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the ENGINEER

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Bolt from the blue

Defending the Earth from asteroid impacts

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Striking home?

This issue's cover feature (p14) focuses on an event that most of us will probably never see but that has the potential to drastically shorten not only individual lives but the lifetimes of entire civilisations, and even species: a massive asteroid strike into the planet's surface.

Unlikely though this is, it has happened before – the dinosaurs and many contemporary species were wiped out by an asteroid strike around 70 million years ago – while small and not-so-small objects collide with Earth regularly. What has happened before can happen again; indeed, some think it is inevitable.

Fortunately, the skies are now watched and monitored to an unprecedented extent; and, as Jon Excell details in this online edition of *The Engineer*, objects with the potential to obliterate civilisations are identified and tracked. Moreover, there are ideas for deflecting objects that are on a collision course with Earth, and several technologies will soon be tested by both NASA and ESA.

There was a time when such subjects were deemed worthy of only a few crank science-fiction authors and film-makers; indeed, in the June issue of *The Engineer* our resident scifi writer, Jon Wallace, took a look at imaginings on this theme and indulged in a few of his own flights of fancy.

> "Governments must resist the temptation to snigger at the doom-prophesying egg-heads"

However, bright lights over Chelyabinsk in Russia in 2013, a subsequent loud explosion and thousands of shattered windows gave us a small demonstration that the threat is real. Our feature points out that international co-operation is a must for tackling such threats, so governments must resist the temptation to snigger at the doom-prophesying egg-heads and make sure they have robust contingency plans for planetary defence.

Elsewhere in this issue, we cover a sector thought by many to be mundane but that enables many important basic industries, and manufacturing: industrial gases.

We'll be back in print with our September issue, looking in depth at the subjects of haptics, pumped hydro energy storage in the UK, and advanced robotics research.

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CIVIL & STRUCTURAL

Refugee housing is global study focus

Camp visits will inform designs intended to cope with extreme temperatures

HELEN KNIGHT REPORTS

The world is witnessing the worst refugee crisis ever recorded, with levels of human displacement at their highest.

Conflicts such as the Syrian civil war are leading to the creation of a new generation of refugee camps that are meant to provide temporary accommodation. However, many people remain in these camps for years, living in extreme climates ranging from 45°C to -10°C.

Now an international collaboration, led by researchers at Bath University, is hoping to improve living conditions for those residing in the camps by designing better housing.

Conditions inside the shelters can be life-threatening, according to the university's Dr Dima Albadra, who is herself from Syria. "It can be unbearable, especially for children, so we are aiming to design something that would reduce these extremes of temperature to a healthy level," she said.

The three-year EPSRC-funded project, which also involves the Princess Sumaya University for Technology and the German Jordanian University, both in Jordan, and Mersin University in Turkey, will aim to design low-cost and easy-to-construct shelters that are capable of moderating temperatures and ensuring the privacy of residents.

The researchers will conduct the largest-ever global study into the thermal, air-quality and social conditions in camps housing displaced people. They will investigate the views of camp occupants and aid agencies such as UNHCR (United Nations High Commissioner for Refugees) on the housing, said lead investigator David Coley, professor of low-carbon design at Bath University.

"We are going into the refugee camps to talk to the population and find out what they are doing to keep cool," he said.

The researchers will investigate different materials for constructing and insulating the buildings. Materials such as clay bricks that have a high thermal mass, or the ability to absorb and store heat energy that can be released at night when the temperature drops, will be among those considered, he said.

The researchers will use computer models to create different housing designs. By taking accurate temperature measurements from inside existing shelters, they will generate a validated model that can then be used to test different materials and building shapes, said Coley.

In this way, the researchers plan to create 20 potential shelter designs. They will then build scale models of some of the designs, which will be tested in a thermal chamber to investigate how they hold up against cycles of different conditions such as heat, cold and humidity. They will also be thermally tested at full scale in a climate chamber at Bath University's Building Research Park in Swindon.

"That allows us to make sure that, over the course of a year, they can withstand wind and weather," said Coley.

The most promising of the designs will be transported to camps in Jordan for testing in local conditions, and to obtain the feedback of camp occupants and aid agencies.

Research will be conducted in the Zaatari and Azraq refugee camps in Jordan as well as camps in three other countries, chosen to offer the widest possible range of climatic, cultural, social and political conditions. These are likely to be the Mae La camp in Thailand, the Kilis camp in Turkey and the Nyarugusu camp in Tanzania.

The researchers hope the project will result in a manual for aid agencies that explains the benefits of each shelter design and provides guidance on construction and matching designs to the local environment and culture.

Researchers will investigate different materials for constructing and insulating the buildings against the weather

Readmoreonline

Aerospace
UK skies nearing capacity, warn air traffic chiefs

Automotive
Calls for Brexit clarity as car manufacturing declines

Civil & Structural
Independent review aims to take lessons from Grenfell Tower fire

Defence & Security
'No hiding place' for illicit nuclear materials

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Software allows any camera to collect 3D data

Energy & Environment
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Medical & Healthcare
Algorithm tailors walking rehab to individual needs

Policy & Business
Government spends £138m to strengthen research-business links

Process
Why big and small businesses should be working together for innovation success

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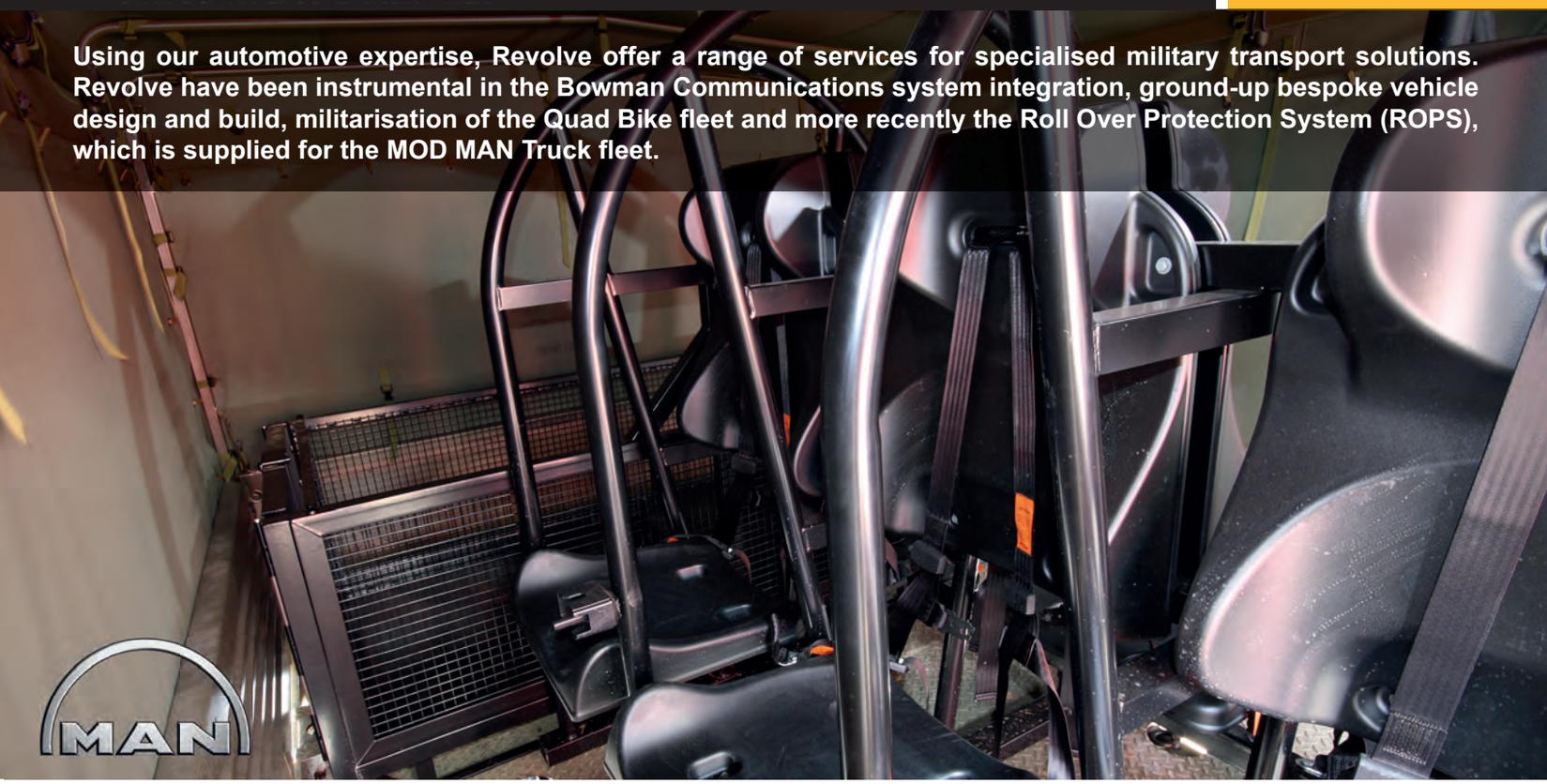
Using our automotive expertise, Revolve offer a range of services for specialised military transport solutions. Revolve have been instrumental in the Bowman Communications system integration, ground-up bespoke vehicle design and build, militarisation of the Quad Bike fleet and more recently the Roll Over Protection System (ROPS), which is supplied for the MOD MAN Truck fleet.



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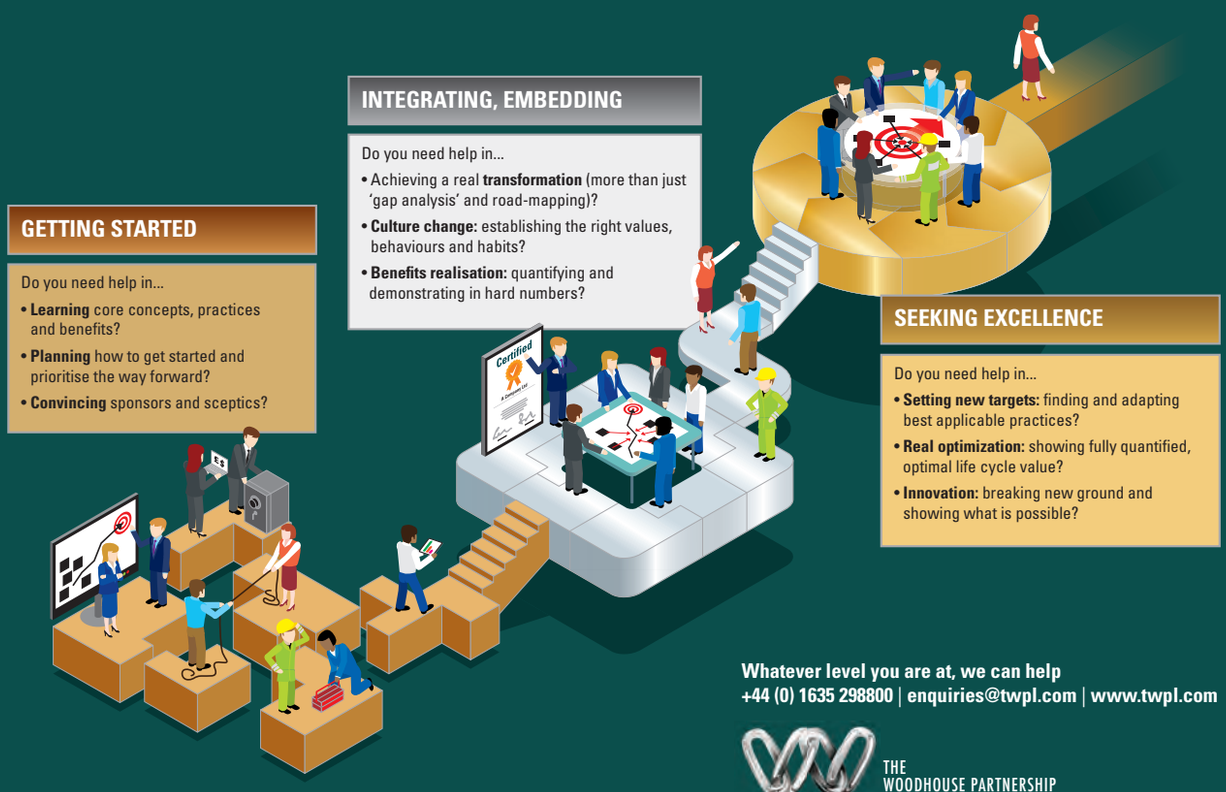

GETTING STARTED

Do you need help in...

- **Learning** core concepts, practices and benefits?
- **Planning** how to get started and prioritise the way forward?
- **Convincing** sponsors and sceptics?

INTEGRATING, EMBEDDING

Do you need help in...

- Achieving a real **transformation** (more than just 'gap analysis' and road-mapping)?
- **Culture change:** establishing the right values, behaviours and habits?
- **Benefits realisation:** quantifying and demonstrating in hard numbers?

SEEKING EXCELLENCE

Do you need help in...

- **Setting new targets:** finding and adapting best applicable practices?
- **Real optimization:** showing fully quantified, optimal life cycle value?
- **Innovation:** breaking new ground and showing what is possible?

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THE WOODHOUSE PARTNERSHIP

TRANSPORT

Supersonic moves in desert tubes

Long-distance maglev transport technology completes full-systems test

STUART NATHAN REPORTS

The test sent a levitating test sled along a section of tubing

Hyperloop One (H1), one of the companies developing Tesla Motors owner Elon Musk's concept for a supersonic long-distance maglev transport technology, has achieved its first full-systems test.

The test, at the company's facility in the Nevada desert, was not of a deployment-ready system — it involved sending a levitating test sled 96m along a section of tubing rather than a pod capable of carrying freight or passengers — but the vacuum, propulsion, magnetic levitation, guidance and braking systems were all integrated and tested together for the first time, and the tube used, 3.3m in diameter, was full size.

The sled reached a speed of 70mph in 5.3 seconds, accelerating at 2*g*, propelled 30.5m by a linear motor mounted inside the tube. It's a long way from the target speed that Hyperloop One has set for the system — 700mph — but, as a first step, company founders Shervin Pineshar and Josh Giegel declared themselves delighted.

"By achieving full vacuum, we essentially invented our own sky in a tube, as if you're flying at 200,000ft in the air," said Pineshar, Hyperloop One's executive chairman. Engineering director Giegel added: "This is integrating all of the pieces. It's the first phase of a test programme that will get us to a production unit."

Commenting on the first run, Philippa Oldham, IMEchE's head of transport and manufacturing said: "While this was a successful first trial the speeds were still relatively low and so it will be interesting to watch the development of this programme."

Hyperloop One is not the only company developing systems, which were proposed by Musk in 2015 but that he decided not to develop himself; two others, Hyperloop Transportation Technologies and Arrivo, are also at work, but H1 is the first to demonstrate a full-sized vacuum tube.

H1 also unveiled its initial design for a transit pod, made from aluminium and carbon fibre and 8.5m long. In an interview on US news network CNBC, Giegel indicated that its next phase of tests is intended to take its sled up to 250mph in a tube with 304m of motors, which it has built since the May, 2017 test. The vacuum system had worked better than anticipated, he added. "We expected to get down to about 0.001 of an atmosphere, but we got a lot lower than that, and that was without complicated sealing technology," he said.

Pineshar indicated that the company hopes to build its first full-scale system and get it operational, by 2021. "We're working closely in concert with governments around the world; there's multiple feasibility studies," Pineshar said.

AWARDS

Shortlisting the key innovations for the future

Awards put collaboration in the spotlight

JON EXCELL REPORTS

The Engineer has revealed the shortlist for this year's Collaborate To Innovate (C2I) awards.

Now in its second year, C2I was established to uncover and celebrate great examples of engineering collaboration, with a particular focus on collaboration between businesses and the UK's world-leading academic research base.

For this year's competition, *The Engineer* invited entries across seven categories covering key areas of technology development.

Shortlisted entries included pioneering developments in healthcare technology; inspiring applications of technology to major civil projects; new ground-breaking energy schemes; and cutting-edge developments driving the future of connectivity and data.

The judging panel for this year's awards – comprised of some of the UK's most-respected engineers – praised a group of entries that illustrate the strong links between industry and academia; the role that engineering plays in addressing a broad range of societal challenges; and the high levels of innovation occurring across the UK.

This year's Young Innovator award celebrates the work of the UK's most promising future engineers, as well as the best examples of how industry is helping inspire school-age students.

The ultimate winners of each category will be announced at a special event in London on Tuesday 5 September, and will present their work at our C2I conference on 7 December 2017 at the Lloyds Bank Advanced Manufacturing Training Centre, Coventry.

Newsinbrief

Virtual battery

The government has launched the Faraday Challenge, a new £246m battery technology investment programme. EPSRC will lead phase one, a £45m competition exploring technology challenges and the creation of a 'virtual Battery Institute'. Innovate UK will build on promising research and phase three, led by the Advanced Propulsion Centre, will look at scaling up the technology at a National Battery Manufacturing Development facility.

Small agreement

Canada's SNC-Lavalin has signed an agreement to accelerate the development of US-based Holtec International's SMR-160 small modular reactor and support international licensing. SNC-Lavalin Nuclear chief nuclear officer and executive vice-president Preston Swafford said: "Partnering with Holtec in the SMR-160 brings us a 'walk-away-safe' reactor design that will deliver a clean, affordable, reliable electricity supply."

Paint job

Alstom has opened the largest rolling-stock modernisation facility in the UK, a 13,000m² space in Widnes that includes virtual reality painting simulators. One of the first jobs will involve the execution of a €28m contract to re-paint the 56-strong fleet of Class 390 'tilting' Pendolino trains, which are used by Virgin on the West Coast Main Line.

Oxon electrics

BMW has announced that its next-generation electric Mini will be built in Cowley, Oxfordshire. The battery-electric Mini will be a variant of the brand's three-door car and follows BMW's corporate strategy of offering its brands and models with a fully electric or plug-in hybrid drivetrain.

OIL & GAS

Improved yield is built on sand

Welsh and Iranian scientists work on enhanced oil recovery

STUART NATHAN REPORTS

A collaboration between scientists in Wales and Iran has found that microscopic sand particles could help improve the yield of oil from difficult-to-exploit resources.

The researchers, from the Energy Safety Research Institute (ESRI) at Swansea University and the Islamic Azad University in Iran, are working on enhanced oil recovery (EOR), a technique that involves extracting oil from wells where most of the resources have already been removed. This is often done by pumping other substances into the well to displace the remaining oil, which is sometimes bound to the underground rock formations.

A variety of substances are used for this, ranging from hot water to carbon dioxide and chemical agents such as surfactants. Key to the success of the technique is reducing the surface tension between the oil and water in the well.

The ESRI–Azad team has been working with complexes made up from surfactants and fumed silica nanoparticles. This is a type of silica produced in a flame, which has low density but very high specific surface area.

Swansea researchers used a slightly different technique to investigate the effect of complexes; generally, a technique called core flooding, where a rock sample containing bound oil and water is treated with the EOR materials under test, is used. For this research they used a glass micromodel, which gives better visualisation and understanding of pore space geometry, topology and the effects of the heterogeneous mixture of oil, water and solids. Unexpectedly, the addition of the fumed silica to the EOR agent improves the proportion of oil recovered from 45 per cent to 58 per cent.

"It is a surprise that the addition of silica nanoparticles, essentially nano-sand, to the surfactant solution leads to such a large flow modification," said Prof Andrew Barron, who led the team at ESRI. The particles seem to reduce the viscosity of the oil, as well as changing the way it interacts with water, both of which contribute to improve the amount of oil swept towards the recovery point.

Barron said the research was "great example of international collaboration aimed at developing new materials for minimising the impact of oil production through maximising recovery".

The technique involves extracting oil from wells where most of the resources have been removed

MARITIME

All around the world

Catamaran employs renewable technologies

A former racing catamaran powered by renewable technologies has set off from Paris on a six-year round-the-world voyage.

Energy Observer is a 30.5m-long vessel that has been adapted by engineers to produce its own hydrogen using renewably powered electrolysers.

According to the team behind the project – led by Jerome Delafosse and Victorien Erussard – the boat's primary power source is a 130m^2 array of solar panels that cover its surface. This will be complemented by energy from two vertical-axis wind turbines. As well as driving the vessel's electric propulsion system, these will be used to power electrolysers that will produce hydrogen from sea water for fuelling the boat during the night.

The vessel is also equipped with a kite sail that can be used to propel the boat during high winds. In this scenario, the tugging effect will rotate the boat's propellers and could be used to generate more electricity using the boat's reversible electric motors. **JE**

RENEWABLES

Wind farm is floating into the future

Hywind project is due to begin operating this year

JON EXCELL REPORTS

The construction of the world's first commercial-scale floating wind farm is almost complete, its developers have announced.

The £190m Hywind project, which is 75 per cent owned by Statoil and 25 per cent owned by Abu Dhabi energy firm Masdar, will see five 6MW floating wind turbines installed in up to 120m of water at Buchan Deep, around 25km from Peterhead on Scotland's north-east coast.

The 30MW wind farm, due to begin operating later in 2017, is expected to generate around 135GWh of energy per year, enough electricity to power approximately 20,000 households.

Unlike conventional offshore turbines, which are fixed to the seabed by foundations, the Hywind device is attached to a cylindrical structure that floats in the water. Tethers anchored to the seafloor hold it in place.

Earlier this month, the first of five turbines for the wind farm was shipped from Stord in Norway, and the installation is expected to be complete by the end of August.

A pilot Hywind device, installed off the coast of Norway and equipped with a 2.3MW Siemens turbine, has operated successfully since 2009.

Floating turbines are considered attractive because they can be placed in deeper water where the wind speeds tend to be higher and steadier. Because they don't require extensive foundations, they are also cheaper to assemble and install.

A number of other projects are under way around the world. The technology is thought to hold particular promise in Japan – where deep water makes conventional offshore wind impractical.

The turbines will be 25km offshore

DEFENCE & SECURITY

Checking security in just a heartbeat

An individual's electrocardiogram could be used to authenticate their identity

JASON FORD REPORTS

A Belfast company has received funding to accelerate the development of technology that could one day start cars with a heartbeat.

B-Secur, whose biometric technology uses an individual's electrocardiogram (ECG) to quickly and securely authenticate identity, has raised £3.5m comprising £1.5m from Accelerated Digital Ventures (ADV), £750,000 from the Bank of Ireland Kernel Capital Growth Fund (NI) and the remainder from private investors.

"The unique features of using a heartbeat to authenticate individuals are that not only can you identify the user but you can also tell a number of wellbeing metrics about them, such as whether they are tired, stressed or even under the influence of drink or drugs," said Simon Rea, chief operating officer of B-Secur.

He added that the ECG signal could be captured using a number of conductive materials, such as metals, fabrics or inks, and also from a number of locations on the body including wrists, fingers or the chest.

"As long as our algorithms pick up a strong signal, they can work across a number of use cases and devices," he said.

"This ultimately allows this type of technology to be applied across a number of technology devices because there is no need for a specific sensor or capture point."

Rea added that the company was focusing on a variety of markets, including identity and access management, where B-Secur was piloting a product that allowed a user to be continuously authenticated using their heartbeat, and to access secure areas without having to enter a code or hold a security pass.

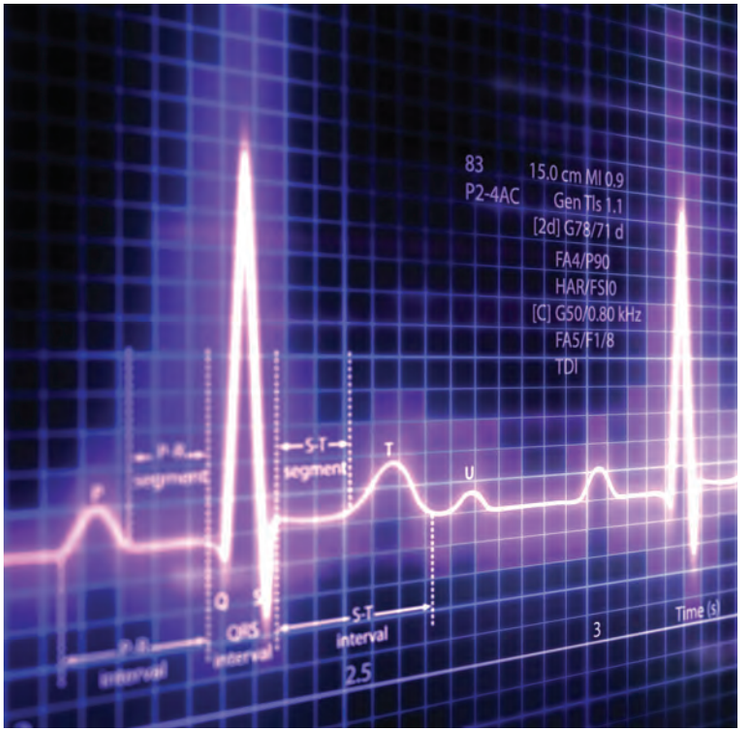
"This product also collects vital information about the employee, such as heart rate, location and wellbeing metrics," he said.

"This will ensure the safety of these employees in dangerous and highly security-conscious environments."

B-Secur is also working with partners to license their algorithms into wearables of the future, which would enable these products to bring authentication to devices, data and apps.

Looking ahead, B-Secur is exploring the introduction of ECG technology into future cars.

According to Rea, this would allow users to start their car's engine using just their heartbeat, and would then provide various safety features to alert drivers to early signs of tiredness, or detect the influence of drink or drugs.



Wearable products could bring ECG authentication to devices, data and apps

UNMANNED SYSTEMS

Unmanned systems heading for testbed

BAE Systems is part of a team that will design and deliver the UK's first testbed for autonomous systems

BAE Systems has been awarded a grant to design and deliver the UK's first dedicated autonomous systems testing service, on the south coast of England.

The company has been awarded £457,000 by the Solent Local Enterprise Partnership (LEP) to help provide the service.

Based around Portsmouth, Southampton and the south-east of the Isle of Wight, BAE Systems, together with ASV Global, Blue Bear Systems Research, Marine Electronic Systems, SeeByte and Southampton University, will provide the service's infrastructure, with other organisations joining in later this year. Solent LEP and partner organisations are investing £1.5m in the project.

According to BAE Systems, the new service will be ready for use later this year and customers will be able to conduct trials and test systems such as unmanned boats, air vehicles and autonomous sensors in the Solent.

The service will make use of a secure maritime communications network and a mobile command-and-control centre. **JF**

AUTOMOTIVE

All-electric Mini contract is big deal for Cowley

BMW has invested heavily in the Cowley plant

JASON FORD REPORTS

BMW is to produce the next-generation all-electric Mini at its Cowley plant in Oxfordshire.

The new battery-electric Mini will be a variant of the brand's three-door car and follows BMW's strategy of offering its brands and models with a fully electric or plug-in hybrid drivetrain.

The electric Mini will go into production in 2019, increasing the choice of Mini powertrains to include petrol and diesel engines, a plug-in hybrid and battery-electric variants.

The all-electric Mini's drivetrain will be built at BMW plants in Dingolfing and Landshut, Bavaria, before being integrated at Cowley, which is the main production facility for the three-door model. According to Dom Tribe, management consultant and industrial sector specialist at Vendigital, the Cowley plant was updated three-and-a-half years ago and the tooling, equipment and automated robots *in situ* are only part-way through their life cycle. Tribe said: "The company has invested heavily in Cowley and there is plenty of capacity to build the all-electric Mini as customers are likely to choose it in place of standard petrol or diesel variants.

"Another major factor influencing the decision to make the all-electric Mini at Cowley will have been the fact that it was not a brand-new car but rather an evolution."

The new electric Mini is one of a series of electrified models set to be launched by the BMW and Mini brands. In 2018, the BMW i8 Roadster will become the newest member of the BMW i family. The all-electric BMW X3 has been announced for 2020, and the BMW iNEXT is due in 2021.

Production will begin in 2019

Green future lacks vital components

As the death knell sounds for diesel and petrol cars, we're not getting the full story on the energy and environmental costs of their successors

Why don't we have energy rating labels for our cars and other vehicles?

We think we already do – via the checks on tailpipe emissions and CO_2 that are backed up by government legislation and the car manufacturers themselves, with the latter always looking for ways to reduce emissions via lower fuel consumption. So it's all good.

Except this single measure, used around the world as an indicator of what constitutes an environmentally friendly motor vehicle, is a snapshot. Just in itself, it's misleading for consumers, governments and societies as a whole. Worse, it's exactly this focus on tailpipe emissions that has the potential to drive up CO_2 discharges, given that the number of cars worldwide is expected to double to two billion by 2035.

At Cranfield University's Sustainable Manufacturing Systems Centre, we've looked at what the push for lower tailpipe emissions has meant, such as more lightweight vehicles with aluminium engines. Less fuel is used and emissions are lower – but what about all the energy required to manufacture the lighter engines? It's a disturbing picture of hidden environmental costs and damage.

The production of each aluminium cylinder block consumes 1.8 to 3.7 times more energy than the production of a block in cast iron. The nearly twofold increase in energy consumption occurs when the aluminium components are produced in reusable metal moulds, referred to as high-pressure die casting. The almost-fourfold energy increase results when the aluminium cylinder blocks are produced by sand casting; where the components are created in expendable sand moulds.

Overall, more than 70 per cent of global aluminium production is based on fossil fuels. Under these conditions, the energy-intensive production of aluminium generates more than 10kg of CO_2 per kilogram of aluminium. That means a typical aluminium car would need to be driven for between 185,000km and 560,000km before there were any environmental benefits from the lower fuel use involved. The average life expectancy of motor vehicles is only 210,000km, so the majority of cars aren't helping the environment – they're just increasing CO_2 emissions.

We also need to bear in mind the waste from the production of aluminium: what's known as 'red mud'. It has a pH value of 14 and is highly toxic. Two tonnes of red mud is created for every tonne of aluminium, and we already have great lakes of the stuff, which burns anything in its path.

These figures come from a detailed 'cradle-to-grave' study of the total energy and CO_2 impact of passenger vehicle engine production, based on interviews of more than 100 manufacturers and industry experts, from mining through to engine production and on-the-road use. The study focused on the most representative engine in use globally – a 1.6-litre four-cylinder engine – and compared aluminium models with the more traditional cast-iron engines with the same driving performance. The aluminium industry has argued that the highest energy consumption occurs during the production of 'virgin' aluminium from ore and that cylinder-block production primarily uses recycled aluminium. Our study took this into account, adopting the best-case scenario for aluminium via infinite recycling.

We have to start looking at the full energy costs and environmental implications of manufactured products such as cars, and energy rating labelling would be one way of helping consumers to get a more truthful indication of what's green and what's not. Aluminium is just one of the hidden costs. Electric cars are accepted as a sustainable transport option of the future — but what about the huge energy costs involved in manufacturing the batteries?

Taking into account the full life-cycle costs of manufacture and use, the best option appears to be vehicles fuelled by natural bio-gases.

When they can, consumers want to make green choices. We rely on the 'authorities' — whether that's driven by industry or government — to give us accurate and balanced information. Without sharing data on the whole life cycle of manufactured products, we're not getting that. We're not even close.

Prof Mark Jolly is head of the Sustainable Manufacturing Systems Centre at Cranfield University

Systems, not silos

Engineering's systems approach can inform government efforts to get desirable outcomes in sectors such as energy – particularly biofuels

The systems that constitute the world around us do not recognise the silos into which we organise ourselves. This is a key lesson for engineers as they seek to integrate their individual efforts towards achieving positive outcomes.

Whether concerned with small components within discrete technical systems such as engines or buildings, or with large pieces of infrastructure that form part of complex socio-technical systems such as cities or the national energy system, individual design efforts must integrate harmoniously within a larger whole.

Public policy, such as engineering, deals with complex systems, and the academy is working to apply some of the lessons learned from engineering systems approaches to help government achieve desirable outcomes in sectors such as energy, transport and manufacturing. A current example of the benefits of a systems approach to policy analysis is provided by the academy's new report on biofuels: *Sustainability of liquid biofuels*. These are fuels derived from biomass, such as biodegradable agricultural products or industrial waste. They are important because much of our transportation is likely to rely on liquid fuel for many years – we will be unable to meet climate-change targets without deploying low-carbon liquid fuels.

The academy's report was commissioned by the Department for Transport and the former Department of Energy & Climate Change to assess in detail the sustainability of biofuels. Due to the complexity of the factors that underpin the sustainability of biofuels, this could be achieved only by adopting a systems approach.

This is illustrated by the concern that the production of biofuel from crops that could otherwise be consumed as food might create harmful competition for land between food and fuel. The review concluded that the addition of a biofuels market could actually benefit the agricultural sector – provided mechanisms for prioritising food markets were in place – such as by providing an extra incentive to plant crops, invest in process efficiencies and crop yields, and drive improvements in infrastructure. Nevertheless, the potential for competition with food needs to be carefully managed, especially in places that experience food scarcity.

The second major concern around biofuel production from food crops relates to so-called indirect land-use change. Direct conversion of uncultivated land to produce biofuel feedstocks is prohibited, but indirect changes in land use can arise from the need to grow more crops elsewhere to service pre-existing demand from products such as food or animal feed. Among other impacts, this has a carbon footprint, because soils and vegetation contain large stocks of carbon that, when disturbed, can result in release of CO_2.

The academy's report found that indirect change in land use caused by biofuels from food crops was a legitimate concern; it has almost certainly occurred and can significantly increase a biofuel's carbon footprint. The tricky part is tracing the causation between the production of biofuels from a crop in one part of the world and a rise in production from newly converted land in another. However, there is extensive research to improve our understanding of indirect market effects from biofuel demand and help identify and avoid the biomass feedstocks that pose greatest risk.

> The report was commissioned to assess the sustainability of biofuels, which are so complex that a systems approach was required

Biofuels policy has also encouraged a move towards biofuels from wastes and residues, with 57 per cent of biofuels supplied in the UK now produced from wastes and non-agricultural residues.

Ultimately, the academy concludes that the UK government can and should increase the levels of biofuels required in our fuel, while taking steps to manage the risks. This should include setting a cap for the supply of all crop-based biofuels and continuing to incentivise the development of biofuels derived from wastes – such as waste cooking oil – and agricultural, forest and sawmill residues.

A systems perspective entails considering not just the direct impacts of biofuels but the wider policy context. While substantial effort has gone into developing sustainability criteria for biofuels, many other land-using sectors are not subject to the same levels of sustainability governance. There is a real danger that inroads made through policies that ensure biofuels are low-carbon will be negated by changes in land use driven by other markets that attract less scrutiny.

One of the challenges is the many stakeholders involved in policy development and implementation. For example, while energy policy is now chiefly the remit of the Department for Business, Energy & Industrial Strategy, biofuels policy is largely administered by the DfT and most of the issues of land-use management are within the purview of the Department for Environment, Food & Rural Affairs, the Environment Agency and others.

This situation applies across many complex issues facing society. There is rarely a single solution, but a systems approach – built around a clear vision of the intended outcome – can help tackle the complexity. It engages stakeholders with simple questions such as "What does 'good' look like?".

Good systems engineering is not common and, as challenges become ever more complex, engineers must do all they can to embrace a systems view – and encourage policymakers to do the same.

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

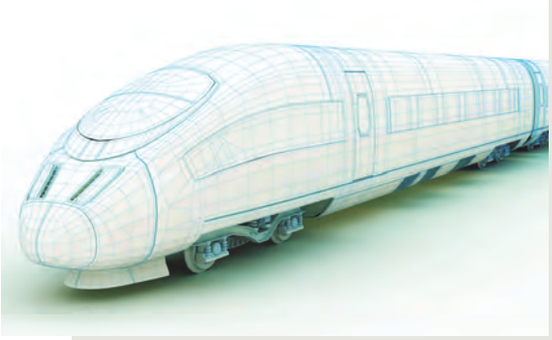
***Sustainability of liquid biofuels* is available at www.raeng.org.uk/publications/reports/biofuels**

Mailbox

Thehottopic

Which way is north?

Our online poll on the ever-contentious HS2 north-south rail project provoked as much debate as ever



A grand idea, but what benefit to the engineering and service companies in the North, aside from the construction phase? All it will achieve is to facilitate better access to London and the South-east. Now, if it were to handle freight or if that could be improved on existing lines, there may be some benefit. But most of the engineering and production/manufacturing facilities have long gone elsewhere in the world. So all it will ultimately do is marginally speed up the movement of people.
Nick Cole

There will be some benefit to industry during the construction phase, but little after. The project will over-run in terms of cost and time and the second phase will never be built – simply because it will be out of political fashion by then.
Mark

I live in the north of England. I don't need a faster rail route from selected hubs to London (look at the HS1/HS2 route map and tell me it isn't designed to suck resources into London). I do value faster door-to-door travel to relatively nearby Liverpool, Sheffield, Leeds and more. And why is rail pushed as best for door-to-door improvement? I may have mentioned the Manchester-Sheffield road tunnel before. And more cross-Mersey road bridges.
Tim

It's not just about commute times; it's about capacity and the capability to get freight back onto the railways to relieve congested roadways. Short-term thinking has destroyed much of the industrial base and this has to change. Pity this has come too late to prevent the erosion of a large part of the indigenous rail engineering industry.
Nik

It would be far better to start from the North and work south. Or pick a middle point and start a north-and-south contract, with a bonus for the contractor that crosses the finish line first.
Chris Gilmartin

The capacity argument is overblown. Capacity is not well managed on the West or East Coast main lines and both are poor for disruption response. The money allocated to HS2 could be better spent on modernising lines and electrifying a greater part of the network. This would create a national rail system with greater connectivity and not just focused on a few cities. Comments that the released space on the classic lines will allow freight to be moved by rail overlook the fact that road freight dominates the market and shippers/freight interests will not use rail unless there is a compelling commercial case. If HS2 is ever built, passenger train companies will jump at the released paths and operate trains to compete with HS2, so any projections on revenue must be suspect. The recently announced routes do little for major cities such as Liverpool, Stoke-on-Trent, Coventry and the East Midland cities. The mess at the London end looks like another disaster waiting to happen in terms of project planning and budget over-runs. Political types trying to get us to believe this will all be super will be long gone when it all goes wrong.
Phil Mortimer

If HS2 is so good, why do its promoters require PR people? It is said that the North will benefit. How? The lines go to London, not Manchester to Leeds or Liverpool or Newcastle or Carlisle or York. There are no northern intercity links! Who profits? The North or the South? I think you can guess. How about a northern referendum – not on HS2 but for becoming independent of Westminster as they have no idea what the people in the North want. If just half the money was spent improving the current infrastructure, the UK could have a world-class train network.
Chris

Inyouropinion

Dagenham digester

Turning food waste into gas for heating

Even better, a plant in Swindon is being built to convert non-recyclable black-bin waste into bio-synthetic natural gas. The value of gas production is that it is easily stored.
Chris Gregson

I would say that the order ought to be:
1. Reduce food wastage – 2-for-1 offers encourage waste, as do expensive small loaves; it is often cheaper to buy a large loaf than to buy a small one.
2. Compost and recycle this organic content.
3. Burn or digest the waste according to economic calculations. Anaerobic digestion just converts to gas-fired heating; incineration generates heat and power with economy of scale.
Jack Broughton

Electric revolution

Reactions to the 2040 phase-out of conventional vehicles

Perhaps one option to protect the grid network, if every house owned an EV, would be for distribution network operators or electricity suppliers to provide and fit a 'smart charger' to every household. Every smart charger on a substation would communicate with the others and effectively load-balance the charging cycles to reduce peak load. Yes, we'd still need extra generation capacity, but at least the current infrastructure might be up to the job (or need much less substantial works carrying out).
Matthew D'Arcy

I agree and accept that electric vehicles are 'the future' but we have to look at the whole problem as an engineering issue if this future is to be a practical proposition. Do we have the sheer electricity-generating capacity to cope with large-scale EV use? The present answer is a resounding 'No'. Are local electricity distribution systems strong enough for several kilowatts of load to be added to every house? Again the current answer is a resounding 'No'. Unless we have a policy and a deliverable plan to resolve these issues, the recent political announcement is just hot air. The 'hydrogen economy' is no better in this respect because it too is critically dependent on electricity generation. We need to take the politics and the utopian thinking out of the air-quality and climate questions and start doing some honest engineering calculations.
Rob Hill

Bring back the Sinclair C5!
Dave Halmcan

Thesecretengineer

Our anonymous blogger thinks it's time we addressed the elephant in the room relating to public perception of STEM

I read the comments under the last Secret Engineer piece with interest and noticed that a few referenced something that's been bugging me for a while. So, in part, this is a response to that; it is a sort of 'meta-opinion piece', if you will forgive my being so nerdy. Which is precisely what I have a problem with.

When did we start apologising for having an interest in technical things, or just for being educated within a certain field?

I think I first became aware of it in the late 1980s but, as a fairly young person, it was the creeping realisation of a change in attitude rather than something specifically noted.

I seem to recall that *Top Gear* and its ilk started using phrases such as "It's a bit nerdy but…" or "This is a little technical but bear with me." It was as if the dissemination of important information – information of inherent interest – was a distasteful exercise that could not be escaped. Even shampoo adverts felt the need to warn viewers about the impending illustration of pseudo-science before coming out with something utterly banal. At about the same time, I also noticed that offhand, dismissive comments were being made about "men with pipes".

However, I am not going to write two consecutive pieces on television programme makers, so please be assured that this is something I observe around me generally, and the 'visual arts' are merely one part of it.

If I go back further to the dim and distant days of my youth, my impressions of school broadly conform with the stereotypical dynamic regarding sporty types and academics. Funnily enough, all pupils seemed to belong to one camp or the other, with only a very few managing to cover the bases of both softball and mathematics. Of course, the sporty types seemed glamorous and were a hit with the girls (once we'd reached the age where girls were of interest.) I couldn't say if this was because children were still less refined and more animalistic in their methods of attributing status, or merely because sporting success was more conspicuous. Perhaps there was simply a more introspective and private satisfaction to be found in academic achievement.

As we grow older, though, there should surely be a growing realisation within our peer group that, while a small number will be able to achieve greatness through physical prowess and the playing of games, most will need to establish their place in society through other skills and abilities. Games and sports are important for any number of reasons but they do not exactly shape the world around us.

This, then, should be where those of us who have sweated over exercise books rather than exercise machines find ourselves elevated. Sadly, however, that cannot happen while popular culture seeks to undermine us – and certainly not if we aid that process by meekly compounding the problem.

It is no wonder that there exists a growing movement of politicos being dismissive of experts; an increasing number of public and blunt refusals to accept scientific opinion. This is the natural conclusion to the steady victimisation of the past 30 years, and something that is harmful to the future of us all.

It does take two parties to create a victim, though, and thankfully in this case we can do something about it. I say stop apologising for being bright; stop qualifying comments because others may not have the wit to understand what lies behind them; and stop allowing people to proudly flaunt their ignorance unchallenged.

It's time we stood tall and fought back against being treated with dismissive disdain.

Join the debate theengineer.co.uk

Impact statement

Is technology up to the challenge of protecting the planet from large meteor strikes? Jon Excell reports

For the inhabitants of the Russian city of Chelyabinsk, the events of 15 February 2013 will never be forgotten. Just after 9.00am, as commuters made their way to work along snow-covered roads and schoolchildren settled down for their lessons, a 20m-diameter meteorite – travelling at an estimated 12 miles per second – exploded above the city with a force equivalent to 30 Hiroshima bombs.

Amazingly, no one was killed. But the resulting shockwave and shower of cosmic debris wreaked havoc over a wide area, damaging thousands of buildings, putting around 1,600 people in hospital, and drawing international attention to a risk that astronomers, scientists and Hollywood film-makers had been nervously contemplating for decades.

Every year, around 40,000 tonnes of space rock falls to the Earth. This is mostly in the form of dust and small meteorites but, occasionally, something more substantial enters our atmosphere. The Chelyabinsk meteor was thought to be the largest object of its kind since the so-called 1908 Tunguska event, when an asteroid of around 40m in diameter devastated a 2,000km$_2$ area of remote Siberian forest.

Further back in our planet's history, the impact of large asteroids is thought to have influenced the evolutionary course of life on Earth by, for instance, triggering the extinction of the dinosaurs.

Today, astronomers estimate that around 1,600 potentially hazardous so-called near-Earth objects (NEOs) are out there. And, while the prospect of an enormous asteroid sending humans the same way as the dinosaurs is extremely remote (see table), experts argue that we cannot afford to ignore the hazard posed by smaller objects.

As head of planetary protection at NASA, Lindley Johnson is better placed than most to comment on this threat. The veteran air force pilot even has an asteroid named after him in recognition of his NEO detection efforts.

"A significant impact is extremely rare, maybe a once-in-a-century kind of event," he told *The Engineer*, "but the Earth gets hit every day by small stuff and it's just a matter of time before it gets hit by something bigger."

An object the size of the asteroid that struck Tunguska, which we can expect on average every 100 years, would, he said, have the potential to cause huge devastation. Indeed, had the Tunguska asteroid's trajectory been just slightly different, it might have altered the course of the 20th century.

"Luckily, Tunguska was a remote area," said Johnson. "But had it impacted three hours later that would have been about the position where Moscow is and it would have been a different story."

It's not just Tunguska-sized objects that have the potential to cause carnage. According to leading European NEO expert Professor Massimiliano Vasile of Strathclyde University, smaller asteroids such as the one at Chelyabinsk, whose type hits the Earth more regularly, can also pose a threat.

"We've had close approaches with objects of that size maybe three or four times in the past two years," he said. "They are still capable of causing significant damage, largely because of the velocity with which they impact."

The good news is that, across the world, engineers and scientists are developing and deploying a host of technical solutions aimed at spotting, tracking and even deflecting asteroids that could be on a collision course with our planet.

Today, the main tools for detecting asteroids are Hawaii's PanSTARRS (Panoramic Survey Telescope and Rapid Response System) telescope and the NASA-funded Catalina Sky Survey (CSS), which uses three telescopes based in Arizona's Santa Catalina mountains. Between them, these facilities are responsible for almost 90 per cent of discoveries and identify around 1,800 objects every year.

Additional information is gathered by deep-space radar systems at Arecibo in

The Chelyabinsk meteor in 2013 exploded above the city with a force equivalent to 30 Hiroshima bombs

Puerto Rico and at the Goldstone complex in the Mojave desert. These facilities are used to measure the size, shape and orbital path of asteroids.

However, while we can take some reassurance from the fact that the skies are more closely monitored than at any point in human history, there are concerns that existing techniques don't pick up everything.

"Above 140m, we have improved our knowledge a lot... but the fraction of objects we know about below 100m is small," said Vasile.

NASA's Johnson added that, although scientists were making the best possible use of current capabilities, other technologies – such as space-based infrared telescopes – would potentially be much more effective.

"Because these objects absorb sunlight and re-radiate it as heat, an infrared telescope in space would be especially sensitive to detecting them," he said.

NASA is already enjoying some benefits of this technology through its NEOWISE project, which has taken an IR surveying telescope originally used for scientific missions and repurposed it to hunt for asteroids.

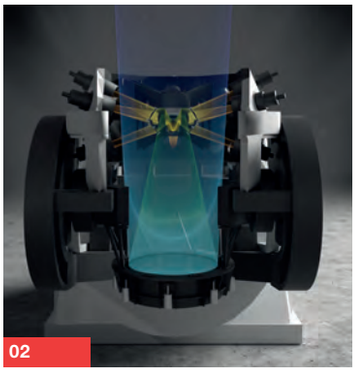
"One of the greatest things it does for us is allow a more accurate estimation of size," said Johnson. This is because the heat radiated by the object is a better indicator of size than the brightness-based estimates that are typically used.

NEOWISE has already operated past its planned lifetime and engineers believe it has now moved into an orbit where it is exposed to too much sunlight to function correctly. The agency is now working on the development of a new telescope, NEOCam, specifically designed to look for hazardous asteroids in the regions of space closest to the Earth's orbit.

Meanwhile, engineers at the European Space Agency (ESA) are taking a different approach to the detection problem – building a terrestrial telescope that they claim will be able to scan the heavens more thoroughly than ever. Taking its inspiration from the compound eye of the fly, the so-called Fly Eye telescope will use 16 separate lenses to take multiple images of the sky in different directions. Instead of finding and following objects at high resolution, the new technology will capture several lower-quality images that cover a wider area of the sky, enabling it to automatically detect movement and alert astronomers when there is an NEO worth investigating.

01 NASA's NEOWISE project has repurposed an IR surveying telescope to search for asteroids

02 The ESA Fly Eye telescope's 16 lenses are inspired by the compound eyes of flies



"The Earth gets hit every day by small stuff and it's just a matter of time before it gets hit by something bigger"

Lindley Johnson, NASA

The impact of large asteroids is thought to have influenced the evolutionary course of life on Earth

"The Fly Eye telescope will have a larger field of view that allows a complete scan of the night sky," said Dr Rüdiger Jehn, co-manager of ESA's NEO detection activities. "No asteroids coming from these directions will be missed," he added.

So what should we do if we discover an asteroid on a collision course with our planet? The most heavily researched option, and the one generally considered to hold the most promise, is the use of a kinetic impactor: a spacecraft that would deliberately crash into an asteroid at high velocity in an effort to alter its trajectory.

Clearly, the effect of the impact would vary depending on the size of the asteroid. But even the tiniest effect could be enough, said Johnson: "You need to slow down the object by one or two centimetres per second. If you do this several years in advance, that is enough to cause it to miss the Earth because the difference in velocity builds up over time."

The most advanced project in this area is NASA's proposed DART (Double Asteroid Redirection Test) mission, which recently moved from concept stage to a preliminary design phase. The agency hopes to crash a spacecraft into Didymos B, one of a pair of binary asteroids in near-Earth orbit. Following this encounter, which is expected to take place in 2022, a combination of Earth- and space-based monitoring techniques will measure changes to the object's orbit.

Here in Europe, the Airbus Defence and Space-led NEOShield project is also studying the potential of kinetic impactors. The group's recently proposed NEOTwist project hopes to crash an impactor into an asteroid and then use a small observation module to measure changes to its path through space.

Airbus engineer Emanuele Monchieri told *The Engineer* that a big challenge of this project was ensuring that the asteroid was struck in exactly the right place, and his group has been working on the guidance, navigation and control systems required. He added that a key factor in determining the best impact site was finding out as much as possible about the asteroid's composition, and there was a lot of interest in developing the technology necessary for taking samples of asteroids and returning them to Earth for analysis.

A greater understanding of an asteroid's composition could have a major influence on the technique used to deflect it, added Strathclyde's Vasile.

"The amount of regolith changes how much you can deflect," he said.

"If you shoot a bullet into sand or solid rock, you see different effects."

Beyond the use of impactors, researchers are considering a range of less dramatic, so-called low-push approaches that could be used to exert a more subtle effect on an asteroid's trajectory. One of the most promising techniques is the use of a 'gravity tractor': a spacecraft that will fly alongside the asteroid for a period and exert a gravitational effect on it.

"If you have enough time and the object is small enough [100–200m diameter], a gravity tractor could be effective," said Johnson. "One of the advantages is you can more precisely control how much velocity change you give the asteroid."

Vasile's team has explored an alternative low-push technique in which a spacecraft flies alongside an asteroid and uses lasers to heat its surface, generating a plume of gas and debris that gives the asteroid a subtle push. Laboratory simulations tested the technique with objects of different sizes.

"We investigated with asteroids as big as 20m diameter and had to go up to eight years' warming time; for smaller ones you can go down to two years," he said.

Other options under consideration include attaching a low-impulse rocket to the asteroid itself, or placing an automated 'mass ejector' system on the surface of the asteroid that would extract mass from the rock and eject it into space, again giving the object a steady push into a different orbit.

However, in some circumstances a steady push – or even a kinetic impactor – may not be enough. "If you had 100 years you could use pretty much any deflection technique conceived in the past two decades," said Johnson, "but, if you had only one year, there wouldn't be many options."

This is where the technique of last resort comes in: the use of nuclear weapons. Two main options are under consideration: either a nuclear charge is detonated at a distance from the object (causing a flow of radiation that vaporises the asteroid's surface and pushes it into a different orbit); or we take the approach of Bruce Willis in the film *Armageddon* and bury a giant bomb beneath the surface, blasting the asteroid to smithereens. Both are dramatic actions that would be hard to control and would have unpredictable consequences. However, most experts agree that, in the face of impending disaster, these would represent our best hope.

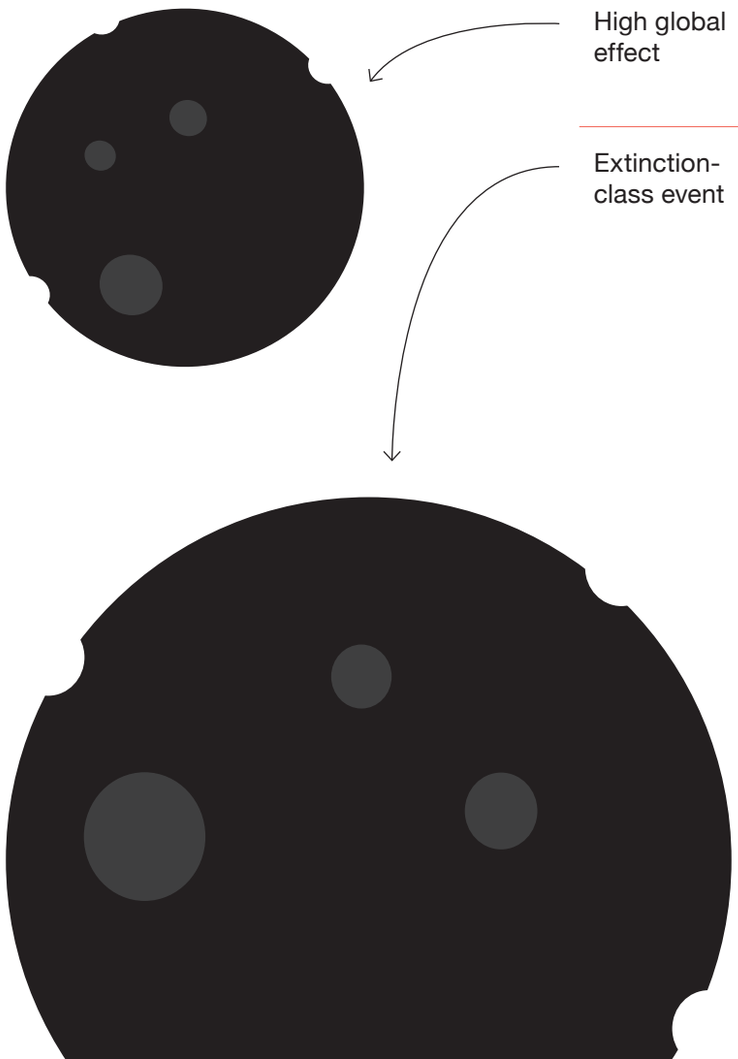
While none of these deflection techniques have been directly trialled beyond the lab, there is reasonable confidence in their success thanks in part to the way in which previous scientific missions have cracked related challenges. For example, NASA's Deep Impact mission, in which Johnson was involved, successfully crashed an impactor into a comet back in 2005. The aim was to learn more about the comet's composition by analysing the resulting plume. ESA's Rosetta mission, similarly, which led to the first successful landing on a comet, has also helped push the development of some key technologies.

There is even a precedent for sample return thanks to Japan's Hayabusa mission, which successfully returned material from an NEO back to Earth in 2010.

Another area that could stimulate the development of technology is the space sector's growing interest in tapping the resources found in comets and asteroids. Glasgow University's Professor Colin McInnes is an expert in this field.

Impact frequencies and consequences

Type of event	Diameter of impact object	Impact energy (MT)	Average impact interval (years)
High-altitude break-up	<30m	<5	10-50
Tunguska-like event	>30m	>5	250-500
Regional event	>140m	~150	5,000
Large sub-global event	>300m	~2,000	25,000
Low global effect	>600m	~30,000	70,000
Medium global effect	>1km	>100K	1 million
High global effect	>5km	>10 million	6 million
Extinction-class event	>10km	>100 million	100 million



"Using water for human space flight you've still got to lift water out of the air-speed gravity well at great expense," he said. "If you can bake it out of asteroids, in principle you could use solar energy to crack that into hydrogen and oxygen so that you'd have propellants in situ." To do this, he added, engineers must solve technical challenges that could also be applied to asteroid deflection.

Nevertheless, while the concepts are well studied and some technical solutions have been demonstrated, most NEO experts agree that a dedicated mission is desperately required to put the theory into practice.

"The technology is mature, but it hasn't been demonstrated that it would be effective in diverting an asteroid," said Johnson. "On paper they're well understood, but I wouldn't want to rely on any of these systems until we'd had a chance to test them."

As with so many engineering challenges, the biggest hurdle may be political. "None of the solutions are that far from being ready to launch," said Vasile. "The problem is always that you are talking of several million pounds of investment; and convincing people to invest that to test something like this is difficult. An impact with an asteroid is a typical situation in which a politician doesn't feel compelled to invest because it's a rare event that is longer term than their career."

Johnson agreed: "It takes a very long planning horizon to understand and realise the kind of capabilities that are needed."

Finding a solution will also require joined-up international collaboration.

"It's not something that a single country can or should deal with," said Vasile. "For example – say there is an incoming asteroid and the US decides it has enough resources to deflect it. It launches a mission; the mission goes wrong. It simply moves it a bit and, instead of impacting on the ocean, the asteroid falls on China. That's something you don't want to happen."

Perfecting an air of confidence

The UK and Ireland general manager of Air Products is focused on the centrality of industrial gases. Stuart Nathan reports

The industrial gases sector is difficult to categorise. It is normally grouped with the chemicals industry and, indeed, the relatively few companies that comprise the sector are members of national and regional chemical industry associations.

But chemicals is a manufacturing sector and industrial gases are, for the most part, not manufactured; they are elements or elemental molecules, and are either harvested from the atmosphere or generated through basic chemical reactions. This would place industrial gases among the primary industries, such as mining or oil and gas, but it has little in common with those.

Tim Hulbert, who runs the UK and Ireland businesses of Air Products, one of the largest and longest-established suppliers of industrial gases, admits the sector is a bit of an oddball. "However we'd categorise ourselves, the manufacturing industry in the UK, in all its variety, relies on industrial gases for its operation," he said.

Air Products has had a UK presence since the 1950s, arriving around a decade after it was founded in Allentown, New Jersey. Its founding principle marked it out from its peers. Rather than organising around a number of large industrial plants and distributing its products from there, it started "in a way that was then untapped – generating gases at its customers' sites," Hulbert explained. "The company grew from that key idea into a global business that these days employs about 16,000 people and generates $8bn [£6.05bn] of revenue," he added.

In the UK, Air Products ranks as a medium-to-large player, generating around £800m in annual revenues and employing about 1,500 people, of whom slightly over half are engineers, according to Hulbert.

The company has undergone changes in recent years. Previously known as Air Products and Chemicals, it operated some of its businesses more in line with the traditional chemicals sector, producing substances that were used, for example, in the manufacture of semiconductors and electronics. That began to change in 2014 when a new chief executive, Seifi Ghaseni — the first CEO brought in from outside rather than promoted through the ranks — decided to refocus the company on its core industrial gases business. The electronics materials sector was spun off into an independent entity called Versum, while performance chemicals was sold to German specialist Evonik, which had been growing through acquisitions of non-core performance chemicals firms since its purchase of Degussa in 2006.

01

"Our approach to R&D is driven by customer need and is often very specific to a sub-segment's demands"

As its name implies, Air Products derives most of its products from the air. Its core process is cryogenic separation: liquefying air by cooling it, then allowing it to evaporate through a distillation column so that its components separate out.

But this is not the only way the company derives products. To a great extent the process depends on the customer, and a lot of business is still done the old way, with gases generated on site for clients.

"We have the full range [of facilities] because what makes the most sense for individual customers is a function of many things," said Hulbert. "Part of it is their volume demand, but there's also their usage profile: the purity and pressure of the gases they need. So the smallest customer may need just a cylinder of gas, which we may deliver ourselves or via an agent. [This goes] right through to customers where delivering liquid products is the right option for them. Many of their applications may benefit from the cryogenic properties of liquid nitrogen, for example."

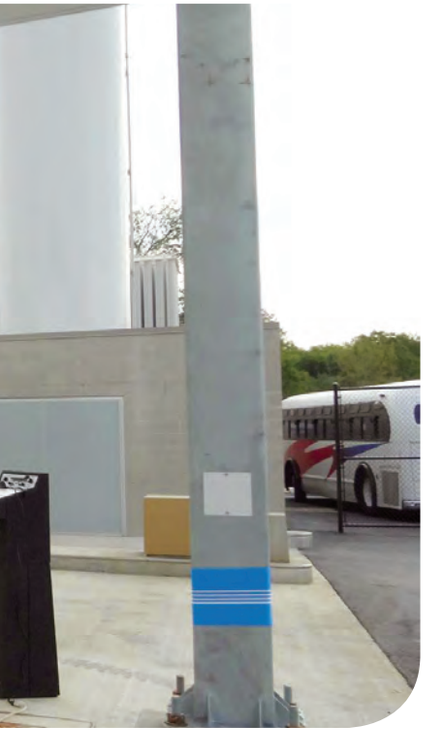
In such cases, the best way to supply this demand is from a large cryogenic plant that benefits from economies of scale. "We have large plants that supply operations like BP in Hull," said Hulbert.

Air Products' largest single site is at Seal Sands near Billingham, on Teesside. It also has plants at Carrington, near Manchester, where it has recently invested £30m in replacing a plant built in the 1960s,

to supply nitrogen, oxygen and argon to the North-west and Wales.

In volume terms, the company's main products are nitrogen, oxygen and argon (all derived from air); hydrogen (made by steam-reforming methane); helium (from subterranean deposits in locations around the world); and carbon dioxide (often from purifying waste streams). Nitrogen has the greatest demand by far, Hulbert said, being used often as an inert gas for blanketing and purging, as well as for the cryogenic properties of the liquefied gas, which boils at -196°C.

The industrial gases sector is commonly perceived as being not technologically advanced, and being quite slow with innovation. Hulbert admits there is a kernel of truth in this.



02

01/02 Air Products is developing dispensing technologies for hydrogen as an automotive fuel

"At the heart of a cryogenic distillation process it's essentially no different from when it was discovered and commercialised 100 years ago."

But the liquefaction of air is an energy-intensive process and the company is keen to improve efficiency. The cryogenic distillation R&D centre — also in Carrington — works on technologies such as the packing of the distillation column, which affects both the efficiency of separation and the purity of products.

"As recently as the 1980s, the only companies that had on-site generation — apart from the industrial gas companies themselves — were steelworks, refineries and petrochemical works," said Hulbert. "These days you can go into pretty much any industry."

"We generate nitrogen on site for customers who use tens of cubic metres per hour rather than thousands of tonnes per day because we've invested in R&D, to not just develop the way we do separation but enable us to get cost-effective solutions at smaller and smaller scales."

Often these on-site generators do not use cryogenics but methods such as membrane separation or pressure-swing absorption [PSA], which produce a less pure product. But Air Products consults its customers to determine what purity they need and adjusts their delivery strategy accordingly.

This can result in much lower energy usage, he said. "We liquefy a gas — the air — then vaporise it to separate the components, then liquefy again for transport; we drive it around the country and it's stored as a liquid. Sometimes our customers then vaporise it again. So we look at what purity they need and, if they don't need cryogenic purity, we can look at a lower-energy PSA process."

Other research strands focus on customer needs and what can be done with the products in their various forms. For example, the food industry is a major customer, using nitrogen in its liquid form for rapid freezing and as a gas in packaging to slow down product spoilage. A recent R&D effort has put those cryogenic properties to a new use.

"The bacterium Campylobacter is a subject of great concern in poultry production and processing; the Food Standards Agency is very concerned about its control," Hulbert said. "We've developed a technology that uses liquid nitrogen to treat poultry carcasses as they pass through factories, such that the bacterium is removed to the point of meeting all standards. There are other ways, such as steam, but companies were finding it didn't work well in the summer when Campylobacter levels tend to increase.

"Ours is now the only method on the market to achieve all the required standards. We did our first installation 12 months ago and we've spent a lot of time running it and testing it to prove it's effective and sustainable. We're now at varying stages on four or five other installations. That's a typical example of how we approach R&D. It's very much driven by customer need and is often very specific to a sub-segment's demands."

Another cryogenic application is in sport. Football teams such as Fulham FC have installed liquid nitrogen therapy units at their grounds for treating players' injuries.

"We could also talk about our gas tracker, which is designed to help sites that perform welding to control the flow of the gases they use and reduce consumption," Hulbert said. "Although they end up buying less gas, we think it's good for our business. Our purpose is to help our customers to be more productive, and that includes meeting environmental goals."

Elsewhere, Air Products is involved in the development of hydrogen as an automotive fuel. "Most of our activity is around dispensing hydrogen," Hulbert said. "We have dispensing technology in use in London and, as government support allows infrastructure to develop, we'll participate."

CareerCV

Tim Hulbert general manager, industrial gases UK and Ireland, Air Products

Education

1993 MEng in Chemical Engineering, Imperial College London

Career highlights – Air Products

1995-98 Based in Czech Republic and Poland, working on packaged gases and merchant bulk business development

1998-2004 Responsible for securing on-site deals and selling applications technology in the UK, Ireland and Scandinavia

2006 Commercial manager, Germany

2007 European pricing manager

2009 Product manager, with profit and loss responsibility across northern and central Europe

2012 General manager, generated gases

2014 Appointed to current position

Naval gazing

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, he predicts a humble future for the world's great navies

Ever since HG Wells' *The War of the Worlds*, in which HMS *Thunderchild* engages Martian tripods off the Essex coast, the world's navies have fired the imaginations of science fiction writers.

Perhaps this is no great surprise. The ocean dramas played out in human history, from Actium to Lepanto, from Jutland to Midway, offer tales of individual bravery and genius, of empires crushed and born, of cruel fate and blind luck played out on an empty expanse, far from the ambiguities of occupation and collateral damage. Further, they are tales of men marshalling their knowledge of engineering in a race to develop more powerful war machines, from longship to aircraft carrier. All of man's talent for inventive destruction, for myth making and drama, can be found in the centuries of struggle to rule the waves, and this has proved ripe for retelling within the ocean of space.

When scifi writers seek to invent great star-faring empires, they often define them by conflict; and when it comes to depicting great battles between spaceships, they turn naturally to the language of the navy. So it is that *Star Trek* captains order the assembly of boarding parties, and *Star Wars*' Imperial Navy is one of cruisers, destroyers and corvettes. So in love are we with the Dreadnought era, we see the Battleship board game retold (rather terribly) as a Wellsian alien invasion tale, Japanese Second World War battleship *Yamato* reborn as a spacecraft in the famous anime, and navy veteran John G Hemry's Lost Fleet books populated by First World War vintage Royal Navy ship names: *Courageous*, *Valiant* and *Victorious*.

So it is that those of us with a taste for epic future fleets are puzzled when we seek inspiration from modern naval technology. This month *The Engineer* reported on BAE Systems' deal to build Type 26 frigates for the RN. The project epitomises the trend for fewer and fewer platforms, which promise dazzling technology – and even more blinding bills.

Admirals seem not to have heeded Lord Vader's warning not to be too proud of technological terrors. All of the RN's major modern projects seem to play host to rather vital deficiencies: the Type 45 destroyers' engines don't work; Astute submarines run aground and collide with other vessels. The sense is of the race for technological superiority diminishing and hobbling a once great navy.

The sight, last year, of HMS *Belfast* dwarfed by private yacht *Motor Yacht A* at her Thames mooring seemed symbolic. Could it be that the future will see ocean dominance passing into private hands? What direction would this take scifi stories? Perhaps, in the search for new tales, we should look to a nearer future: one of new naval conflicts, between corporate interests rather than nations.

We could imagine a world where once great navies, sinking under the cost of their white elephants, turn to private sponsorship to keep them afloat. Ships are renamed in honour of their sponsor, and carry brand guideline officers, there to ensure that the ships are kept properly emblazoned with garish logos, the crews properly indoctrinated in corporate identities. The situation seems more humbling than dangerous, until USS *Pepsi*, competing for the business of a wealthy port, opens fire on HMS *Irn Bru*, plunging once friendly nations into conflict.

Perhaps the world's organised navies will disappear entirely, leaving only heavily armed oligarch superyachts and monstrous cruiseships ploughing the ocean wave. We may see a future where billionaires compete to construct larger and larger craft, leviathans of unimaginable scale.

As catastrophic climate change takes hold, one drunken oligarch has a vision of an angel instructing him to gather the world's animals to his ship, saving them from the coming flood – but, made lazy by years of indolence, and boggling at the sheer number of species to collect, our hero skips that part of the Noah tale and moves right along to the drinking instead.

The navies of the future may be humbled in other ways. Perhaps a great Pacific war will be snuffed out before it begins, a super-hack fusing the computer cores of mighty future ships before they can fire a shot. Abandoned by crews in rowing boats, left to rust on the waves, these vast vessels turn the Pacific into a lake of *Mary Celeste*s. A future entrepreneur travels from wreck to wreck, picking them apart for their precious scrap – until he stumbles across a ghoul from the past: an ancient creature with toe-length beard, dressed in the rags of an admiral's uniform, still refusing to abandon his ship. Instead he fights a ghost battle, issuing orders to his departed crew and unleashing phantom broadsides on imagined enemy ships.

The glamour and might of great navies still cast a spell on the world, but their utility is more and more an illusion. The future of navies seems glitchy, automated and, worse, unromantic.

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

"The utility of great navies is more and more an illusion"

Jon Wallace

Will the world's organised navies disappear entirely?

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Stacks of promise

The hydrogen fuel-cell Toyota Mirai could be a gamechanger but for its price point. Chris Pickering **reports**

It's a rain-soaked morning on the M25. Having negotiated the outskirts of suburban Surrey, we're splashing through puddles on the UK's busiest motorway. As road tests go, it doesn't get much more 'real world' than this – which makes it the perfect place to put the futuristic Toyota Mirai through its paces.

Fuel-cell vehicles have existed in prototype form for decades – the principle itself dates back to the 1830s – but the Mirai is one of the first true production cars to embrace the technology. Admittedly, at £66,000 (or £61,500 with the government's zero-emissions grant) it's not a mass-market proposition just yet. In theory, however, you can speak to your local Toyota dealership about buying one.

The electric drivetrain that underpins the Mirai is in fact quite conventional. The motor and gearbox come from the Lexus RX450h, while the nickel-metal hydride battery is shared with the Japanese-market Toyota Camry Hybrid.

Of course, the clever bit is the fuel-cell stack, which is designed and built in-house at Toyota's special projects plant. The polymer electrolyte membrane (PEM) design has 370 cells joined in series to produce up to 114kW (153bhp).

The hydrogen is carried in two tanks, one mounted under the rear seats and the other in the boot. These consist of a gas-tight plastic liner, a carbon-fibre-reinforced polymer middle layer and a glass-fibre outer skin. Together the tanks can store around 5kg of hydrogen at 700 bar, giving the Mirai a range of 300 miles (and that, says Toyota, is a realistic figure, not just a laboratory claim).

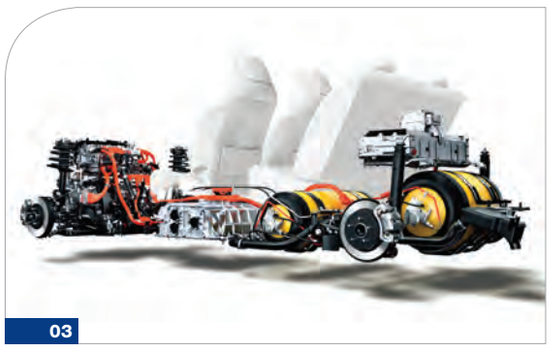
A raft of safety measures helps to ensure that there's no risk of the Mirai becoming a miniature Hindenburg. For a start, the tanks are immensely strong: they're certified to 225 per cent of their operating pressure and the design has been subject to a barrage of crash and penetration tests. There's also a relief valve on each tank to vent the gas in case of an abnormal rise in temperature (such as with a fire), while two strategically placed hydrogen detectors will shut down the car and seal off the tanks if a leak is detected. As a final layer of protection, the cabin is fully separated from the hydrogen compartment.

Not that we intend to put any of that to the test today.

The Mirai glides happily through the monsoon conditions of the commuter belt. By and large, it feels like any other electric car. Squeeze the accelerator and the motor responds crisply, with more than enough urge for everyday driving. True, the Tesla Model S – similarly priced in its entry-level version – would blow the Mirai into next week, as would just about anything else at this price point, but its performance is similar to that of an ordinary family saloon.

However, the Mirai has the edge over its combustion-powered opposition when it comes to refinement. The electric drivetrain is whisper quiet most of the time. Accelerate hard from low speed and you can hear the fuel cell stack's air compressor quietly whistling away. It's a

01/02 The Mirai is one of the first true production cars to embrace fuel-cell vehicle technology



03

04

strangely characterful sound that could almost be described as sporty were it not for the fact it nearly – but never quite – corresponds to the pedal input.

Less engaging is the handling. Although safe and reasonably composed the softly sprung Mirai can feel a touch wallowy at times. At 1,850kg it's no featherweight, but there's no shortage of heavier cars that do a better job of disguising their mass. Still, that's not really what the Mirai is about and the trade-off is a suitably silky ride quality to complement the hushed atmosphere of the cabin.

The only other fly in the ointment is the brake feel. It's quite crisp initially but, when the regenerative braking kicks in, the pedal goes disconcertingly numb. This is a common issue with electric and hybrid vehicles but it's one that others have started to overcome.

Fuel-cell vehicles also raise a few questions of their own, and we're en route to answer one of them right now. The plan is to take the Mirai to the Cobham services on the M25, which is home to one of the UK's rapidly increasing number of hydrogen filling stations. Admittedly there are only eight such filling stations in the UK, with a further six expected by the end of the year. But if you live in one of the pilot areas – now spread as far afield as Plymouth and Edinburgh – this number is approaching practical.

The refuelling process is simple enough, if marginally more protracted than for petrol and diesel cars.

You begin by offering up your charge card to the machine and choosing between 700 bar and 350 bar pressure. Next, you open the filler cap on the car and remove the dust cover. Once the filling hose has been attached, you squeeze a trigger to lock it to the car. There is then an audible squirt as the dispenser carries out a quick leak check, after which you press a button on the screen to commence fuelling.

The only option is to fill the tank completely. Depending on the ambient conditions, this can take between three and five minutes from empty, but today we've used only about a quarter of a tank. It sounds a bit convoluted but it's not that different from using a conventional 'pay at pump' system.

Topped up with £11.89-worth of hydrogen, we head back to Toyota's press garage and reflect on our morning with the Mirai.

It's refined, well screwed together and reasonably practical. Those facts alone wouldn't cut it at this price, particularly given the recent proliferation of pure electric vehicles and plug-in hybrids that share many of the same benefits. But Toyota reckons that, if the Mirai's fuel-cell stack were produced in similar volumes, it could be manufactured for less than the cost of an equivalent combustion engine. Granted, you still have the motors and batteries to consider, but these are not the exotic items that they once were.

As a proof of concept, the Mirai demonstrates that hydrogen fuel-cell vehicles are indeed ready for the real world (just as the first-generation Prius did for hybrids 20 years ago). At a more manageable price point, this car as you see it today could already be a gamechanger.

All that remains now is for the real world to catch up.

03 The immensely strong hydrogen tanks are mounted under the rear seats and in the boot; each is fitted with a release valve in case of an abnormal rise in temperature
04 A trigger locks the filling hose to the car

"As a proof of concept, the Mirai demonstrates that hydrogen fuel-cell vehicles are indeed ready for the real world"

May/ June 1940 Material benefits

The 'Little Ships' are known for their Dunkirk heroics, but that was not their sole contribution to the war

In the months of May and June 1940, 338,226 service personnel of the British Expeditionary Force were evacuated from Dunkirk in northern France, having retreated there on the order of General John Vereker, 6th Viscount Gort.

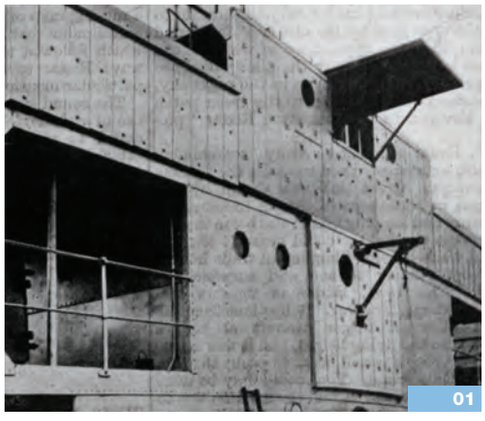
Surrounded by marshes and possessing a suitably long stretch of beach, Dunkirk presented a tangible temporary staging post from which the Second World War's Operation 'Dynamo' could be carried out. The evacuation saw 900 naval and civilian vessels cross the English Channel to rescue the stranded troops. The 'Little Ships', crewed mainly by Royal Navy reservists, formed a significant part of what wartime Prime Minister Winston Churchill described as the "miracle of deliverance".

Among the Little Ships' crews, however, observations had been made that would lead to the development of a material that, towards the end of the war, would save thousands of lives and tons of steel. The material was plastic armour and, in August 1945, Dr JP Lawrie of the Royal Naval Scientific Service penned an article for *The Engineer* that summarised the material's development and its quick evolution for use during the D-Day landings of 1944.

"In the grim days of Dunkirk, it was observed on some of the 'little ships' with bituminous flooring that bullets from attacking aircraft failed to penetrate, but were retained in the deck composition," wrote Dr Lawrie. "Examination showed that, although these stopped bullets were probably almost spent, or had arrived at an angle, the composition of the deck sheathing tended to prevent penetration, and an investigation of the possibilities of developing a 'plastic armour' was begun."

Wartime necessitated austerity, which spurred innovation. Attempts to protect merchant vessels saw the introduction of concrete to safeguard wheelhouses and gun positions, but this was ineffective due to potentially fatal fragments that flew off the concrete when hit by bullets.

Lawrie noted that deck sheathing on a number of Little Ships was "a form of mastic asphalt consisting primarily of bitumen and limestone powder, to which is added some grit". To overcome the problem with ballistic concrete, the Admiralty asked the Road Research Laboratory of the Department of Scientific & Industrial Research to investigate "whether a bituminous mixture… could be produced to provide protection against aerial attack to sand-cement concrete slabs in use in merchant ships".


01


02

01 Plastic protective plating for bridge protection

02 Damage to PPP – no casualties

Lawrie noted: "Their research on concrete led the laboratory to the belief that the use of larger particles of stone would improve the resistance of plastic armour. Trials showed that, using a larger stone in the ration of 50 per cent to the asphalt, 0.303 armour-piercing (AP) bullets were stopped by a protection weighing only 38.5lb per sq ft, compared with 50lb per sq ft for concrete. As the weight of solid mild steel to give protection against 0.303 AP bullets is 36lb per sq ft, it was apparent that, in view of the acute shortage of steel and armour plate then prevailing, a stone-filled mastic asphalt offered good possibilities as a protective armour.

"Satisfactory results were obtained, a working specification was drawn up and, under the joint supervision of the Admiralty and the laboratory exactly one month after the research had begun, work was commenced on the armouring of vital parts of a merchant ship."

By October 1940 a more detailed investigation of the principles of plastic armour design had begun, with the first tests concentrated on stopping AP shot, followed by bomb and shell splinters and 20mm high-explosive shells. Experimental targets of plastic armour were made first with 50 types of stone. The results of tests using 0.303 bullets showed that certain flint and quartzite gravels gave the best protection. The granite then in use was immediately superseded by these new materials, said Lawrie.

Plastic protective plating (PPP) followed – a lighter, more efficient material made of pitch, fine sawdust and lime that was enclosed in metal and suitable for mass production. By the end of 1942 most gun positions were protected by PPP instead of in-situ plastic armour; later, PPP was installed on ships "in enormous quantities" in preparation for D-Day .

"Special plates were made for use on bulldozers and flamethrowers to give protection to their drivers," said Lawrie. "It has been found that the protection offered is in excess of that anticipated." **JF**

Word of the issue

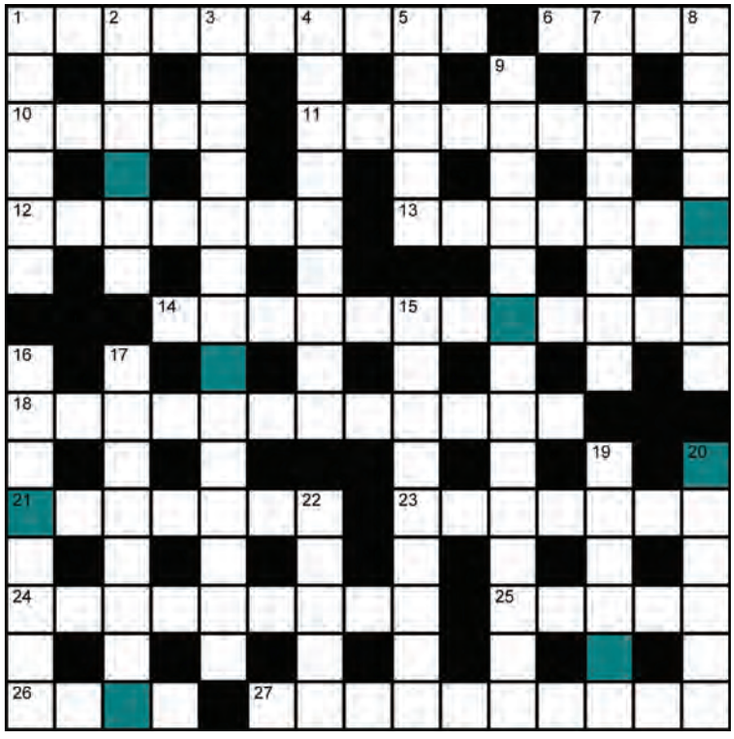
Anthony Poulton-Smith explores the origins of the word ‘metal’

The Bronze Age heralded man’s first experiences with metal. With etymology we would expect any references to metals at this time to be most simplistic, for this is also true of all words with a long history. Modern English has a wealth of words, however, all these were once new and based on words and terms borrowed from existing terminology. This has always been the case and why, when we look at the origins of the oldest words, the origins seem overly simplistic.

‘Metal’ came to English from Old French metal meaning not only ‘metal’ but also ‘material, substance’ and evidence of the more basic origins and general meanings associated with the word. This is also seen in Latin metallum, again ‘metal’ but also ‘mine, quarry, mineral’ and in turn from Greek metallon ‘metal, ore’ and earlier as ‘mine, quarry, pit’. Related words are seen in metalleutes ‘a miner’ and metalleia ‘a search for metals, mining’.

Bigpicture

The US Navy is to conduct trials of a railgun that can launch projectiles at speeds in excess of Mach 6. Initial repetition rate (rep-rate) tests have been carried out at low muzzle energy. In the next stage, rep-rate testing will be at 20MJ by the end of the summer and 32MJ by 2018.



Prizecrossword

When completed rearrange the highlighted squares to spell out a heavy precious metallic element. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaurmedia.com**

Across

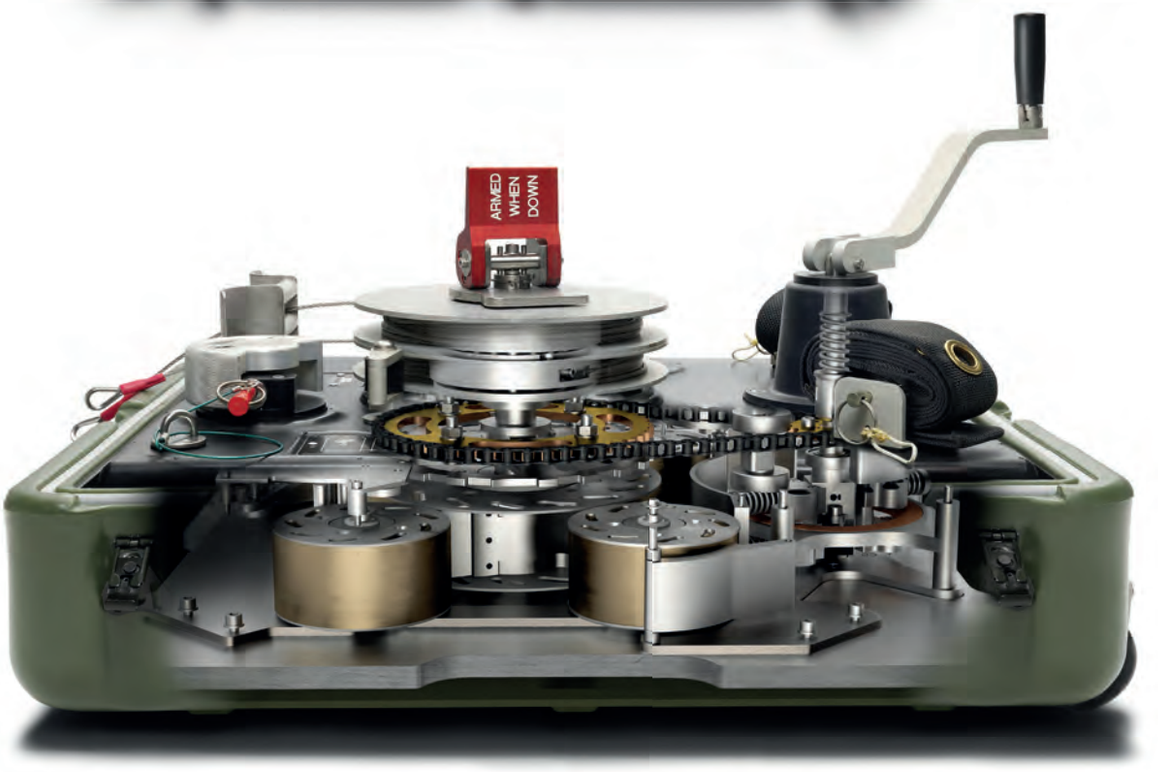
1 Two thicknesses of masonry with a space between (6,4)
6 Physical injury (4)
10 Coloured transparent gem (5)
11 Beaten into thin sheets (9)
12 Clean with a broom (5,2)
13 Relating to a wedding (7)
14 North or South for instance (7,5)
18 Worldwide traveller (12)
21 Produced by the action of intense heat (7)
23 Delivered from danger (7)
24 Immobility by virtue of being unreactive (9)
25 Rendered inoperable (5)
26 Charge with a function (4)
27 Brochure of courses at college (10)

Down

1 Artistic movement featuring geometrical planes (6)
2 Shape of something rotating rapidly (6)
3 Call box (9,5)
4 It’s hung when decorating (9)
5 Collects together (5)
7 Skilled in aesthetic skills (8)
8 Adjust an electromagnetic wave (8)
9 Incapable of being squashed (14)
15 Humorists who use ridicule and irony (9)
16 Device to start a machine (8)
17 Ray of light at night (8)
19 Switch that interrupts an electric circuit (3-3)
20 Venomous British snakes (6)
22 Remove fleece (5)

July’s highlighted solution was Greenhand. Winner: **John Whalley**

DCA



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