy access by public transport. To register for tickets, visit www.industrysouth.co.uk.

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01 and 02 Southern is traditionally the place where those looking to invest in new hardware come to scout the offerings of major vendors

"Many of the exhibitors share particular expertise in areas such as aerospace or medical technology"

Engineering Eventsexhibitions 2016

February	Venue	Date
Southern Manufacturing	FIVE, Farnborough	9–11 Feb
Embedded World	Nurnberg, Germany	23–25 Feb
Metav	Dusseldorf, Germany	23–27 Feb
Packaging Innovations Show	NEC, Birmingham	24–25 February
March	**Venue**	**Date**
Ecobuild	ExCel, London	8–10 March
JEC World	ExCel, London	8–10 March
Maintec	NEC, Birmingham	22–24 March
April	**Venue**	**Date**
Mach	NEC, Birmingham	11–15 April
National Electronics Week	NEC, Birmingham	12–14 April
Medtech	Stuttgart, Germany	12–14 April
Drives & Controls	NEC, Birmingham	12–14 April
Med–Tech Innovation	Ricoh Arena, Coventry	12–16 April
Hannover Messe	Hannover Messe	25–29 April
Commercial Vehicle Show	NEC, Birmingham	26–28 April
May	**Venue**	**Date**
JEC Americas	Atlanta, USA	3–5 May
All Energy	SECC, Glasgow	4–5 May
Electronic Warfare	Rotterdam	10–12 May
Edie Live	Birmingham, NEC	17–18 May
Product Design & Innovation	Tower Hill, London	18–19 May

June	Venue	Date
Subcon	NEC, Birmingham	7–9 June
Plastics, Design, Moulding	Telford Exhibition Centre	14–15 June
Plastics Recycling Expo	Telford Exhibition Centre	14–15 June
Plastics Packaging Show	Telford Exhibition Centre	14–15 June
July	**Venue**	**Date**
Farnborough Air Show	Farnborough	11–15 July
September	**Venue**	**Date**
International Manufacturing Technology Show – IMTS	Chicago, USA	12–17 Sept
The Energy Event	NEC, Birmingham	13–15 Sept
AMB	Messe Stuttgart	13–17 September
Micronora	Besancon, France	27–30 Sept
PPMA Show	NEC, Birmingham	27–30 Sept
TCT Show	NEC, Birmingham	28–29 Sept
Wild Energy Hamburg	Hamburg, Germany	27–30 Sept
Northern Manufacturing	Event City, Manchester	30 Sept–1 Oct
October	**Venue**	**Date**
BI–MU/SFORTEC	Fieramilano	4–8 Oct
November	**Venue**	**Date**
Aero Engineering Show	NEC, Birmingham	2–3 Nov
Automotive Engineering Show	NEC, Birmingham	2–3 Nov
Composites Engineering Show	NEC, Birmingham	2–3 Nov

Getting serious on infrastructure

As UK infrastructure projects grow in scope and intensity, the skills gap begins to bite.

Evelyn Adams reports

George Osborne wants the UK to get serious about its infrastructure projects. That was the message he gave as part of his December 2015 spending review, which included making £61bn available for projects, along with an £11bn investment in London's transport.

The funding has been described as the largest transport investment programme since the 1970s and will include the electrification of railway lines such as the Trans-Pennine, Midland Main Line and Great Western.

"Construction of HS2 to link the so-called 'northern powerhouse' to the south can begin," Osborne said during the announcement.

He added: "We'll fund our new transport for the north to get it up and running. And we will be spending over £5bn on roads maintenance this Parliament. Businesses also need an active and sustained industrial strategy."

It wasn't just transport that got a boost. Osborne also doubled expenditure on energy research, while making a commitment to building small modular nuclear reactors. All this investment means it's an ideal time to pursue a career in civil engineering. "There are a number of large-scale civil engineering projects across a range of sectors to be excited about in the UK, from transport and water to energy and digital infrastructure," said Chris Marsh, director of resourcing at Atkins.

Among them is the transformation of Birmingham New Street Station, which opened earlier this year. Marsh also cites Crossrail, along with future projects such as HS2 and Swansea Bay Tidal Lagoon as examples of schemes that should get future civil engineers inspired about career opportunities.

"The UK plans extensive new infrastructure investment," said Simon Harrison, group strategic development manager at Mott MacDonald. "Crossrail 2 will facilitate a better quality of life for Londoners, as well as enabling the continued success of this amazing world city. The northern powerhouse will provide better transport links across the north and help breathe new life into the region that saw the birth of modern industry. There will be a host of new electricity projects, including nuclear power stations."

Crossrail 2 is among the most ambitious infrastructure projects proposed in the UK. It will create a north-south crossing of the capital between Wimbledon and Tottenham Hale via Clapham Junction, Chelsea, Victoria and Euston. The £25bn project will become operational by 2030 and is estimated to support 200,000 new jobs in engineering, construction and manufacturing through its supply chain. Consultancy firm KPMG claims that the project could contribute up to £102bn to the UK's economy by increasing productivity.

> "There are a number of large-scale civil engineering projects across a range of sectors to be excited about in the UK, from transport to digital"
>
> Chris Marsh, Atkins

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"One of the great challenges of the day is to not only renew our major infrastructure but to simultaneously increase capacity it as we do," said Dervilla Mitchell, a civil engineer and Arup director. "Across the spectrum we are seeing rail projects such as HS2, Crossrail – which will bring 1.5 million more people to within 45 minutes of central London – and the 20 years in the making King's Cross development matched with utilities project [such as] the Thames Tideway all attempting to respond to these challenges."

The industry is desperately trying to fill its skills gap. Construction output is forecast to increase 17.8 per cent by 2018, according to forecasts from the Construction Products Association. Earlier this year, the government published its National Infrastructure Plan for Skills. The plan expects that the pipeline of projects will create a demand for over 250,000 construction and over 150,000 engineering workers with the need to recruit and train an additional 100,000 workers by the end of the decade.

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01 Birmingham New Street Station

02 Workers at London Bridge

03 Work will soon begin on Hinkley Point C

04 Electrification plans are creating opportunities

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"There is still a role for those with a passion for deep technical knowledge and analytical skills"

Simon Harrison, Mott MacDonald

The transport sector appears to be the worst affected by the shortage, which has a peak demand forecast between this year and 2020. The energy and utilities industries will also experience peak demand for skills beyond 2020. It is hoped that the increase in funding for apprentices will help fill this gap, and recruiters are on a drive to find engineers, both at graduate level, and form parallel industries.

To help with this apprenticeships were given much-needed funding during the spending review. As part of a new scheme, large employers now have to commit to spend 0.5 per cent of their wage bill on funding apprenticeships. The scheme will come into force in April 2017, and will help ensure that large companies shoulder some of the cost of training, George Osborne said.

Earlier this year, a House of Lords report into the costs of High Speed 2 said that a lack of skills, long-term planning and capacity in the UK construction sector is the reason behind its soaring costs. As such, recruiters are keen to find talented engineers in this sector. "While a problem for the industry as a whole, the current skills shortage presents a great opportunity for considering future career paths," said Mitchell.

Marsh said that doesn't mean jobs will be easy to come by. Engineers still need the right connections and qualifications. He added that anyone wanting to pursue a career in civil engineering should network with people in the industry. "To be a successful civil engineer it's not just about technical skills on projects," he added. "Softer skills, such as the way we communicate, and how we create and develop relationships with teams and clients are vital."

Harrison said: "The good news is that civil engineering is a broad profession, with room for a wide diversity of talent. Increasingly we look for people able to work flexibly in multidisciplinary teams, and able to express their ideas clearly not just to fellow engineers but also to non-specialists in business and in public service, and to the general public. However there is still a role for those with a passion for deep technical knowledge and with great analytical skills.

"The world's need for new infrastructure is enormous, and the design and delivery of this infrastructure, if done well, can contribute enormously to making a better future. And that's why now is a good time to look at civil engineering as a career."

Watson-Marlow Fluid Technology Group (WMFTG) is the world leader in niche peristaltic pumps and associated fluid path technologies, operating in the biopharmaceutical, environmental, food and other industrial sectors.

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Hose and tubing products are at the very core of our fluid handling value proposition. Candidates must be degree qualified in a relevant engineering discipline, and be able to manage their own time and projects with tight deadlines.

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For full details of all our vacancies as well as information on how to apply visit **www.wmftg.com/gb-en/about/careers**

WATSON MARLOW
Fluid Technology Group

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Jan 1942

Tide turner

The legendary Lancaster bomber quickly began to make its mark on the Second World War

To celebrate our 160th anniversary here at *Engineer* Towers we're looking to showcase the magazine's archive, exploring its depths in greater detail than ever before. We'll be looking to unearth some obscure gems, as well as pay tribute to iconic engineering achievements. And they don't come any more iconic than our first subject – the Avro Lancaster heavy bomber.

Like *The Engineer*, the Lancaster is celebrating a landmark year, with this month marking the 75th anniversary of the aircraft's maiden flight in January 1941. The bomber would not enter active service until the following year, but by August 1942, when *The Engineer* was invited to see it in action, the Lancaster had already started to make a name.

"But a few months after its completion, the 'Lancaster' has left its mark on the German landscape and its people," wrote our predecessors. "It has helped powerfully by night to batter Cologne and Essen, with bombs of the heaviest calibre. By day it carried out the epic raid led by squadron Leader JD Nettleton, VC on Augsburg, and the raids on Danzig and Flensburg."

"From the initial flights and the report of the Ministry of Aircraft Production testing staff, it was soon obvious that the Allied cause had now what has since been aptly styled by many pilots as a 'war winner'."

Of course, the Lancaster's most famous hour was to come a year later during Operation Chastise, better known as the Dambusters mission. Armed with Barnes Wallis's bouncing bomb, 19 of the aircraft were involved in the attack on the Möhne and Edersee Dams in Germany's Ruhr valley. Eight of them would not return, with 53 aircrew killed during the mission and another three taken prisoner.

While the story of the Dambusters certainly added to the Lancaster's legend, its iconic design also won it a place in the public consciousness. Despite being "designed and built in record time" in what this magazine referred to as "a triumph of aeronautical engineering", the bomber was also noted for its "particularly graceful lines and a pleasing appearance, perhaps rarely seen in large military aircraft".

A more technical description comes later in the article: "In design it may be described as a mid-wing four-engined all-metal cantilever monoplane, with a retractable undercarriage. In general, it is powered by four Rolls-Royce 'Merlin XX' liquid-cooled engines, which have given such a good account of themselves in other bombers and fighter aircraft.

"Other engines, notably the Bristol 'Hercules', are also being fitted to the 'Lancaster'. An outstanding feature which was demonstrated on the occasion of our visit is its great ease of control, and this, coupled with its high speed, is of great defensive value."

It is testament to the Lancaster's quality that variants of the aircraft were still in operation as late as 1963, with two surviving aircraft still airworthy to this day. Central to this longevity was the modular design, which in 1942 was described by *The Engineer* as enabling "ease of production, easy transport, and easy maintenance and repair".

The article added: "The design, the makers claim, lends itself to rapid and relatively cheap production," our predecessors wrote, "as the entire machine is built up of numbers of components which are manufactured largely as separate and self-contained units, and are easy to transport and to assemble."

"Full 100 per cent interchangeability has been aimed at and achieved, and this, coupled with ease of construction, has contributed largely to the ease of maintenance and repair."

This flexibility, along with the aircraft's operational excellence, would prompt Air Chief Marshal Arthur 'Bomber' Harris to refer to the Lancaster as the RAF Bomber Command's "shining sword". It became the mainstay of British heavy bombers following its introduction, flying 156,000 sorties between 1942 and 1945. During this period, Lancasters would drop over 600,000 tonnes of bombs, and 3,249 aircraft would be lost in action.

Manufactured primarily at Avro's factory at Chadderton near Oldham, Lancasters were also built in one of Canada's largest aircraft factories and flown by the Royal Canadian Air Force. The Lancaster is perhaps the most fondly remembered of all British military aircraft, and one that undoubtedly played a vital role in turning the tide in favour of the Allies. Seventy-five years on from its maiden flight, *The Engineer* salutes this incredible aircraft.

> "It was soon obvious that the Allied cause had now what has since been aptly styled by many pilots as a war winner"
>
> *The Engineer*

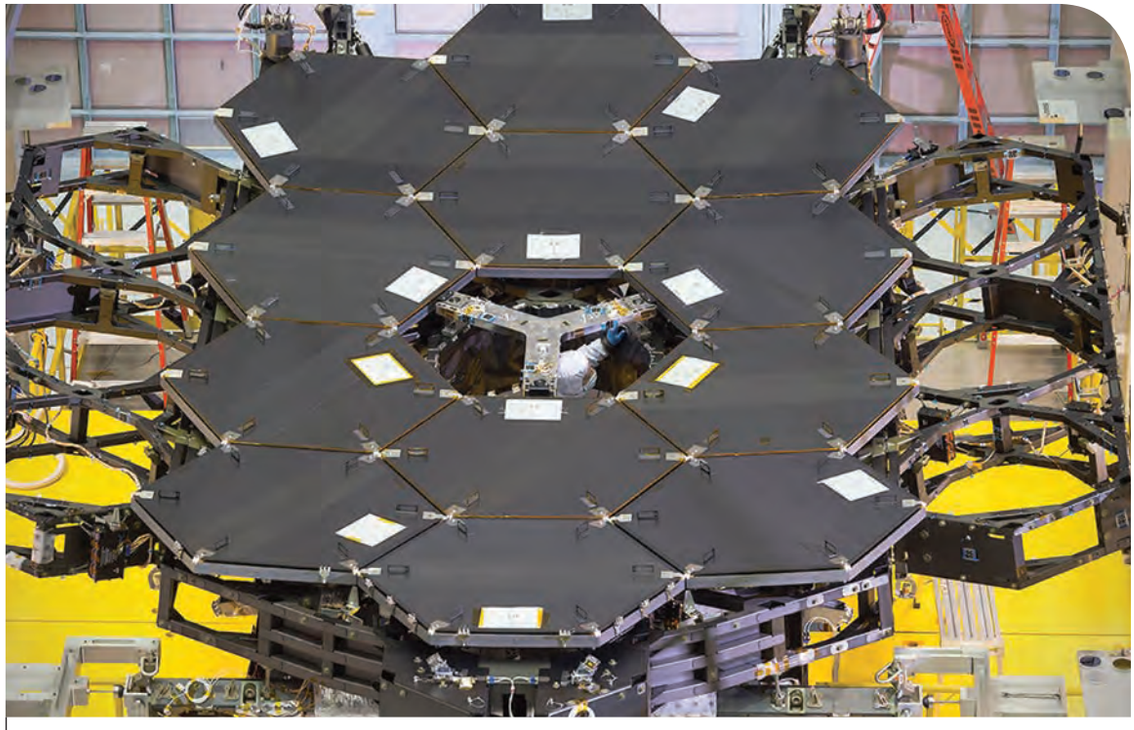
The Lancaster bomber entered active service in 1942

Word of the issue

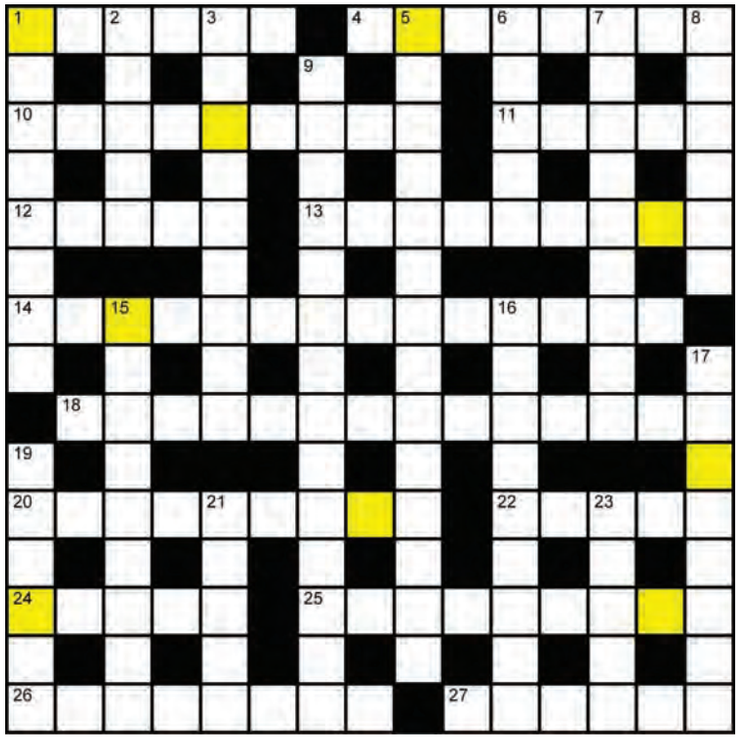
Anthony Poulton-Smith explores the origins of the term ‘crank’

Nothing is written about the crankshaft before 1803 (although the Romans used this mechanism). Here we are interested in the origins and use of the basic term ‘crank’. The noun is found in Old English as cranc and used in crancstaef when referring to ‘a weaver’s instrument’ and as crencestre or ‘a female weaver’ (literally a spinster). This has the Germanic base of krank and seen to mean ‘bend, yield’ and the English usage has always been to refer to a handle turning an axis. This is not the case in other Germanic languages, which have tended to use the figurative sense of ‘weak, small, sickly’. The latter use is also found in the 19th century, defined as ‘infirm, weak’ and easily seen as related to the modern ‘cranky’. This is related to the sense of ‘an eccentric individual’, thought to have to come into use when speaking of the cranking of a barrel organ which, will never be known for its range, versatility or depth.

Bigpicture



The primary mirror on the James Webb Space Telescope (JWST) is taking shape at NASA’s Goddard Space Flight Center in Maryland. Designed to succeed the Hubble telescope, JWST is an international project that includes a Near Infrared Spectrograph (NIRSpec) developed and built by Airbus Defence and Space. *Photo: NASA/Chris Gunn*



Prizecrossword

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

Across

1 Numbers arranged in rows and columns (6)
4 Precipitation caused by industrial gas emissions (4,4)
10 Headgear worn by ranch hands (6,3)
11 Diffused water at boiling temperature (5)
12 Harsh or corrosive in tone (5)
13 Plot of a book or play or film (9)
14 Acting between small chemical units (14)
18 Vehicles that have been previously owned (10,4)
20 Final point in a process (9)
22 Undergo a chemical change (5)
24 Rub through a strainer (5)
25 Decorate with needlework (9)
26 Acquisition of something for payment (8)
27 Not in physical motion (6)

Down

1 Craftsman skilled in operating machine tools (8)
2 Structure taller than its diameter (5)
3 With the objective of (2,5,2)
5 Device found in many older-style televisions (7-3,4)
6 Lacking originality (5)
7 Any artefact that is distinctive of the US (9)
8 An integer (6)
9 Item of furniture for storage (5,2,7)
15 Officer charged with receiving and disbursing funds (9)
16 First layer of paint applied to a surface (9)
17 Understandable only an enlightened inner circle (8)
19 Finish a task completely (4,2)
21 Bloodsucking worm (5)
23 Inspection of accounting procedures (5)

December’s highlighted solution was sawmill.

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