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Solar flight

Light materials enabling Impulse's circumnavigation of the world

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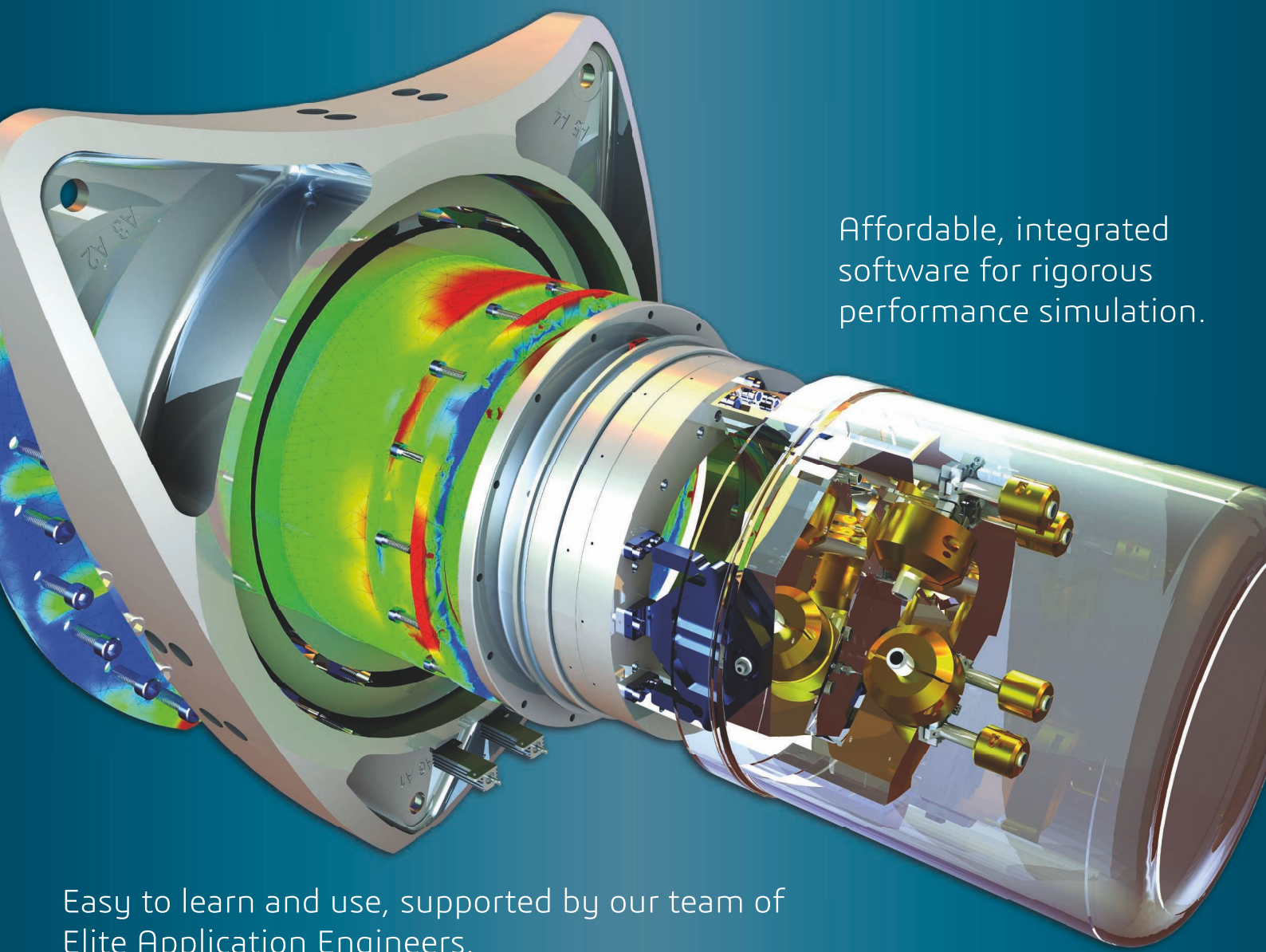

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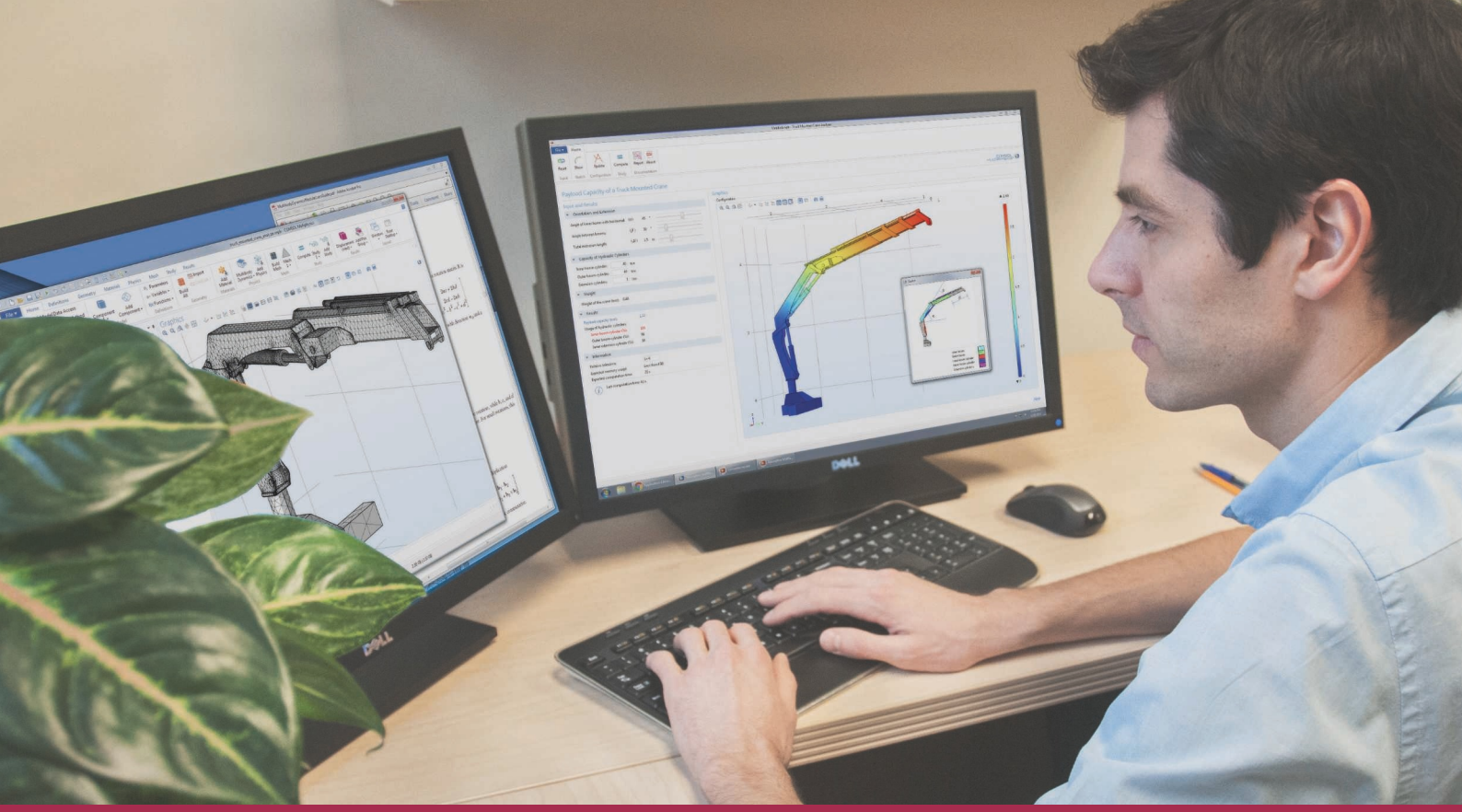

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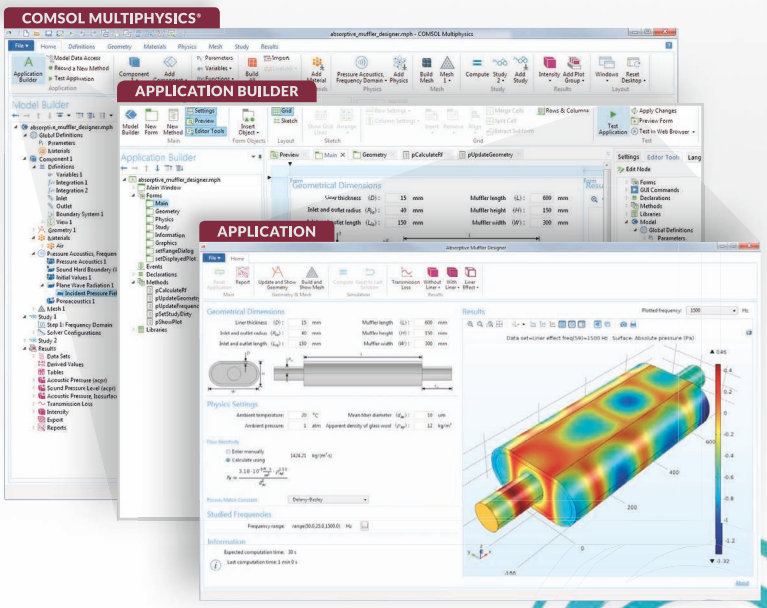

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Difficulties in green design

Tim Fryer, Editor (tfryer@findlay.co.uk)

There was much self-congratulation in Paris in mid-December at the close of COP21 – the Climate Change Conference. Everyone seemed happy that, 'we are serious about this now', before returning to throw Yule logs on their home fires. But, who is actually going to do what as a consequence of this agreement remains to be seen. It struck me as a destination without detailing the journey – the nub of the matter is that we must burn less fossil fuels. So, is that all?

Away from the energy sector, can design engineers have any impact on climate change? It is not as straightforward as it sounds. Obviously an electromechanical product can be efficient and therefore use less fuel, but what do you make the product out of? For example, the environmentally conscious engineer might choose to design a product out of recyclable materials like aluminium and steel – the British Metals Recycling Association calculate that 60 to 80% savings can be made in recycling metals compared to making them from ores. But when it comes down to it, the flood of cheap steel from China is likely to mean it will be made from ore there, which is shipped halfway around the globe.

It may be cheaper, but in terms of emissions it is far from ideal. Or perhaps you may be tempted to improve the efficiency of a moving object by lightweighting, perhaps using composites. Environmentally sound in use, but only a limited amount of it can be made from recyclable material. In these sorts of cases the life-span of the product, and the energy saved during it, can be balanced against the emissions created during manufacture. A more energy efficient product is not necessarily more environmentally friendly.

It almost seems as if the environmental agenda can be split into emissions reduction and waste reduction – and often these two, without clever engineering design and insightful supply chain management, can be pulling in opposite directions.

Lord Bamford honoured

The JCB chairman, Lord Bamford, has been appointed as an Honorary Fellow of the Institution of Mechanical Engineers after more than 50 years in the industry.

IMechE president Professor Richard Folkson presented Lord Bamford with the Honorary Fellowship. He said: "This is a very well deserved honour, recognising the huge impact Lord Bamford has made to UK manufacturing and innovation. It is thanks to his leadership and vision that JCB is the success it now is and he is one of the strongest and most inspiring ambassadors for British engineering."

Lord Bamford's career began with a two year engineering apprenticeship at Massey Ferguson in France before starting at JCB World in 1964. He has been chairman of JCB since 1975. He spearheaded the establishment of the £22million engineering-focused JCB Academy in Rocester, which opened in 2010.

UK wind winds up

Quarterly figures, released by the Department of Energy and Climate Change, show that in July to September, the amount of electricity generated by offshore wind increased by 52% compared to the same period in 2014, while onshore wind generation was up by 30%. Wind generated 9.5% of the UK's electricity (5% from onshore and 4.5% from offshore) due to higher wind speeds and increased capacity. Overall, 23.5% of the UK's electricity was generated by renewables in Q3 2015, up 6% on 2014. Other renewable contributions are bioenergy (9.1%), solar PV (3.5%) and hydro (1.4%).

Successful landing of reusable rocket

US private space company SpaceX, backed by Tesla's Elon Musk, has successfully landed an unmanned orbital rocket - the first time such a feat has been accomplished.

SpaceX's Falcon-9 rocket launched from Cape Canaveral to dispatch 11 communications satellites to complete a 17 satellite, low Earth orbit constellation for ORBCOMM. This array is said to be the first satellite network dedicated to providing reliable and cost-effective M2M communications to and from the most remote areas of the world.

The secondary test objective for the mission was the landing of the stage one rocket in an upright position at a landing site six miles from the launch pad. After reaching a height of 200km, the first stage used its boosters and thrusters to perform a flip and touch down safely 10 minutes after it had launched. The achievement has been hailed as a milestone towards reusing rockets.

In November 2015 Blue Origin, backed by Amazon founder Jeff Bezos, landed its rocket. However, this was a much smaller mission that didn't reach orbit.

Nanoparticles control soft robots

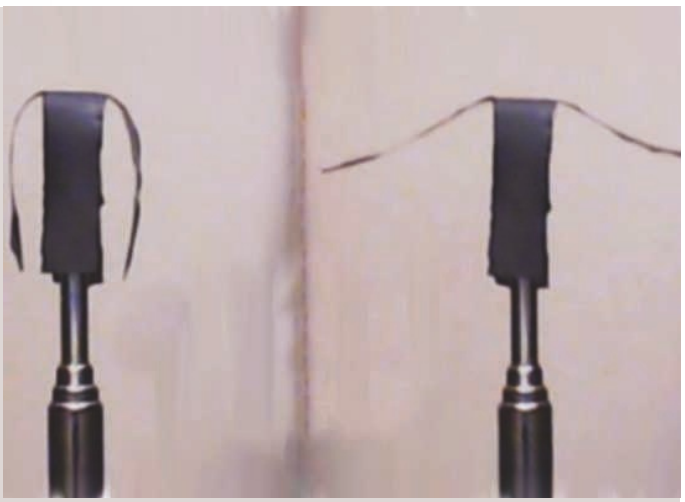
Researchers from North Carolina State University have developed a technique for using chains of magnetic nanoparticles to manipulate elastic polymers in three dimensions, which could be used to remotely control 'soft robots'.

The ability to control the motion of soft robots, coupled with their flexibility, gives them potential for use in applications ranging from biomedical technologies to manufacturing processes. Researchers are interested in using magnetic fields to control the movement of these soft robots because it can be done remotely and because magnetic fields are easily obtained from permanent magnets and electromagnets.

The NC State researchers have found a way of embedding long chains of nanoscale magnetite particles in sheets of elastic polymer to form a magnetic polymer nanocomposite. By applying a magnetic field, the researchers can control the way the nanocomposite bends.

Sumeet Mishra, a PhD student at NC State, said: "The nanoparticle chains give us an enhanced response, and by controlling the strength and direction of the magnetic field, you can control the extent and direction of the movements of soft robots."

The researchers believe this technique may be especially attractive for some biomedical applications. "Electrical control can raise safety issues for some medical



applications," said Mishra. "And both electrical and light signals pose challenges in terms of communicating those signals to devices embedded in the body. Magnetic fields, on the other hand, pass through easily - and pose fewer safety challenges."

NEWS

The IET recognises young women in engineering

The Institution of Engineering and Technology has presented its Young Woman Engineer of the Year awards. Orla Murphy, an acoustic and audio engineer at Jaguar Land Rover, won the IET Young Woman Engineer of the Year. On winning the award, Murphy said: "This opens so many doors – I'm meeting different people and broadening my network. I hope to be given more opportunities to talk to schools and perhaps to bigger audiences. Right now I'm working as a STEM ambassador and am involved with TED, but I want to do more and I plan to make the most of this opportunity."

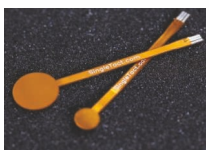
Siemens controls engineer, Emma Goulding won the IET Mary George Prize for Apprentices. "I think it's disappointing that the amount of women in engineering is so low at the minute and that needs to change. We're missing a lot of great talent simply because girls think it's an industry just for men," she said.

The Women's Engineering Society Award was given to Helen Cavill, process improvement manager at M&H Plastics. "I enjoy solving real-world problems and often describe myself as an 'engineering detective'," she said.

Picture shows (L - R): Rossella Nicolin (finalist), Olra Murphy, Ashleigh Sumner (finalist), Emma Goulding and Helen Cavill.

TECH BRIEF

Capacitive mini-sensor



Pressure Profile Systems has unveiled the SingleTact, a miniature capacitive force sensor that is claimed to deliver superior sensitivity and repeatability compared to resistive force sensors.

SingleTact is an ultra-thin, single-element sensor claimed to accurately quantify forces with less than 1% repeatability errors, while having over three times the sensitivity of resistive sensors. The device is designed to help engineers to develop innovative products where precise and reliable force measurements are required using open source software and firmware.

Events

09 - 11 February
Southern Manufacturing and Electronics 2016
Farnborough
Exhibition

24 - 25 February
Hazardex 2016
Runcorn
Hazardous areas event

31 March
DEVELOP3D LIVE 2016
Warwick Arts Centre
Exhibition

07 April
The Engineering Simulation Show 2016
The Roundhouse, Derby
Exhibition

21 April
Plastics, Prototyping & Metals Exhibition
Concorde Conference Centre, Runway Park, Manchester Airport
Exhibition

25 June - 01 July
UK Robotics Week 2016
Across the UK
Nationwide and industry wide robotics event

06 – 07 July
Manufacturing and Engineering North East
Metro Arena, Newcastle
Exhibition and conference

28 - 29 September
TCT Show + Personalize
NEC, Birmingham
Additive manufacturing exhibition

19 – 20 October
Engineering Design Show
Ricoh Arena, Coventry.
Conference, workshops and exhibition

For more event details go to www.eurekamagazine.co.uk

NEWS

Here is a selection of the latest products featured on the Eureka website. Just enter the reference number in the search box for the full story.

Cooled thermal camera for industrial **111924**

Quiet, oil-free compressor **111921**

Shaft bearings self-align for consistent fit **111890**

Quick to install inverter drives **111889**

Vector control drive for multi-pump solutions **111926**

First capacitive miniature force sensor **111987**

Extra flexibility at high temperatures **111897**

Soluble 3Dprint material provides support **111396**

MapleSim release enhances model development **111671**

FloEFD CFD software cuts time **111849**

CPI to support metals innovation

The Centre for Process Innovation (CPI) is to run an innovation support programme aimed specifically at small and medium sized businesses operating across the UK metals processing supply chain. This programme will enable companies to respond to the changing business environment caused by the recent downturn in the steel sector.

The £400,000 programme is being funded through Innovate UK. CPI will leverage the existing relationships with the Materials Processing Institute and other Centres in the High Value Manufacturing Catapult, which will supply much of the on the ground delivery resource.

This programme aims to improve innovation processes and give participating companies the opportunity to develop new projects that will prepare them for the future.

Graphene filters for nuclear waste

Researchers from the University of Manchester have demonstrated that graphene can simplify the production of heavy water and help clean nuclear waste by filtering different isotopes of hydrogen. The process could mean producing heavy water for nuclear power plants could be ten times less energy intensive, simpler and cheaper. Membranes made from graphene can act as a sieve, separating protons – nuclei of hydrogen – from heavier nuclei of hydrogen isotope deuterium. Deuterium is widely used in chemical tracing technologies and also as heavy water required for operation of nuclear power stations.

The heaviest isotope, tritium, is radioactive. Future nuclear technology is based on fusion of the two heavy isotopes. The researchers tested whether deuterons – nuclei of deuterium – can pass through graphene and boron nitride. They found that deuterons were not only effectively sieved out by the one atom thick membranes, but were sieved with high separation efficiency. Dr Marcelo Lozada-Hidalgo, University of Manchester, said: "This is really the first membrane shown to distinguish between subatomic particles, all at room temperature. Now that we showed that it is a fully scalable technology, we hope it will quickly find its way to real applications."

Combined solar and hydrogen energy

A team of scientists have come up with a new type of energy system, dubbed 'hydricity', which combines the power of sunlight with hydrogen fuel. The solar-hydrogen energy hybrid system could have the potential to provide renewable power around the clock. An integrated system would produce both steam for generating electricity immediately, and hydrogen for storing it for later use.

The team, from Purdue University, Illinois and Switzerland's Federal Polytechnic School of Lausanne, said it can produce hydrogen at an efficiency of 50% and electricity at an unprecedented 46% efficiency, due to the way the high-pressure turbines can be used to run in succession of the lower-pressure ones.

Over the course of an average 24-hour cycle, it's claimed that hydricity could reach a Sun-to-electricity efficiency of 35%, which is as good as the best multijunction photovoltaic cells combined with battery power. The hydrogen fuel produced alongside the electricity could be used in transportation, chemical production and other industries; it doesn't discharge when stored or degrade with repeated use.

Eaton and Nissan power ahead with second-life battery systems

Eaton and Nissan have partnered to combine their expertise in power electronics and lithium-ion batteries respectively, to bring reliable and cost-competitive energy storage and control technologies to the market.

Robert Lujan, electric vehicle director (left in picture), Nissan Global, said: "The batteries as power units far outlast the typical life of a car. Having produced our own electric vehicle batteries at our leading manufacturing sites for many years, this scheme will allow us to expand the life of our existing 24kWh product therefore reducing the need to use additional resources to produce new batteries."

Nissan's lithium-ion electric vehicle batteries are given a second-life in these UPS systems, where they can be stacked and used to power private residences, small offices and data centres up to grid-scale applications. It is claimed that, with 'gentle' use, the batteries could last up to 10 years before needing to be replaced.

Cyrille Brisson, vice president marketing (pictured right), for Eaton's Electrical business in EMEA added: "These systems will really facilitate the wider adoption and deployment of renewable generation; giving people greater control over their energy supply and consumption. The multiple benefits of such a unit include continuity of supply, increased grid stability and efficiency, avoidance of peak energy tariffs and reducing the reliance on expensive fuels like diesel to compensate for no-grid or poor-grid situations."

There is also an onus on providing developing parts of the world, such as Sub-Saharan Africa with a cheap form of renewable energy to replace expensive and polluting forms of power.

Brisson added: "Over 3billion people rely on polluting and inefficient cooking, lighting, and heating methods that are expensive and have serious health impacts. Enabling the delivery of cleaner, more affordable energy to these people, including the 1.2bn people who have no access to electricity at all, will really make a difference."

Solution to last month's Coffee Time Challenge

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In last month's Coffee Time Challenge we asked you to look at the humble loo brush and suggest either alternatives or ways that it may be improved. The solution we had in mind is called LooBlade. While not a radical rethink of the role of the loo brush, it demonstrates a rethinking of every element of it. Key elements are:

- Swipeclean technology, 8-blade cleaning head maintains contact with the bowl, swiping the surface clean and reaching under the rim with ease;
- Bacteria-neutralising anti-microbial additive kills 99.9% of germs that come in contact with the blades;
- Unique hollow-point head feature helps clear blockages;

- Ventilated holder ensures any remaining moisture is quickly evaporated;
- Hydrophobic coating means that water runs off quickly, minimising dripping, drying quickly and improving hygiene.

In next month's Eureka we go a step further and discuss a toilet design that does away with the need for the toilet brush altogether. It also uses no water and offers a complete recycling solution.

TECH BRIEF

Toolbox enables system-level modelling

Maplesoft has released the MapleSim CAD Toolbox, an add-on to MapleSim that allows engineers to understand and improve their mechanical designs by importing their CAD assemblies into MapleSim. The toolbox allows engineers to learn how their designs will behave as part of a larger, multi-domain system, and apply the analysis tools of MapleSim to investigate and optimise their designs and final application.

The MapleSim CAD Toolbox imports CAD models directly into MapleSim, recreating the model components and preserving their kinetic and kinematic properties as well as the spatial relationships between components. It offers feature detection, allowing users to add new coordinates at points of interest, such as the centre of a hole or along the edge of a component, and share coordinate frames between separate bodies, ensuring the bodies will be properly aligned when joined.

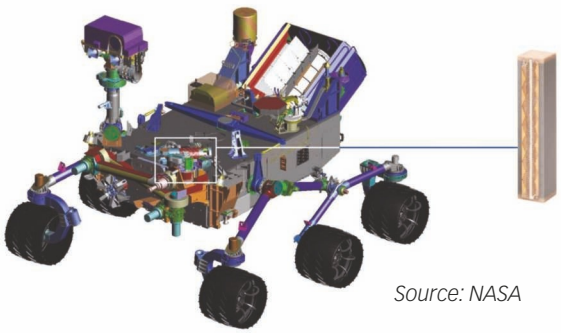
The CAD toolbox handles files from virtually any CAD system.

Piezo actuators make their mark in space

Piezo actuators convert electrical energy directly into mechanical energy and allow for motions with a resolution in the sub-nanometer range. They achieve travel up to approximately one millimetre and there are no frictional parts to limit resolution. With no mechanical wear, as motion is based on crystalline solid state effects, piezo actuators are the ideal drive solution for many precision applications in industry, life sciences, microscopy, medical engineering and research.

The service life and reliability of piezo actuators can strongly depend on the conditions at the site of application as humidity, temperature and operating voltage have a considerable impact on performance. Since no polymer insulation exists that is absolutely impermeable, the life expectancy for conventional polymer-insulated piezo actuators can decrease dramatically at high humidity. Ingressing moisture combined with the electric field applied, can cause a short circuit between the electrodes, which will create irreparable damage to the actuator. The service life of the piezo can also be affected by the dynamic operating forces and alternating mechanical stress conditions.

The answer lies in using the best materials, the manufacturing processes, appropriate design and the insulation material. Once that is proven to be right, there is nothing to stop their use even in the most extreme environments, like outer space.



Source: NASA

100 billion cycles without failure

35 million miles away on Mars, PI's PICMA multilayer piezo actuators are a component used within the NASA Curiosity Rover project. They perform oscillations of a chamber that contains rocks and rock powder that has been scooped up from the surface of the dry planet. At frequencies in the range from 0.9 to 2.2 kHz, the chamber can sort particle sizes or separate rock according to density.

To be selected as a component on-board the $2.5bn project, the PI actuators service life was tested and needed to deliver incredible results. The extensive NASA performance tests showed that 96% of original deflections were still achieved after 100 billion (10^{11}) cycles. Therefore, PI actuators were chosen to be part of the car sized robotic rover that to this day is still exploring the red planet.

Low operating voltage

The effect that the applied voltage has on the lifetime is particularly important. At 80V for example, the service life is expected to be 10 times higher than what can be expected at 100V. PICMA® actuators are also a step ahead in terms of operating voltage in contrast to most conventional actuators because they achieve their nominal displacement at operating voltages significantly below 150V. This is achieved with stacking particularly thin ceramic layers.

Virtually any shape

Using modern production technologies, the multilayer actuators can be manufactured in virtually any shape. Round or triangular cross-sections with insulated centre holes can also be achieved on benders, chips and stack actuators, that allows for easier integration. The individual layers are then equipped with electrodes and laminated. As with standard actuators, the ceramic is then sintered together with the inner electrodes using a co-firing process.

Assured repeatability

Stable and reliable operation is as important in space as it is here on earth. All fields of application such as white-light interferometry (WLI) which is often used for inspection tasks in LCD production or high-precision surface inspection in other manufacturing fields, require high dynamic precision positioning that delivers assured repeatable levels of accuracy. This is why, PI's PICMA® multilayer piezo actuators are often selected as the high precision positioner of choice.

PI UK is a subsidiary of the global enterprise Physik Instrumente GmbH. The PI UK office, based in Bedfordshire, is dedicated in supporting UK design engineers with their precision motion and positioning challenges and requirements. Contact one of PI's UK based technical specialists for advice or information on how Piezo actuators or Piezo motors could enhance the accuracy, increase the reliability and reduce the overall cost, within your systems.

PI UK - 01234 756360 or uk@pi.ws

Light **materials** on

Circumnavigating the world in an aeroplane powered by solar energy – a simple enough task? Perhaps not, taking the comparison of the solar powered car. Even without the power burden of having to take-off, the cars undertaking the 3000km Darwin to Adelaide World Solar Challenge are allowed to start off with 10% stored energy to help them on their journey that can take up to two days. In fact, of this year's 29 starters, nine did not finish.

The indignity of finishing the journey on a trailer is not an option for Solar Impulse - reliability is paramount. Additionally, each stage of Solar Impulse's journey would have to be up to five days long, continuously flying through day and night, far longer than its land-based equivalents. So is it 'mission impossible', or just 'mission very difficult'?

The Solar Impulse team are half way to proving it to be the latter as they have already flown in eight stages from Abu Dhabi to Hawaii, where the aircraft waits until the summer of 2016 brings longer days of sunshine. Having reached such a stage it is clear that the fundamental technical challenges have been met, but it has already been a long journey.

It started in 1999 when Swiss adventurer Bertrand Piccard, along with Englishman Brian Jones, circumnavigated the globe in a hot air balloon. It was the first time that anyone had flown around the globe without using any fuel for forward propulsion. Allegedly he proclaimed on successful completion of the journey, with only a few drops left in the hot air burner fuel tank, that the next time he would do it would be without using any 'traditional energy'. And in 2003 he launched the Solar Impulse programme to do just that.

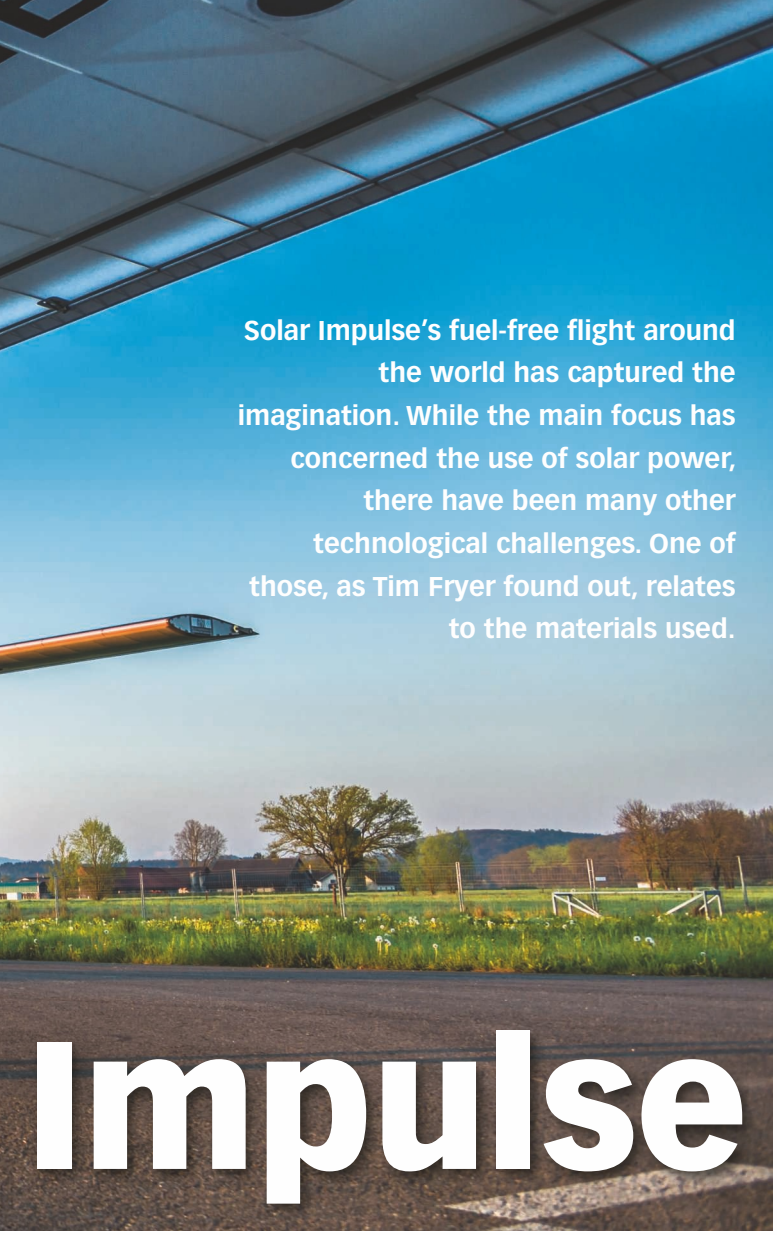
To put the challenge into perspective, a jet airliner uses about four litres of fuel every second – or about 50,000kg of fuel for a transatlantic flight. Transferring to fuel-less flight has meant losing 50 tonnes in fuel weight, a big step in the 'lightweighting' effort crucial to the success of the project.

Eureka has been following the journey, most recently in the May 2015 issue (The strange phenomena of solar flight), just a few weeks after the first leg from Abu Dhabi (United Arab Emirates) to Muscat (Oman) – a 772km journey which took 13 hours.

That article outlined the technology behind the solar flight; the use of over 17,000 solar cells covering the top surface of wings and fuselage to trickle charge the batteries, providing power day and night to the four 17.4hp motors.

Light-weight flight

Providing enough power meant having sufficient solar panels, and the more solar panels you have the more weight and the more power you need... classic chicken and egg scenario. The design settled on an optimum wing span of 72m, 3.5m more than a Boeing 747-8 or Airbus A380. The critical factor in making an aircraft with such a broad wing span



Impulse

Solar Impulse's fuel-free flight around the world has captured the imagination. While the main focus has concerned the use of solar power, there have been many other technological challenges. One of those, as Tim Fryer found out, relates to the materials used.

was to make it as light as possible. That is where Bayer MaterialScience, since renamed as Covestro, has played a major role.

Dr Hubert Ehbing, director of processing and applications technology at Covestro, explained the relevance of the project. He said: "We want to inspire people. We want to encourage people to think about traditional ways of travelling, to think about having this technology and using it in a different way. To create some pioneering spirit with people."

The technology he referred to was not necessarily new, just applied in different ways to push the available limits. Covestro's main concern was to design the cockpit, a space of only 3.8m^3. This only gives enough room for one pilot, enough food (2.4kg a day) for five days, 2.5 litres of water a day and oxygen, as the daytime flight peaks at the oxygen-rare altitude of 8500m. Adding a second pilot would add too much weight and for the same reason there is no autopilot, so the pilots are trained to live on 20 minute sleep segments throughout the day.

This is not sustainable in the long term, which is the main factor limiting flights to five days. There are two pilots, both with the same sleep training, Bertrand Piccard sharing piloting duties with his fellow co-founder Andre Borschberg.

Even though the cabin is small, it was imperative that weight was kept to a minimum, with total weight of the aeroplane being kept down to a little over two tonnes. But, alongside the material being light, it also had to have excellent thermal properties as, once again, heating inside the cabin was a weight luxury that couldn't be afforded. The temperature at 8500m, which is just under the height of Mount Everest, can fall to -50°C and to make it liveable, if not exactly comfortable, for the pilot it must not fall below -20°C.

Covestro supplied foam materials for the cabin, polycarbonate sheeting for the windows and various glues and coatings, but the company had to prove it offered the best solution in all cases.

Dr Ehbing said: "We have other projects where we tested our materials, but they were not chosen simply because other partners supplied better material, mainly as it always has to be lightweight. The most important factor was, 'can you supply some material that contributes most to reduction of the weight?'"

Determining the best shape to house the pilots required several cycles with both mechanical and heat simulation. Then the physical build was started and looped through many design cycles using a wind tunnel and other tests. "It roughly took three years to optimise the cabin structure," said Dr Ehbing.

The final material used to make the fairing (the external structure) was an ultra low density polyurethane rigid foam, which provided the insulation and mechanical properties required to protect both pilot and equipment. It was also easy to make, maintain and repair. This was the critical area. The only sources of heat in the cockpit were a bit from the electronics equipment, but mainly from the pilot himself. The only way of keeping this heat in at night was through the insulation properties of the

foam and the polycarbonate. The foam developed ultimately allowed the target minimum temperature of -20°C to be beaten, as it will not allow the temperature to go below -18°C.

Higher mechanical strength was required for the canopy opening system in case it was needed for a bail out. The required strength was delivered through a polyurethane carbon-fibre composite produced using a resin-transfer process.

The canopy was made of a special thermoformed multi-layer (aka double–glazed) polycarbonate sheet. This provided a glass-like appearance but with mechanical properties that were better than glass. It also added some safety functions such as anti-fogging.

This whole fairing was coated in a specially developed film that improved mechanical performance and provided weather resistance.

Dr Ehbing commented: "We had to develop a special foam here, which had a good combination of mechanical stiffness and little thermo-conductivity. We developed a new micro cell technology by special modification of the foam structure, in doing so we were able to reduce the thermal conductivity of the foam by 40%. That was what was required for the project here."

However, Dr Ehbing claimed this has opened up new application areas. He said: "Think about building insulation for example, or fridges. If you have a fridge that has an installation material, which makes sure that you have less heat loss, up to -40%, you can reduce the thickness of the walls of the fridge, put more food inside and at the same time have a higher rating of your fridge. We are in discussion with fridge manufacturers now."

This foam has a density of less than 30kg/m^3, which Dr Ehbing describes as 'virtually nothing' and as a consequence the total weight of the cockpit area, targeted to weigh in at 35kg, in fact weighs only 24kg.

Beyond the structural insulating foam, other new materials were developed as well – notably several composite materials for mechanical parts and a special flame resistant foam that was used to house the batteries.

Although the main idea behind Solar Impulse is to promote the use of cleaner technologies, there have been both tangible and anecdotal benefits for Covestro in getting involved, as Dr Ehbing described. "We found new materials and new technologies," he said. "But we also involved lots of people here, 30 in total. For us it was very inspiring as it allowed us to get hands on with new technology, bring people together for different functions, share new ideas and push the limits."

www.covestro.com
www.solarimpulse.com

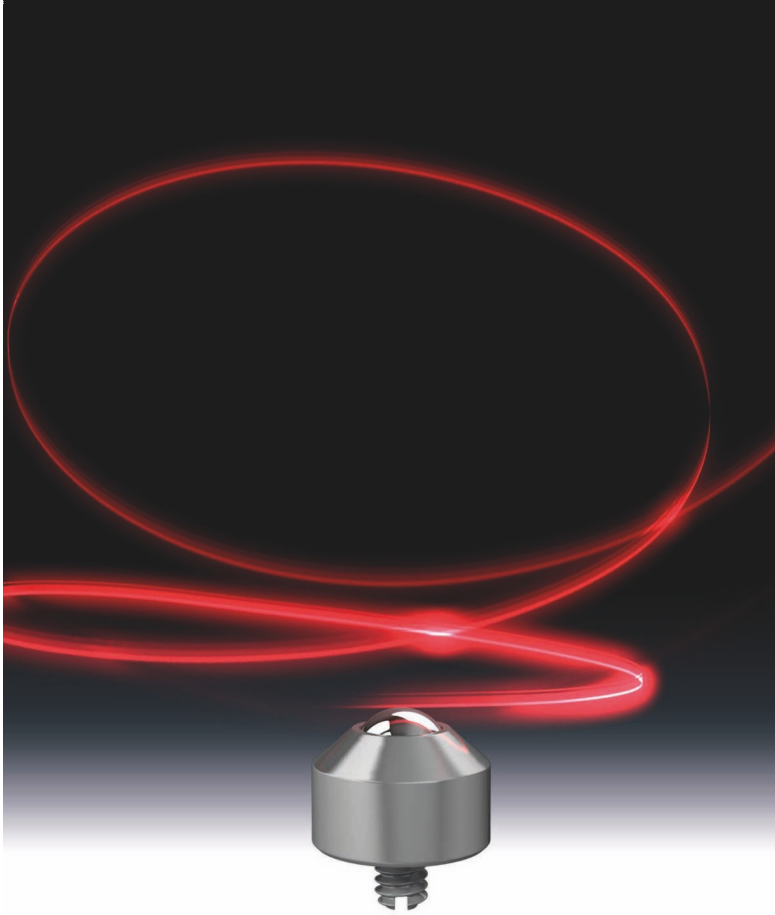
Built to 'convey messages'

The plane making this epic journey is in fact Solar Impulse II, which was largely completed in 2013 although design modifications have continued through the testing and trialling period. The first Solar Impulse was essentially the prototype and work on that was started in 2003 when the founders, Piccard and André Borschberg, started the project. At the time Piccard said: "Solar Impulse was not built to carry passengers, but to convey messages. We do not plan to revolutionise the aviation industry but instead to demonstrate that alternative energy sources and new technologies can achieve what some consider impossible."

The journey so far

The journey from Abu Dhabi to Hawaii has taken on eight legs with stops at Muscat (Oman), Ahmedabad (India), Varanasi (India), Mandalay (Myanmar), Chongqing (China), Nanjing (China), and Nagoya (Japan). The last flight from Japan to Hawaii was easily the longest taking four days, 21 hours and 52 minutes to cover 7212km at an average speed of 86.34km/hr. Maximum altitude was 8874m.

The remaining five flights will first take it to Phoenix and then another US city before travelling on to New York. From there is a choice of a Southern route via North Africa or a Northern route via Western Europe, before a final five day stint back to Abu Dhabi.



CV

David Couthard began racing in Formula One in 1994 following the untimely death of Ayrton Senna, who he succeeded at Williams. He won his first Grand Prix in 1995 and then moved to McLaren in 1996. After winning two races in the 1997 season, he then finished 3rd in the World Drivers' Championship in 1998. He moved to Red Bull in 2005 and secured their first podium a year later. Coulthard retired from Formula One racing at the end of 2008, managing 13 career victories. He continues working with Red Bull as a consultant and joined the BBC as an F1 commentator and pundit.

Life in the fast lane

The off track battle between Formula One teams is as big a part of a race as the drivers fighting it out on track. Justin Cunningham chats to former F1 driver David Coulthard about the changes he's seen and why data crunching dominates performance.

Formula One is a sport driven more by data than any other. Despite austere regulations to restrict performance and development, there is no doubt data steers the design and engineering of the cars and plays a dominant role in managing the on track action.

While data has always been a part of F1, its acquisition and analysis are today as turbocharged as the engines. Witnessing firsthand the way teams have been able to make use of data over the last two decades is 13 times Grand Prix winner David Coulthard. Throughout his 15 year Formula One racing career that started in 1994, he saw teams embrace and leverage all sorts of technology, from 3D printing to lightweight materials. However, none have had a bigger impact on the engineering of the cars than data harvesting and advanced analytics.

"Since I started in Formula One it has gone from conversations around the coffee machine and intuition, to all kinds of information being harvested in real time and sent back to the pits," said David Coulthard, talking at a recent PTC event in Stuttgart. "It is instantly looked at by a team of data engineers at the back of the garage, but it is also sent via satellite to team control centres all over the world where even more engineers and analysts will look at it."

Now a BBC F1 commentator, Coulthard is able to draw on his 246 race starts to give viewers an insight past the glamour, into the heart of today's competitions and into the mind of drivers.

Drivers and cars are no doubt the focus of coverage, but they are the culmination of a much larger engineering effort. Taking Coulthard's career as an example, he spent around 450 hours driving the car competitively, but more than 4000 hours looking at data with engineers.

"One of the big issues with a lot of data is being able to take the good bits and not get lost in the noise," he explained. "A lot of the data coming back is fairly benign, it says that the engine temperature is in the right window or tyre pressure is ok. So, being able to translate that data in to information that can be used to add performance is a large part of racing today."

The use 'Big Data' in F1 is in reality more discrete compared to other applications, generally being confined to two cars, over a weekend, and season. Despite this, the amount of data gathered is immense. Managing and analysing it requires teams of 50 or more, per team, per race. It allows teams to adjust parameters on the car for a safety car or yellow flag, adjust for aging tyres, and even make subtle tweaks to brake balance and differential settings on a corner by corner basis.

"It doesn't matter if it is Grand Prix racing or advertising, whatever product or service you are providing to a customer, it is all about being first to market and best in class, which will see you having continued business," said Coulthard. "In F1, it is about finding anything that will affect your pace. How you react and manage that makes the difference between success and failure."

And this is also a key difference when looking at the way F1 and other industries look at and analyse data. During a Grand Prix analysis needs to be almost instant as live data is streamed from the car.

"It is very much about the here and now," said Coulthard. "Teams can't reflect after the event and come back to rerun a GP the next day. They need to take performance out the data during an event. How will the changing wind and temperature affect the cars performance as they go around the track on a given set of tyres and fuel?

"It means teams are now much better at planning race strategy and optimising when they make pit stops."

However, all this refinement doesn't come without an additional burden. The workload inside the cars is now arguably at its most intense ever, with drivers having to make precise on the fly adjustments as they are wheel to wheel racing at 200mph.

"If you look at a modern day steering wheel, there are 40 odd buttons so the driver can self engineer the car on track," said Coulthard, something that has changed considerably since he first lined up on the grid. "When I first started in Formula One, we had two or three buttons for things like radio and the drinks button. There were very few parameters you could alter once you had taken to the track, and very little that could be analysed when you were off it."

The use of data to bolster car performance is no doubt something that is only going to continue. While driver performance is important, getting a good car is a much larger piece of the competitive puzzle than many may think. While it is difficult to put an exact figure on it, the generally agreed rule of thumb is that the car makes up 80% of performance, and drivers the remaining 20%.

"To win today, it is all about optimising the technologies available," he said. "This is where data really comes in to its own. Data doesn't lie. It tells the facts about performance."

Accelerating train design

It may not be the fastest vehicle on rails but Train Zero is speeding up Bombardier's development of the next generation of rolling stock, as it readies itself for the opening of Crossrail. Tim Fryer climbed aboard.

Testing aerospace subsystems only at the time when they are assembled in the finished aircraft is neither safe nor cost-effective – no one wants to either fly untested equipment or have to go back to the drawing board when it should be the end of the design process. And so the aerospace industry came up with the 'Iron Bird' philosophy. The Iron Bird provides simulation of an entire aircraft, allowing various subsystems to be plugged into it to undergo testing at a much earlier stage in the design and verification process.

It is a 'hardware in the loop' philosophy that has proved invaluable to aerospace companies, and has now found favour in the rail industry. Train manufacturer Bombardier is the company behind 'Train Zero' – the project that aims to cut costs and development times of its next generation rolling stock. It has particular relevance to the company's contract to supply the new trains for Crossrail, but all future train developments will also make full use of the facility.

The consultancy that has designed the system for Bombardier is Frazer Nash, whose brief was to develop a facility that could, 'efficiently develop, integrate and validate train electrical and control systems'.

Colin Freeman, senior consultant with Frazer Nash commented: "The Iron Bird example is always cited where the aerospace industry builds an aeroplane before it flies, bringing all the systems together. And they see massive benefits in terms of their testing, their time to market, their ability to respond to customer change, need, requirements and so on. So there was a desire within Bombardier to take a step change and do something better and different, and that coincided with them looking at developing that next kind of generation of trains. They were looking at a platform-based approach where they could develop these core systems and then tailor things around customer needs."

Model based engineering

Initially the brief had been to improve and shorten the test and validation process but Frazer Nash proposed a model based engineering approach. In this methodology system requirements are modelled early in the design phase and those requirements can be verified through hardware in the loop tests.

Freeman added: "The ultimate aim is to shorten the time that it takes when you actually have that first train built and you come to do the signoff type tests that your customer needs, it effectively passes first time. All of the heartache that you might have suffered previously has been removed by the more targeted, smarter way in the Train Zero facility."

Bombardier works with a lot of third-party suppliers for many of its subsystems. Traditionally those subsystems interface to the train control and monitoring systems found in the driver's cab, but they are now also starting to interface with each other. Consequently there is starting to be a greater requirement to do such things as diagnostic and prognostic testing, and the requirements on those individual subsystems are getting more and more complex.

"Hardware in the loop testing fundamentally is intended to bring those bits of equipment together in the manner that means they think they're on the real train," explained Freeman. "So you can bring in a heating system, you can bring in the door system. You can bring in the propulsion system. You can connect them to the real, bona fide train control system which

The Crossrail trains will be the first to be developed using the Train Zero Lab (right)

Bombardier has assembled for the Train Zero lab. The entire software-based train control and monitoring system which will exist on the Crossrail train is already built in the Train Zero lab. The third-party bits of hardware that are there - sometimes it's an internally developed piece of hardware, sometimes it's a third party company they work with - can now all come together, have simulation models written around them."

Train Zero, which is housed at Bombardier's main manufacturing site in Derby, is purely static, but still has the capability of testing and simulating all moving parts and the environments (e.g. getting too hot) that they might experience.

All these subsystems do, of course, have a wide variety of different interfaces and this presented Frazer Nash with one of its early challenges. "We had to look at the needs of each individual system and say, okay, what interfaces does that have with the train? What interfaces does it have with the outside world? What interface does it have with other systems? How much of that is going to be real, how much of that is going to be simulated?" said Freeman. Typically that involved breaking the system down into elements of the controller, the actuators that it drives, and the plant - the real world environment that goes on around that - and the sensors that monitor it. Freeman continued: "When we came to the point of how can we realise it, what's the best software? What's the best hardware? What's the best approach to use? That's where we brought National Instruments to the table."

What complicates the picture is that there are nine fundamental designs of train carriage and each has many further variations, ranging from the drive systems right down to the lighting in the drivers cabin. Each configuration must be tested as a unique solution. Freeman said; "The National Instruments kit that we used gave us that distributed IO so we could take appropriate test resources and put them where they needed to be on the Train Zero. Every time something changes, it's relatively simple to make sure that that's had a negligible impact on the rest of the design."

Test management

In terms of the software, it quickly became apparent that the NI VeriStand platform was ideal in that it created a single environment in which to combine, execute and manage all the tests. It meant that software and models the suppliers had already worked on could be bought together, irrespective of whether it was in C or C++, MatLab or LabView, it was no longer a bespoke Bombardier environment. "We could compile them altogether, put them all behind a nice neat front-end which looks to all intents and purposes like drive desktop train," added Freeman, "and not have to throw away things - really great stuff that's been done in the past by both Bombardier and its suppliers for this new approach. It's allowed us to pick up what already existed, add to it, refine it, take it in a certain direction, but certainly not throw anything away."

The actual hardware platform behind the Train Zero is PXI based, an advantage of that being in its easy deployment, as Freeman observed: "We've got a PXI based hardware platform and VeriStand gives us access to those resources straight out of the box. We can easily configure that hardware within the VeriStand environment to either communicate direct to a controller or we can take our models, compile them, place them within that VeriStand environment and quickly build up the entire train."

Consequently, Train Zero has the potential of playing an important role in the design process. No longer will suppliers - internal or external – have to work to a initial specification and then hope it works in a final solution. Instead suppliers can use Train Zero as an ongoing part of their own iterative design process, therefore encouraging innovation.

Trains, effectively, can be designed by Bombardier and its partners in tandem, and the first product of Train Zero should be ready in 2017 in advance of the opening of Crossrail.

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The Carbon Spring technology gives you the flexibility to adjust your spring rate in any increment. The great thing about building a single spring from many small elements is the ability to alter just one element and affect a very small change on the assembly. Or, swap out many components and see a large change.

In this way, a Carbon Spring stack can be tuned in very small or large increments. This tune-ability of rate, along with free length and displacement offers unprecedented flexibility in making spring rate decisions.

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Titanium springs often have a high cost per rate! Utilizing a stock of Carbon Spring elements from which to build your required stack and rates, Hyperco Carbon Spring technology can save you money.

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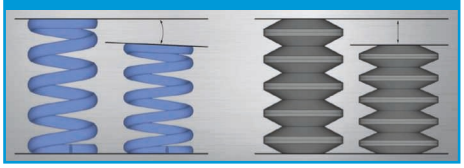
WOUND SPRING	CARBON SPRING
Parallel ends tilt under compression.	*Parallel ends remain parallel under compression.*



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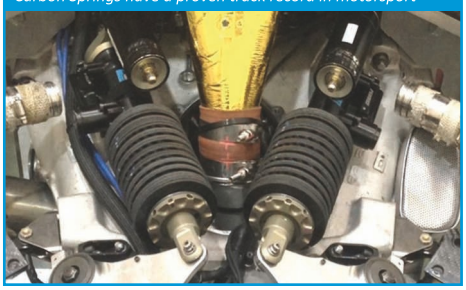

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Riding the future

A UK company has launched one of the more controversial products of recent times in the hope to bring best practice to an emerging market. Justin Cunningham finds out more about the engineering effort behind Uniwheel.

It was supposed to be the Christmas present to get, but last month Amazon pulled personal rideable self-balancing scooters from its website amid fears they could catch fire. Incredibly around 15,000 were confiscated by UK custom officials, between October and December last year, being deemed unsafe for use. What's more, using one on public pavements or roads is being labelled an offence by officials. In short, these personal electrically powered vehicles have become known for their controversial status as much as anything else.

In the midst of all of this, you would guess then it is not the best time to launch a self-balancing scooter? Well, not for one UK tech start up based in London. Last month, Uniwheel invited UK press to its launch event to show off its self-balancing electric mono wheel with the aim to convince the press that these boards are safe, easy to ride, and have a place in 21st Century Britain.

"We see a big future in the UK market," said Steve Milton, chief executive of Uniwheel. "But, we also see big markets in other Europe cities, which are embracing this technology as a way of moving around. It would be a shame for London to fall behind."

Legal obstacles

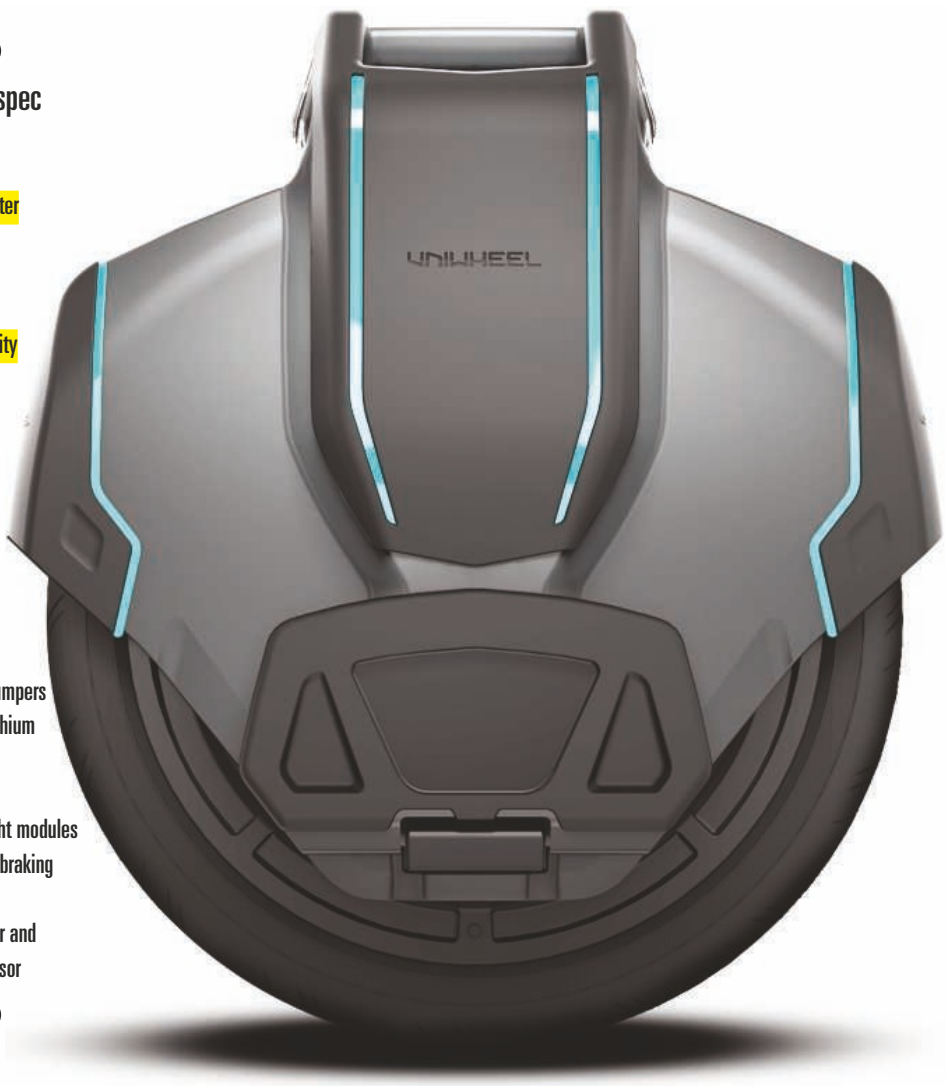
The company understandably question why The Highway Act of 1835 is being referenced by councils and Police departments as reason for making the gyro-wheeled electric vehicles illegal for use on anything but private land.

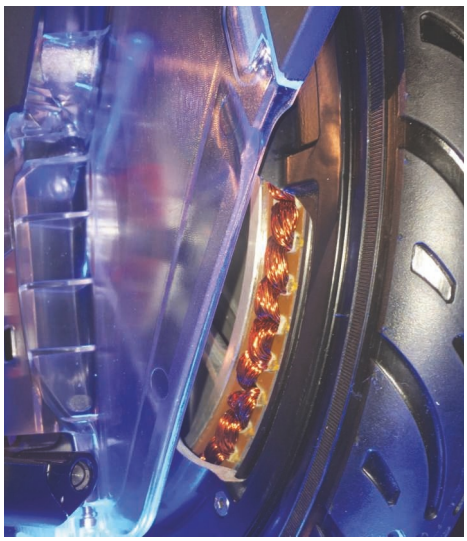
"We are lobbying and pushing very hard to try and change the law because it is so outdated," continued Milton. "It includes things like tying up a mule against a post. How can a law from over 150 years ago take in to account new technologies?"

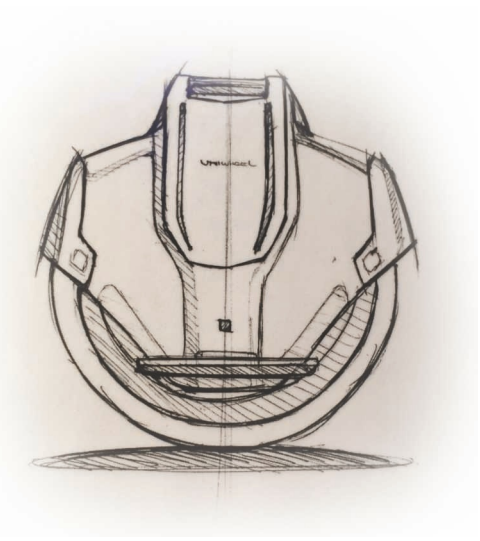
Uniwheel is of the opinion that the law needs to adjusted and brought up to date, but it is also in favour of having the emerging personal electric vehicle market regulated to ensure that safety and build quality standards are something

Uniwheel spec

-Weight
10.8 Kg
-Wheel Diameter
16"
-Max Speed
22 Kph
-Battery capacity
132 Wh
-Charging time
90 mins
-Motor
1500W
-Rated load
100Kg
-Range
11-15 Km
-Replacable bumpers
-Swappable lithium batteries
-Bluetooth 4.0
-Bright LED light modules
-Regenerative braking
-64 BIT CPU
-Accelerometer and gyroscopic sensor







everyone has to comply to.

The team is proud of the fact that Uniwheel is designed, engineered and assembled here in the UK, with expertise and engineers coming from a number of big names in industry including the William F1 team, Jaguar Land Rover and Dyson.

The device follows the broad principles developed for the Segway Personal Transporter, initially released in 2001. At the heart of the design are two 3-axis paired solid state accelerometer and gyroscope sensors – essentially Inertia Measuring Units (IMUs) – which measure acceleration in all three axes, as well as yaw, pitch and roll. This information is fed in to a Proportional Integral Derivative (PID) controller that sends output commands to the 1500W internal hub motor. Uniwheel lead engineer, Eric Sokolowski, said: "When you lean forward it applies power to try and keep you upright."

Two steps beyond

The Uniwheel also uses a pair of infrared sensors above each step, where riders place their feet. If the rider comes off, the Uniwheel knows it, and instantly stops. "We think that should be a standard in the entire market," said Sokolowski. "We're trying to set precedents for the good design and good practice of these devices."

Hall Effect sensors are also used to tell if the steps are folded up or down, and correspondingly if it is about to be ridden. A capacitive sensor is used under the handle to detect if a hand is present, so the device knows it is being carried, and not about to be ridden.

"It is a lot more complex than a lot of the products on the market as we have quite a few sensors and use network architecture," explained Sokolowski. "We have one board that is responsible for the axillaries such as the outside sensors that improve usability, and then we have the main control board to calculate how much power to put into the motor."

The battery is a removable Lithium Iron Phosphate pack that offers the necessary power discharge to accelerate Uniwheel to its top speed of 22kph. Battery selection was also at the heart of delivering the necessary range, rated between 11km and 15km depending on users' weight and how fast they ride and accelerate.

"It is my daily commuter," said engineer, Carson Brown. "All of the engineers here commute on these every single day. I commute 5.5 miles each way and it take me 28 minutes. The tube take 32minutes. This is more fun and I'm in the fresh air. It does take a bit of refining to learn, but when you get it, you get it. You don't learn to ride a bike in a day, it is the same with a Uniwheel."

As you would expect from a product that is young, innovative and trendy, the usability and 'experience' is enhanced by a smartphone app to tell users the distance and speed travelled. It gives estimated range remaining by overlaying a circle on a live GPS map. It also allows you to change the response of the device from an eco-setting up to sport mode. And this all helps the device to learn so it can tailor the set up and response of the Uniwheel to the individual based on how they ride.

www.uniwheel.co.uk

The controversy

Those that have purchased the Segway-esk devices face uncertainty about where they can actually be legally used. The Department for Transport has referenced the Highways Act of 1835 and stated that these devices cannot be legally used on either the pavement or road, and using them anywhere but private land will result in an offence being committed.

The law bans taking 'horse, ass, sheep, mule, swine, or cattle or carriage of any description, or any truck or sledge on the pavement', and many are left bemused that such an old law is now being used. Many users also highlight that this law has not been enforced with skateboards or skaters, which presumably come under the same jurisdiction.

It is a strong sentiment, and unusual for a Government department to single out a product and find legislation against its use after so many have been purchased. Watchdog Electrical Safety First estimate 500,000 people in Britain have bought some kind of personal electrical vehicle, and a further million are considering it.

"You need to use common sense and ride it responsibly," said product design engineer, Steve Godden. "But I have never had any problems riding it in and around London.

"It's like Uber. There is criticism at the beginning but once people use it, learn about it, and realise it is fundamentally better than what is out there now, then they get behind the fact it's worth updating or changing the law for."

But the controversy doesn't stop there, while Uniwheel is confident its device more than satisfies the regulators, some Chinese imports are reported to not even have basic fuses. Several high profile reports claim the dodgy imported devices have caused house fires.

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What to wear?

Bearings design has sometimes led and sometimes reacted to changes in technology. One thing that hasn't changed is that wear on bearings has, and always will be, the single biggest problem the technology faces and a number of suppliers are developing solutions to this problem. Tom Austin-Morgan reports

Where will bearings evolve next? Will it be an innovation in machinery that will require the bearings industry to react, or will a new bearing type facilitate the invention of better machines?

Dr Steve Lacey, engineering manager at Schaeffler, said: "In recent years, there has been a significant increase in the demand for roller bearings that, even under extreme operating conditions including lubricant starvation, highly corrosive or high temperature, still provide a long operating life and optimum performance."

Selecting a suitable material or heat treatment process for bearings often requires advice and guidance, normally from the manufacturer of the bearings. Selection depends on the application itself and the specific environment in which the bearings will operate. This means a number of factors require careful consideration, such as the mechanical, chemical and thermal requirements placed on the bearings, as well as lubrication conditions, particularly if the application requires dry running bearings.

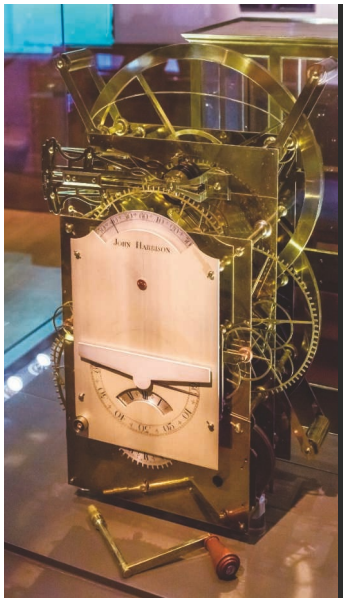
There is a key role here for the type of materials used for the various bearing components (rings, rolling elements, cage, etc.) and how these interact. Some of these materials are industry-recognised standard steels, but others may need to be specially developed by the manufacturer or might involve special surface or heat treatment processes to give the material a certain set of characteristics that are deemed critical for a certain application. Dr Lacey continued: "For most industrial applications, standard hardened rolling bearing steel is sufficient. It is treated, which provides consistent hardness distributed over the circumference and cross-section. The main attributes of this material are high hardness and wear resistance, as well as good resistance to over-rolling."

Roller bearings made from this hardened steel are said to withstand operating temperatures of 120 to 200°C. There are variations of this material, including bainitic hardened steel which reduces the risk of crack formation. Carbonitrided steel is heat treated to provide excellent stability and hardness in the outer functional layer by having increased residual austenite content. This quality is especially suitable for use in applications with a high risk of contamination.

For industries such as aerospace, bearings manufacturers are required to provide special materials and heat treatments due to the extreme conditions the bearing will operate in. For example, M50 steel is used in main shaft bearings and turbine rotor bearings on aircraft engines. This meternsitic hardened material provides thermal stability up to 400°C and increased toughness at high operating speeds. Even harder than these are M50NiL steel which can be subjected to high loads, very high rotational speeds and have a high tolerance to damage.

Oxide-based ceramics, such as zirconium oxide, are used where current insulation as well as wear resistance is required. These sintered materials can be used up to 600°C and are normally used for rolling elements that come into contact with steel-based bearing rings and used in low-load, dry running and corrosive environments like electric motors for car windows.

Silicon nitride-based ceramic rolling elements are suitable for use in food processing applications and machine tool spindle bearings. The main advantages of this material are its low mass and ability to withstand operating temperatures up to



Ancient solutions

Bearings are as old as mechanical design itself, and may even predate the invention of the wheel. It is often claimed that the Egyptians used roller bearings in the form of tree trunks under sleds to move the massive stone blocks used to build the pyramids.

However, the first recorded use of a roller element bearing comes from 40BC; a wooden ball bearing supported a rotating table found in the remains of Roman ships in Lake Nemi, Italy. Leonado da Vinci incorporated drawings of ball bearings in his design for a helicopter in the 1500s. One hundred years later, Galileo proposed a way to prevent friction in these designs by enclosing the balls or rollers in a cage, which was put to practice by John Harrison in his H3 marine timekeeper (left) in the 1740s.

700°C as well as high speed capacity, current insulation, very high wear resistance, reduced friction and increased grease operating life.

GGB Bearing Technology's DU bearings turn 60 next year. In 1956 Glacier Metal Company, GGB's predecessor, introduced the world's first self-lubricating metal-polymer plain bearings.

The DU bearings are comprised of a steel backing for mechanical strength and a porous, sintered bronze interlayer impregnated with PTFE and lead for high wear resistance and extremely low friction properties.

Over the years since this initial breakthrough, GGB's experience in polymer processing and compositional formulations have led to a series of self-lubricating metal-polymer bearing products that offer further advances in performance.

These advances have resulted in a range of stronger, more durable and environmentally friendly lead-free bushings and bearings that perform well under harsh conditions in both dry and lubricated applications.

For example, the DX series that followed was the first thermoplastic lined bearing material which provided improvements in wear resistance and load carrying capability, especially for greased and oil lubricated applications.

Recently GGB has developed DP4 and the bronze-backed DP4-B metal-polymer bushings, originally developed for automotive shock absorbers, these bearings are now used in virtually all applications from aerospace to the food and beverage market.

GGB's DP31 PTFE bushings provide low friction as well as resistance to wear, fatigue, flow erosion and cavitation. Typical applications include fuel injection pumps, power steering pumps, compressors, engine valve-train bearings, hydraulic cylinders, transmission bearings, and hydraulic pumps and motors.

Igus has pioneered plain bearings made from a polymer material called iglidur; these are lubrication-free and need no additional maintenance. They are versatile, with a different colour-coded grade for virtually all industry sectors that require a product to withstand extreme temperatures and harsh chemicals.

Certain industries are switching to plastic plain bearings due to their dry-running nature because they are clean, grease-free, light weight and wear free.

"The latest innovation we've implemented is in 3D printing," said Rob Dumayne, director of energy chain systems and bearings at igus. "Bearings made out of our I3-PL SLS filament material show comparable strength and durability as our core iglidur product range while featuring higher tolerances and a better finish."

Performance bearings for high speed trains

A range of high performance bearings from NSK have been selected for a prestigious new high speed rail project in Japan. The bearings have been specified for the H5 rolling stock to be deployed on the Hokkaido Shinkansen high speed rail line being constructed between Shin-Aomori and Sapporo – the initial section of which is due to open in March 2016. The trains are said to reach speeds of around 200mph.

Hokkaido Railway Company selected NSK's oil bath, double-row cylindrical roller bearings for the axles, a product that can facilitate high speed rotation while generating very little heat. Ceramic-coated insulated bearings were chosen for the main traction motors. The proven safety record and lightness of these bearings is claimed to boost reliability and help prevent electrical pitting on the rolling surface.

NSK has supplied bearings to all variants of Japan's Shinkansen rolling stock since the initial '0 Series' was launched in 1964.

Battery boosts *'E' appeal*

The first season of Formula E captured the imagination of many, and was enhanced by pioneering – and reliable – battery design. Tim Fryer reports.

Sébastien Buemi may be a familiar name to motor sport enthusiasts, in 2009-11 he drove for the Scuderia Toro Rosso Formula One team, and he is now making a name for himself in the fume-free environment of Formula E, the all electric premier motorsport series run by the FIA. After the first three rounds leading up to the Christmas break, Buemi leads the championship driving for the Renault e.Dams team. The series continues at the beginning of February 2016 in Buenos Aires and concludes in London in July.

Unlike F1, the current driver standings is not ordered in pairs according to the racing team, although each team does have two drivers. In F1 the car performance plays a significant part in the results. In Formula E this is less significant, at this stage at least, as the cars were the same in season one, with individual development of the e-motor, inverter and transmission allowed in the current, second season.

Built and designed by Spark Racing Technology, the cars have powertrain and electronics from McLaren, a chassis designed by Dallara, bespoke tyres from Michelin and system integration by Renault. At the heart of an electric vehicle contest is inevitably the battery and for this Formula E turned to Williams Advanced Engineering.

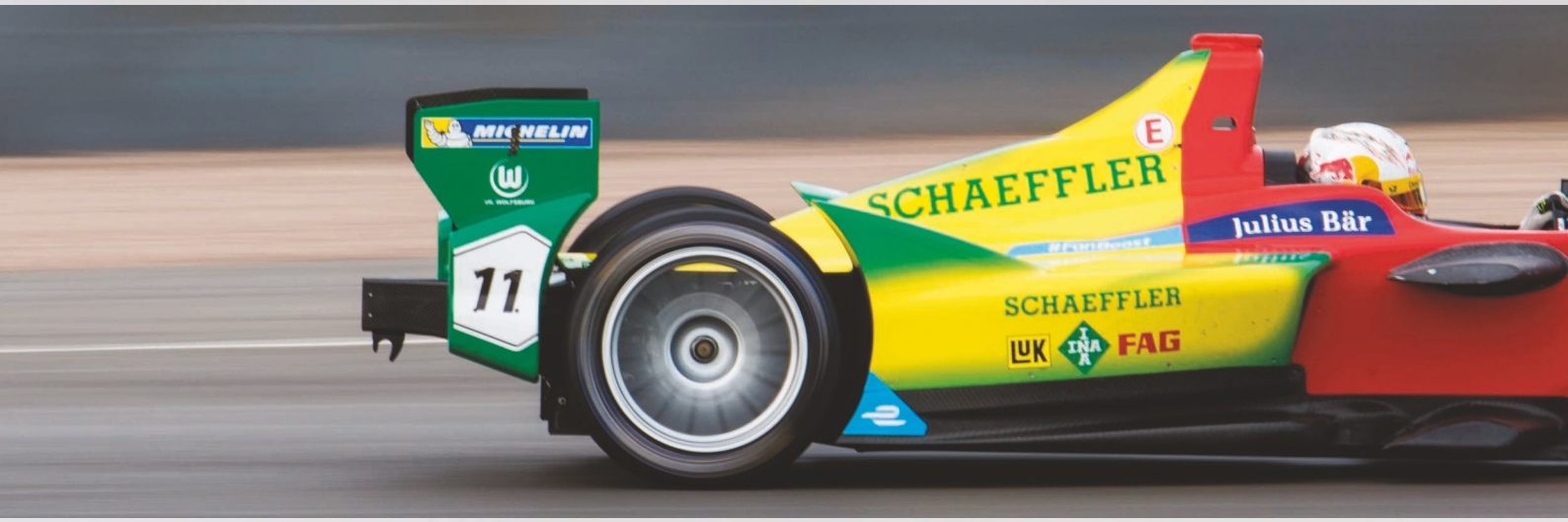
Ian Cluett is head of programmes and commercial at Williams Advanced Engineering and observed: "This level of co-operation historically is unusual in motorsport, but I think it's needed those different organisations to pool their expertise together to develop a car in the time that was available."

This journey began for Williams back in 2006 when it was announced that F1 would go hybrid in 2009. At that point the company looked at two different engineering streams. One was a magnetically loaded composite flywheel-based system. It was tested in an experimental Porsche GT car and Audi won Le Mans using it between 2012 and 2014 but it never raced in F1. There have also been trials with London buses in an attempt to improve fuel efficiency, but Williams took the technology as far as it wanted to and sold it to GKN in 2014.

Cluett continued: "What we raced in F1 was a battery based hybrid system with the energy storage mechanism, and then that's gone through an evolution through Formula One, through C-X75 [Jaguar's concept hybrid vehicle] into Formula E."

Like the first season, the second season of Formula E has a 'series' battery, meaning all cars use the same one. In fact two are used in each race as battery life is not enough to complete a race, so each driver has two cars, each of which will be raced for 20 minutes. In the reactive world of motorsport it has not been decided what will happen next year. Cluett commented: "The intention is that as we get to Season 5 we will have a single car race, but we're pretty hopeful that Seasons 3 and 4 will run with a series battery - an enhanced version of the Williams battery. This season a number of the teams are running their own motor gearbox and inverter solutions, so you'll start to get some powertrain differentiation."

Last year we got through 440 race cycles with only one battery failure. So we were pretty pleased with that.
Ian Cluett

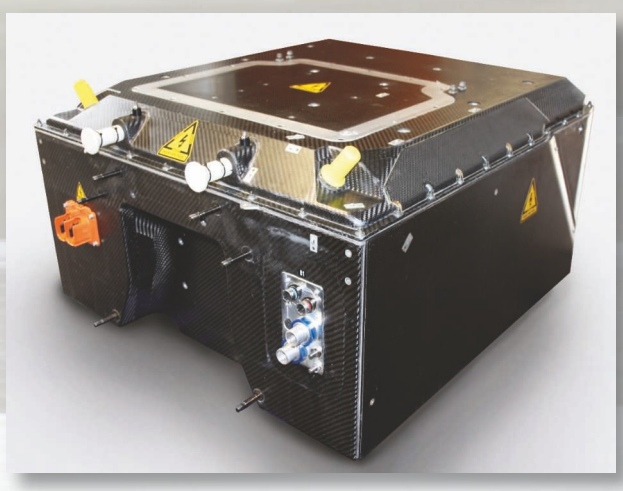


Given this competitive and increasingly open development environment, Williams is understandably cagey about the precise technology within the batteries beyond 'lithium-ion and other cell technologies'. However patent applications for both thermal management system and battery case technology are indications that this has been a big evolutionary step for the design team.

The car itself accelerates from 0 - 100 km/h (0-62mph) in 3 secs and can reach a top speed of 225 km/h (140mph) – more than enough for the city centre circuits that Formula E is raced in. There are very few of the long straights that feature in F1 circuits and the city environment was specifically chosen so that Formula E was not just fun and technically challenging, but also relevant to the future of urban transport.

Developing a battery to meet these criteria was not easy, particularly given the timescales. Williams came in late to the process after the initial battery developer pulled out, giving Williams only 12 months for the whole design, development and test cycle.

Design of the battery has been almost entirely down to the Williams team. Cluett said: "The FIA have become involved through crash safety - they set the crash standards for batteries in racing series. And then also we use calibrated FIA sensors to monitor current and voltage - therefore power in and out of the battery - to ensure everyone's got an equivalent amount of energy they can use. So that's where the FIA has been involved. Within the battery itself, it was all down to us."



Cluett continued: "It looks like a relatively straightforward box, but the box itself is stress member. It is part of the chassis of the car. It bolts onto the crash cell at the front of the car. and then the gearbox and the motor hang off the back of the battery. So the case itself takes quite a lot of stress during a race cycle. It's got something like 4500 parts inside."

Given the complexity of these units, Williams has had to develop a specific battery build facility for this project, at a peak there was up to 20 people manually building the batteries. In the interests of uniformity and therefore fairness, each battery had to be exactly the same, so four cells dedicated to testing Formula E batteries were set up , each capable of testing up to 300kW/1000V/800A.

"The essence of the series is really all about how you use energy," concluded Cluett "So each driver has a fixed amount of energy, it's up to them how they use that. Anything they can regenerate through braking is free, effectively, that just gives them more energy to use to drive the car forward. We're seeing many different strategies being used within the race series, and I think this would drive some of the developments within electric cars as we go forward in the next few years."

Presumably this is not intended to encourage driving like Sébastien Buemi round city centre streets at 140mph, but there is increasing evidence it's becoming more viable.

Renewable racing

Racing electric cars only demonstrates environmental benefits if the electricity to charge them is generated without the associated by-products of burning fossil fuels. For this reason Formula E has signed up to RE100, a collaboration of major organisations who have publicly committed to working towards using 100% renewable energy. During the first year of the championship, Formula E powered its electric race cars with renewable electricity using an innovative zero emission fuel glycerin to run a generator. The new technology is called 'Aquafuel'. The generators are based on standard production diesel engines that have been adapted with Aquafuel's patented technology to run on glycerine.

Achieving these specifications required a maximum battery power of 200kW (equivalent to 270bhp). This is only used for qualifying. In race mode the power is limited to 150kW with an additional 'FanBoost' of 30kW allowed for 5 secs per car.

The **balance** of *power*

Torque vectoring certainly sounds cool, but is it something that's actually useful? Justin Cunningham investigates.

If Jeremy Clarkson was an engineer, it's possible he may have worked on a recent transmission innovation from Redditch based GKN Driveline. The presenter famous for his catchphrase, 'POWER!!' would almost certainly approve of the torque vectoring technology it's developed.

While the automotive industry has been keen to talk about downsizing engines in recent years, many are complaining the fun is being taken out of driving. Bucking the trend is the 2016 Ford Focus RS. Despite using Ford's 'EcoBoost' engine, the Focus RS will produce 350hp, and if that isn't enough to bring the fun factor back, the car will use a torque vectoring all-wheel drive (AWD) transmission system.

GKN Driveline was awarded the development programme just 18 months ahead of the cars' launch, which didn't give its engineers much time to design and integrate the system it is calling the Twinster. It consists of a Torque Vectoring Rear Drive Module (RDM), the Power Transfer Unit (PTU) and Constant Velocity Joint (CVJ) side shafts into the front wheel drive platform. GKN's in-house software and calibration teams also worked in collaboration with Ford and its vehicle dynamics engineers on new control algorithms to optimise the torque vectoring system.

The Twinster uses modular architecture to enable it to be tuned for various applications from stability and safety to higher speed handling and drivability. In this case, Twinster allows even a novice to feel like Lewis Hamilton behind the wheel by increasing the dynamic feel and handling of the Focus RS.

"It allows a non-professional driver to handle a car like a professional driver," said GKN Driveline vice president of global product technology, Dr Ray Kuczera. "The transmission will know throttle position, steering wheel angle, what the vehicle is doing in terms of sliding, oversteering or understeering, and then work out where to apply power to get it to do what the driver wants.

"It's modular so can be designed based on whatever it is you're looking for. It can be tuned for off-road use, which is the way we tuned it for the Range Rover Evoke, or for safe, assured, on-road performance. But, you can also get extreme off-road or extreme driving from it that is at the limit of performance too."

Computer generated drifting

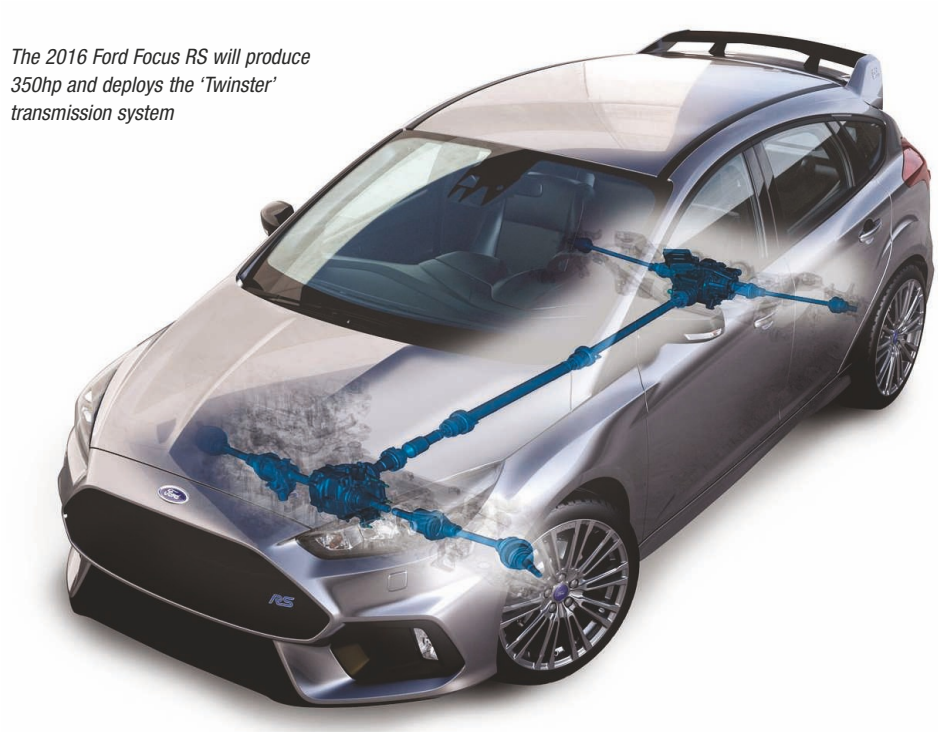
For professional drivers, setting up a car to control oversteer and understeer is part of the job. Knowing when to apply power, brakes, add steering or counter steering, often all simultaneously, is a skill that is gradually developed.

The GKN Twinster system has essentially taken that experience and packaged it together to emulate the skill of professional drivers using clever algorithms in conjunction with its AWD capability. Essentially, the car knows how to corner better than you.

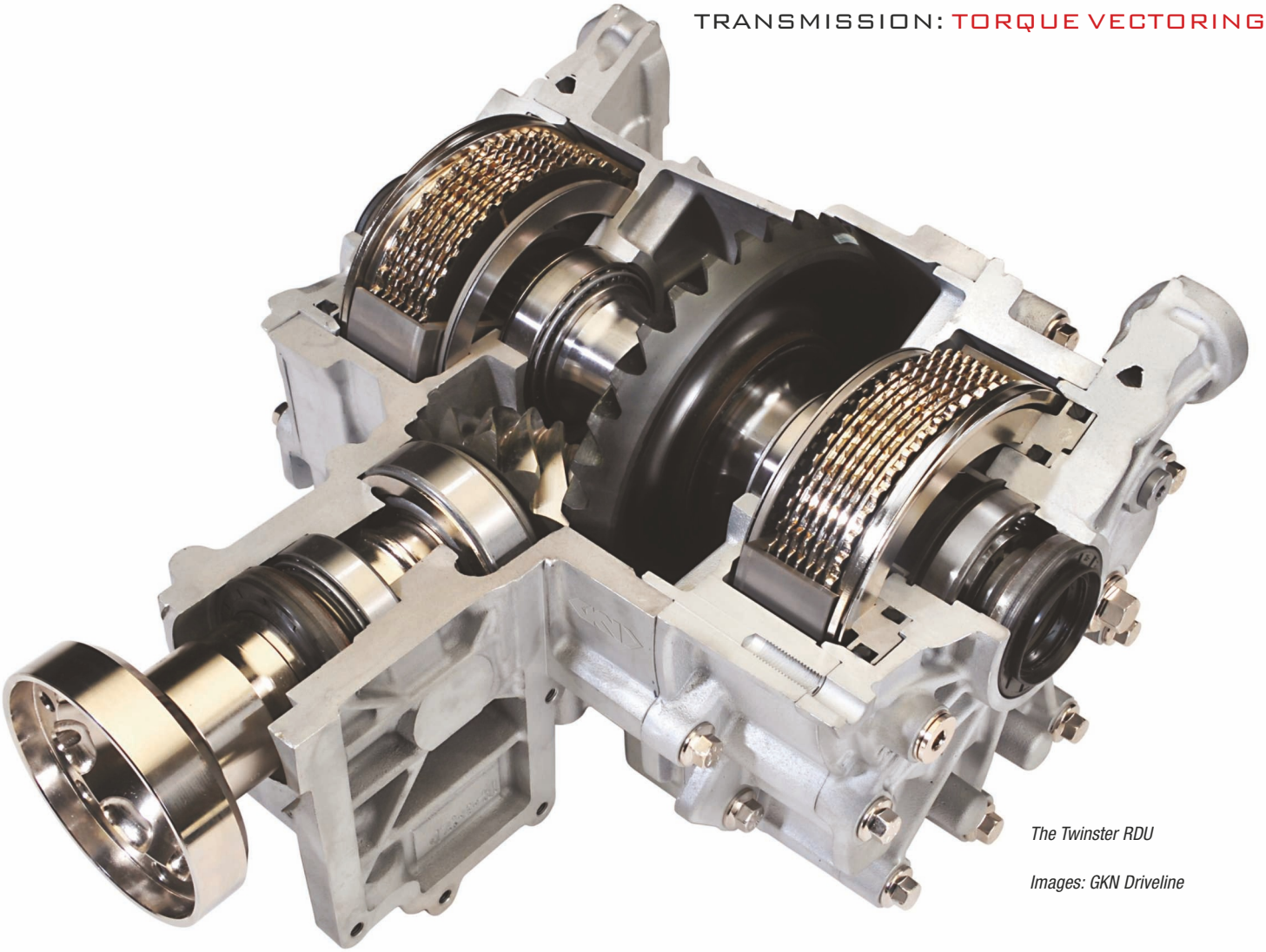
Professional drivers probably cringe at the thought of the Twinster, and are no doubt banned from using these kinds of systems anyway. However, for enthusiasts seeking to fulfil dreams and push the limits corner by corner, the Twinster gives stability, control and a certain amount of forgiveness for those that are a little too keen.

Its rear driveline module (RDM) controls the power between the front and rear, and also between each rear wheel. The torque to the rear wheels is individually controlled by a pair of modulating clutches on each side between the transmission and each wheel.

"They are constantly being varied between being completely open (no torque) and full engagement (essentially locked)," said Michael Clarke, media relations manager at GKN Driveline. "Any state in between is possible, it is not binary on or off, so can be anywhere between the two states based on the driving requirement. The



The 2016 Ford Focus RS will produce 350hp and deploys the 'Twinster' transmission system



The Twinster RDU

Images: GKN Driveline

system is designed to cope with the constant slip that occurs in the RDM. It has been extensively tested so the constant slip is not a problem for durability. The way power is distributed from the front to the rear is through a device called a Power Transfer Unit (PTU), which attaches to the transmission. The PTU takes torque from the front and sends it to the rear through the propshaft. The PTU is located at the end of the transmission, so whatever gear the vehicle is in, all of the wheels are in the same gear."

The front wheels use a traditional differential with no clutches for active control, though there is normal transmission clutch.

Big challenge

A big challenge was how to handle the power. The engine developed by Ford is a 2.3L, 350hp 4-cylinder turbo, delivering 475Nm of torque at the wheels. Designing and controlling a transmission system that can not only put the power down but also modulate it millisecond by millisecond between all four wheels is nothing short of a technical marvel.

While the Twinster can have a similar result as Electronic Stability Control (ESC) systems, which artificially improve handling by applying subtle braking to individual wheel, this all-wheel drive (AWD) system increases power to certain wheels to increase control.

"We steer the vehicle by applying torque to a certain wheel," said Dr Kuczera. "With brake based traction control and electronic stability programmes you're robbing the vehicle of power. With torque vectoring you're sending more power down, so instead of slowing the vehicle down, you're speeding up certain wheels."

The Ford Focus RS uses a selector on the dash to pick a driving mode, which can go from regular driving to the most extreme setting, 'drift mode'. This has the effect of oversteering the rear of the car in a very aggressive manner.

"In this mode the Twinster drives the rear wheels faster than the front," said Dr Kuczera. "This overspeeding of the rear fundamentally changes the way the car feels and handles. In curves, the Twinster makes the vehicle turn in more sharply, responding more immediately to the driver's inputs."

Of course, there is still a need to brake on occasion. And while this system adds stability during acceleration, it works in conjunction with stability control systems that work under braking.

"For driving and handling, torque vectoring is the best way to make the handling better," said Dr Kuczera. "But for stability, if I've lost control of the car, then it makes perfect sense to use the brakes to bring the car back under control."

The twin clutch system is also being applied elsewhere. The 2016 Cadillac XT5 premium SUV will also use similar technology using it for on-road stability as well as off-road traction.

"It makes the car great to drive, makes it very safe, and gives you off-road capabilities in a luxury Cadillac SUV," said Dr Kuczera.

At almost twice the price of a basic Focus (£15,995 vs £29,995), the Focus RS with its Twinster technology is a car for those that want to be engaged with their driving experience, and are willing to pay for it. Clearly, however, you're not going to drive the vehicle to its limit on a visit the supermarket, but what the Focus RS does offer is a commuter car that can double as a track day car.

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Less is more in aerospace

Adoption of additive manufacturing is on the rise. Chris Jones outlines why it could find a natural home in the aerospace and defence sector, not just as it fits the low volume high value profile, but because it brings genuine engineering design advantages.

The core technology behind additive manufacturing, at a basic level, is not a new thing. However, despite initially being conceived in the 1980s, recent technological advances have brought this process from a novel and futuristic intrigue, to a present day reality.

The demand for additive manufacturing is growing: the global market is expected to increase from $3.07bn in revenue in 2013 to $12.8bn by 2018, exceeding $21bn by 2020. This is no more so apparent than in aerospace and defence (A&D) production and MRO applications, which currently account for around 15% of the global market. So, what impact is additive manufacturing having on A&D?

Streamlined for speed

3D printing is helping manufacturers address issues such as weight reduction and speed of production. The former of these is vital in aerospace, as 1g on the ground is equivalent to around 40 to 50g in the air. With greater efficiency and reduction in fuel usage high on the agenda, every gram of weight saved counts. The latter has a greater role to play in MRO as the constant high pressure placed on parts results in some components needing to be regularly replaced. The faster this can be done, the less time aircraft fleets spend grounded – an issue that is costing the industry vast sums of money. Airbus China, for example, recently estimated the cost of a grounded A380 Airbus to be $1,250,000 every day.

In the defence sector, reducing weight is also critical, with emphasis placed on achieving lighter loads and vehicles, as well as reduced inventory at military bases. There is also currently greater scope for the use of additive manufacturing in unmanned, rather than manned, vehicles due to the reduced required safety parameters when there is no human pilot present in the cockpit and the smaller capacity of the vehicle. This was exemplified by the recent 3D printed drone launch off the HMS Mersey, and the technology will certainly continue to play a role here in the production of faster and lighter drones.

Roadblocks to overcome

Despite the advantages of additive manufacturing in A&D, there are some challenges that need to be addressed before the technology can be adopted more widely across the industry. The nature of the inherent risks associated with aviation makes it a highly regulated sector and this impacts the speed at which 3D manufacturing processes are being adopted. The technology has drawn heavy scrutiny from regulators and manufacturers face a challenge in proving the safety of products produced by this new process and gaining accreditation. Some of the areas regulators are keen to focus their attention on over the next few years are how printed products will behave over time and based on the materials used, and it will be interesting to see how the industry adopts means to accelerate its adoption.

Nevertheless, A&D remains at the forefront of the take-off of additive manufacturing and despite the regulatory barriers, there are already innovative uses demonstrating significant results.

Hollow rotating blades

Rotating or runner blades are one of the most important components of rotary heat engines. It is in the moving stages that the thermal energy is converted into kinetic energy and thereby the motive power is generated. The aerofoil or outer part of the blade must be finely tuned in design, with several aerodynamic considerations involving complex Computational Fluid Dynamics. All of this is geared towards providing maximum thermal efficiency by optimising

aerodynamics, while still meeting safety requirements in strength and withstanding vibration.

There are however, two key challenges to address to ensure this can be achieved. Firstly, in conventional manufacturing, machining is subtractive: meaning the material is gradually removed in shaping the design. This imposes significant constraints on the design when trying to achieve optimum levels for these opposing variables of safety and aerodynamics because of the base process of production, the end-product is not optimised.

The nature of the inherent risks associated with aviation makes it a highly regulated sector and this impacts the speed at which 3D manufacturing processes are being adopted

Secondly, blades' aerodynamics must be optimised but, during operation, they are subjected to very high centrifugal and pressure forces that result in a high level of stress that the design must be able to withstand within the safety limits of the material. The stages of aerodynamic design and strength / vibrations tests are completely independent of each other and must be conducted one after the other. But each of these stages favours virtually opposite preferences: the light-weight design is more aerodynamic but more likely to fail under strength and vibration stresses.

Additive manufacturing addresses both these issues. Firstly, it is, by definition, a procedure where components are shaped by adding layers of material. This permits much greater complexity when shaping the aerodynamic design and makes it possible to manufacture components with blind cavities, in this case, hollow blades. This is impossible with traditional methods and unlocks new opportunities and benefits that could not previously be realised.

Looking at the second problem of stress pressures, the centrifugal forces produced by rotation have the greatest focus at the base and almost zero at the tip. The pressure loads are highest on the outer surfaces but almost non-existent in the centre. Thus there is plenty of scope to remove material from the inner regions and nearer the tip of the blade without compromising the blade's safety or strength. This weight reduction actually further reduces the centrifugal force and therefore the stress acting on the blade.

But aerodynamics is paramount, and therefore the outer surfaces cannot be compromised to preserve the original design for high efficiency. Additive manufacturing makes this win-win scenario possible. In fact the lighter design aerofoil has resulted in nearly a 30% reduction in weight for a major aircraft manufacturer and around a 40% subsequent reduction in reaction force.

In recent years, there has been a rapid rise in the recent adoption of additive manufacturing, in no small part due to its uses in A&D. Despite regulatory hurdles to overcome, significant cost and efficiency benefits are being seen across the design and manufacturing lifecycle. Additive manufacturing is set to continue to have a transformational impact on the A&D industry and it will be fascinating to see where the next innovations come from.

The author is Global Aerospace and Defence Lead at Cyient
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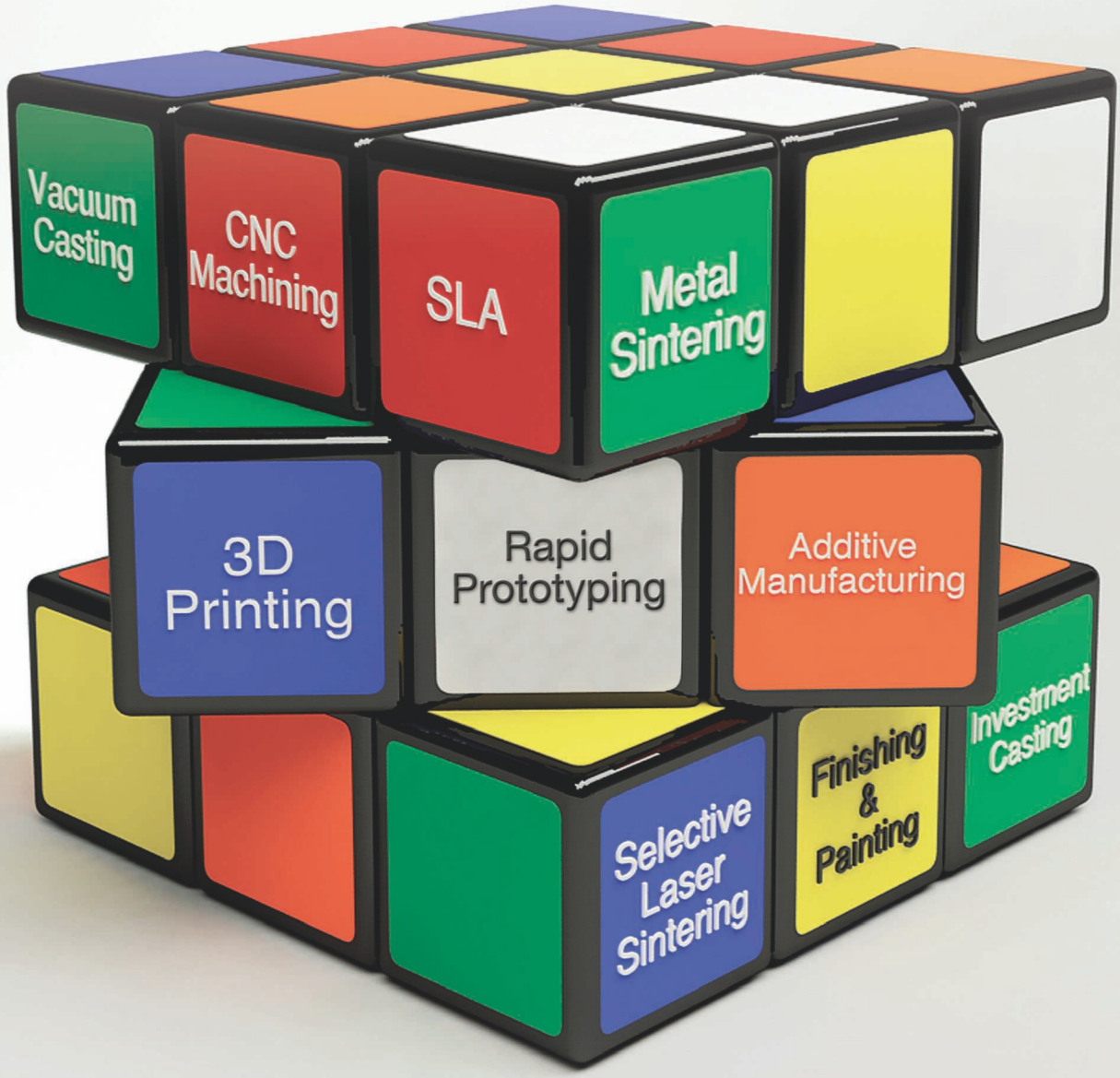

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That annoying bulge

The British plug is a design classic. Its unique 3-prongs that protrude from the plastic enclosure have become the standard both here in the UK and in many parts of the former British Empire.

Designed in the 1940s to combat a foreseen shortage of copper in post-war Britain, the design also put significant emphasis on safety. The third prong, not present in many other contemporary plug designs used around the world, makes accidental shock difficult as it acts as an earth. It is also the longest prong, therefore first and last to enter an electric main.

However, it is bulky. It was designed for use with lamps and of course the household wireless, and never had sleek tablets or mobile devices in mind. It means that for us Brits, and many of our commonwealth cousins, packing a plug for a mobile device leaves an annoying bulge.

In an age of optimisation, continuous redesign, and sleek product development, the humble 3-pin plug has become antiquated.

The challenge

The challenge this month is therefore to redesign the 3-pin plug for the present day. For a start the plug should be able to be stored or packed away more easily, so making it as thin as possible, preferably without the annoying prongs protruding outwards causing that bulge, is essential. In addition, any design changes must not compromise safety – in fact greater safety should be sought, though they should work on all fuse ranges up to 13A.

This is, however, not a complete redesigning exercise. The three pins must remain. Rolling out a new plug system to so many countries and users is well beyond the remit.

The plugs should also reflect the growing use of USB to charge a variety of devices. It is therefore appropriate that any plug should be standalone, and allow USB cables to be plugged in to it... preferably more than one.

The plug should of course be rugged, though it's unlikely any solution will match the bulky virtually indestructible lumps currently in use.

As always we have a solution in mind that will be published in next month's issue, but if you have any entertaining or interesting solutions then feel free to leave a comment on our website or email the editor at tfryer@findlay.co.uk.

Our solution to last month's Challenge, how to improve or reinvent the humble toilet brush, can be found on page 10 of this issue.

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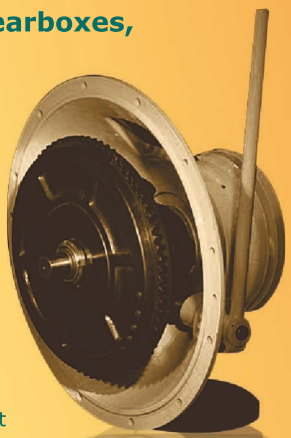

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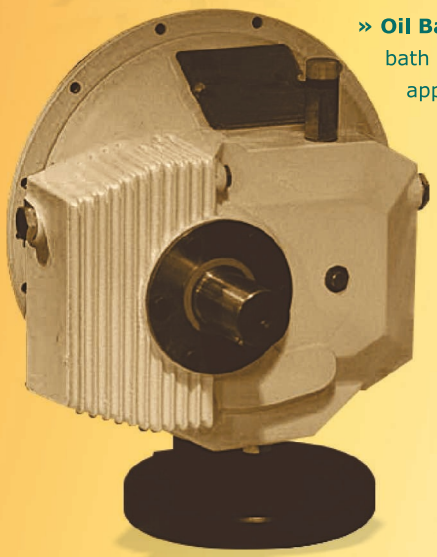

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