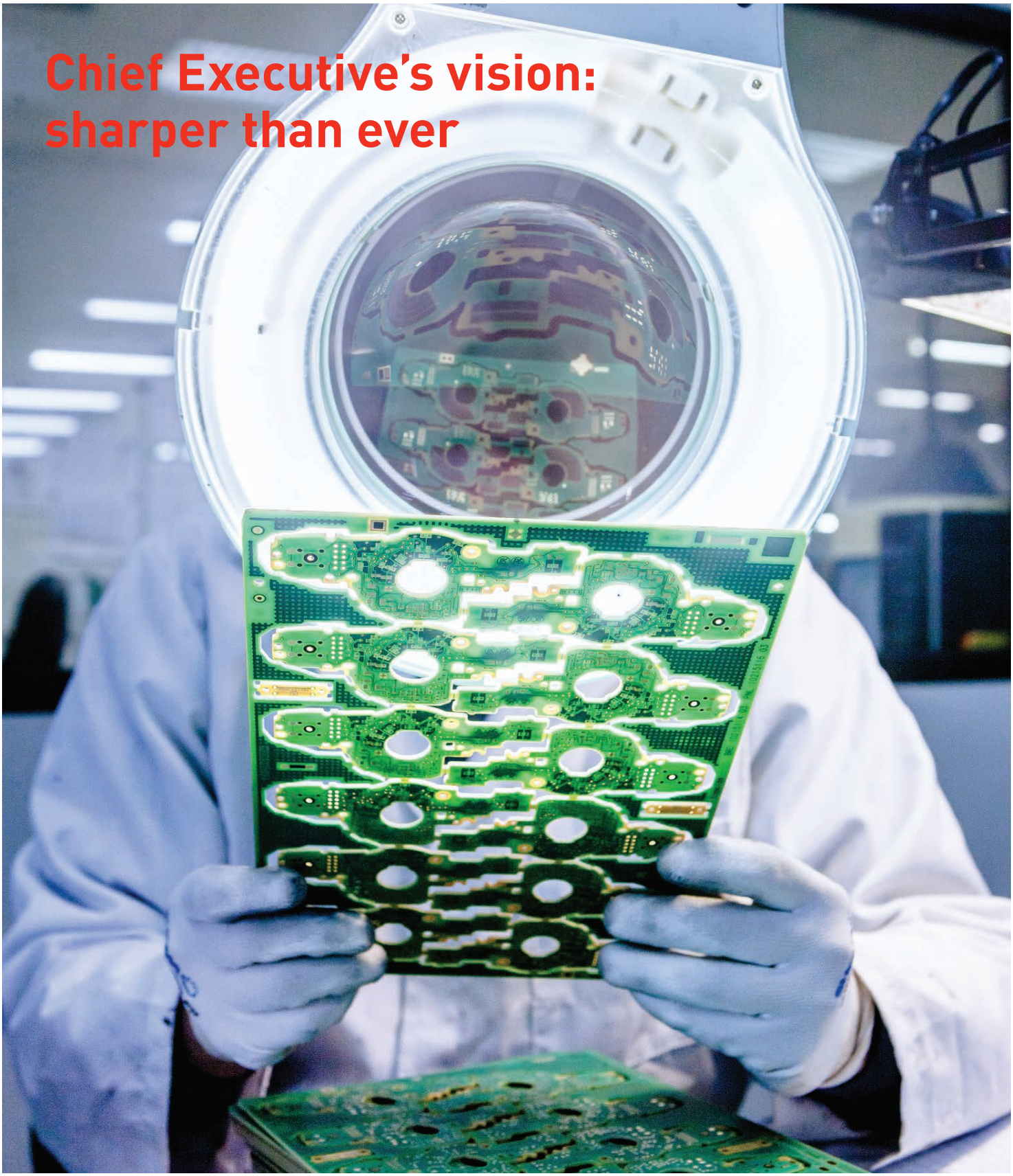
MEGGITT

REVIEW

A MAGAZINE FOR EMPLOYEES
SUMMER 2015

Chief Executive's vision: sharper than ever



• Stephen Young sets strategic priorities • Meggitt pioneers factories of the future and intelligent workbenches • Smarter materials just got smarter with advanced composites acquisition • Aftermarket centralisation begins • China facility moves into high tech manufacturing • Group AR&T innovation attracts funding and partnerships • Quality management and business intelligence systems go global • Meggitt prints 3-D valves and etches Sopwith Camels

Front cover: **Through the magnifying glass.** An operator quality checks the position of screen-printed resistors on a printed circuit board at Meggitt's sensor plant in Spain. These boards appear behind the dashboards of most global car marques, controlling everything from headlamp angle to air conditioning. Read more from page 72.

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Meggitt Production System top of the bill—but great acts in the wings

In January, Chief Executive Stephen Young set out his strategic priorities to some 100 Meggitt leaders, planting the Meggitt group firmly into 21st century operations, technology and higher level customer relations. Six months on, the Review asked him to expand on his thinking and outline progress.

If Stephen Young's name is on any initiative at Meggitt, it is the Meggitt Production System (MPS), closely followed by a renaissance in applied research and development (AR&T). He has championed the wide-ranging operations excellence programme since becoming Chief Executive a little over two years ago and it remains firmly on his agenda. If the process could be accelerated, he says, he would increase the group's investment in it. Factory by factory, MPS is delivering palpable gains in on-time delivery (OTD) and quality, earning new levels of trust from Meggitt customers. Some of them, like Sikorsky with Meggitt Polymers & Composites in Rockmart, have even become participants in MPS.

"It is early days but the system is going well and gaining real momentum. However, it is a process that cannot be hurried if its impact is to last," says Young. Of some 50 Meggitt facilities, two thirds are using the system. A third of those are in the second 'Yellow' phase either starting—or with an eye to—the third 'Green' (practice-makes-perfect phase), where sustainability will be tested to the limits by Meggitt's central MPS assessment team.

For the very few businesses across the group not exposed to MPS, this continuous improvement system comprises the optimum combination of business improvement methodologies for Meggitt. A small central team has used tried-and-tested tools and techniques from the last 20 years of production history around the world to create a system that works for any of Meggitt's diverse businesses. From Coventry to China, from training software to handmade crashworthy fuel tanks, from workforces in the tens to sites of over 1000 employees, the system's claims to 'flexibility, scaleability and targetability' are proven.

"The objective of the MPS implementation is to earn the unwavering trust of any Meggitt customer in the ability of any of our businesses to deliver on time and to the required specification," Young summarises. Operations are to be a core Meggitt strength, a defining competitive advantage. "Most of the big players in aerospace have something similar. However, in terms of where we are in the food chain, we are out in front."

> We need better and more aggregated data and we need it at the push of a button, not the end of the month and that is what Mrep will deliver

THERE'S MORE TO THE SYSTEM, however, than high-class operations at factory level. The Red, Yellow, Green and Bronze phases of MPS's six-phase system culminates in what Young calls 'Supplier Gold'. This refers to the many supplier assessment programmes in which Meggitt must score highly if we are to become customers' default long-term partners.

"The factories are steaming ahead but to progress through the next three phases

Unstoppable momentum

'I'm very optimistic about the next five years. In terms of the long-term health of the business, we're doing all the right things,' said Stephen Young in a recent filmed interview discussing his strategic priorities with journalist, Tom Maddocks.

The film is available through HRISon. Local HR representatives will make arrangements for viewings for any employee who is not on-line.

The new Quality Management System is an essential building block of corporate maturity

of Bronze, Silver and Gold, the entire group must be engaged," he explains. "This means synchronising MPS at strategy level." That process has begun. He cites the first Group functional launch in July—to Group HR Operations. In June, MPS was launched to the Meggitt Sensing Systems and Meggitt Control Systems leadership teams. Similar launches to the rest of the divisions and functions will take place over the next 12 months.

Young observes that this unconventional 'bottom up' rather than 'top down' approach has been appropriate for Meggitt. "Typically, when you launch a continuous improvement system of this magnitude, you start from the top, deploying business strategy. We chose a different path. Back in 2012, we wanted to get to 'Supplier Gold' in terms of operational performance as soon as we could. That meant making a big impact on factory floors across the group first. That desire was amplified enormously when we walked into the well-publicised quality problems of 2013."

These quality issues drew attention to Meggitt's supply chain management. In line with MPS' flexibility, targetability and scalability, the group adapted the Meggitt Production System to speed the introduction of some of the system's supply chain elements. Unscheduled audits of key suppliers led to opportunities for more improvements. "Between these quality issues and our vision for operations excellence over the long term, our customers are genuinely delighted with the way we have responded to what was initially a very difficult situation. One of the facilities concerned has just completed the first MPS Red phase with flying colours. The negative has turned into a huge positive," says Young.

"Now we have got to the stage where we have established some pace in on-time delivery and quality at many operations, so we can roll it out through all aspects of the business—every function, every level—right up to my office."

Young himself envisages participating in a version of DLA, the "Daily Layered Accountability" meetings described as the spinal cord of MPS. The mandatory multi-layered structure of interlocking meetings at the start of each working day creates fresh and accurate performance and operational information flows up and down the management hierarchy of Meggitt factories. Over time, this will reach higher—through the divisions and into his office.

Young's DLAs with his Chief Operating Officer, executive board and divisional Presidents will probably take place twice a week and involve visual factory-style boards aggregating critical information from across the businesses in real time. "Getting that information right today is not as easy as I would like and, while we have not defined all the functional dashboards yet, I can see a time where I will have several on my office wall. The business intelligence system we are launching known as Mrep [management reporting] is going to be a massive enabler in that regard."

Mrep, Meggitt's business intelligence system, will be "best of breed", capable of enabling timely decision-making based on "one source of truth" in a single central data repository (see page 52). The design phase was launched in Q1, with IBM and a dedicated internal team working closely with the SAP Go Forward team and business process owners across the group.

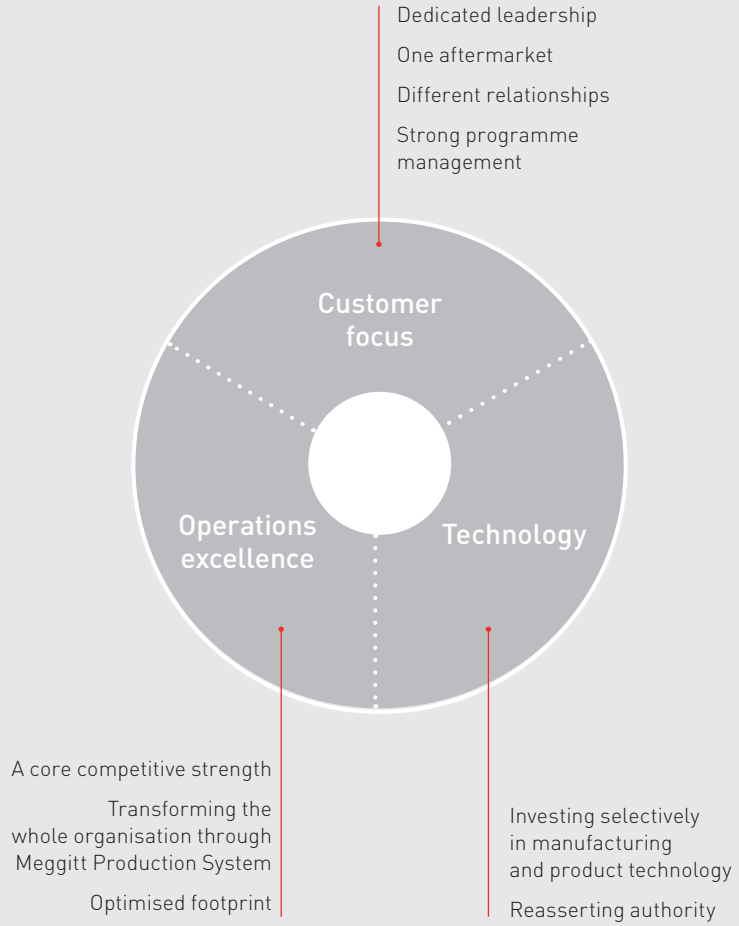
Young explains: "We have a huge amount of data in various management systems—salesforce.com [customer relationship management], SAP [factory management], HRISon [human resources management] and so on. That is a good suite of operating systems. However, each of them has its own reporting. Information has to be retrieved on a site-by-site basis. Getting the three or four critical data from those systems and aggregating them across the group is manually intensive at the moment. We need to manage Meggitt on dynamic information. We need better and more aggregated data and we need it at the push of a button, not the end of the month. That is what Mrep will deliver."

Q1 also saw the launch of a group-wide quality management system (QMS). Part of the MPS operations excellence drive, Young sees this as an essential building block of corporate maturity.

"We must become an organisation our customers can trust and want to do business with, without fail. Part of that involves walking into any one of our factories and seeing in place a globally-competitive system they understand. With one world-class system, we can alert the whole group almost at the press of a button to a supplier issue. With it, we can make one investment, rather than many, in updates and upgrades."

The new QMS embraces all Meggitt businesses, not just aerospace customers. International quality management standards are changing and will affect every Meggitt business, whatever their market. The QMS fully anticipates them so that compliance pays off for every Meggitt business.

Group strategic priorities



If, after the SAP implementation, more standardisation sounds a little tiring, Young is sympathetic. "The businesses have had to work very hard to please customers while building the group's infrastructure behind the scenes. Inevitably there have been growing pains but we have learned many valuable lessons. The QMS and Mrep implementations which are, of course, by order of magnitude much smaller, will be significantly smoother."

Meggitt's SAP Way Forward team is optimising the original implementation with significantly enhanced operational knowledge of this enterprise resource planning system and there have been many improvements to the Group's business processes since launch. "We are making sure we are still getting the best out of our investment as we mature as an organisation."

Young highlights, too, the power of the ongoing MPS implementation to align every function and every business around every plan. "Meggitt Production System creates teams at group as well as site level and enhances the planning, prioritising, sequencing and resourcing of projects across large organisations."

Young draws attention to the group's relative youth. "Some of Meggitt's businesses took off with the dawn of aerospace history in the late 19th century. We're very proud of that. However, we were a decentralised, financially-managed conglomerate up to 2009. Since then, we have behaved as a more integrated group with sites managed by divisions to leverage economies of scale and to make it easier for customers to work with us. At the same time, we have been building the infrastructure and culture that supports that modus operandi. It is difficult and it is time consuming but we are making progress on our journey towards corporate maturity."

One Meggitt—where it makes sense

Meggitt is undoubtedly becoming what used to be referred to as a strategically-managed, interrelated group, sometimes called "One Meggitt".

Many nuggets of technology across the group are waiting to be exploited. Circulating people is one aspect of facilitating essential connections that lead to creative thinking

It is a loose term that could appear to defy the presence of non-aerospace businesses in the group. It is not, however, says Young, market and product specific. "It is about standardising and centralising where it makes sense.

"Clearly, aerospace is our most dominant market and one in which our customers are consolidating and centralising. They want a capability-based engineering group at Meggitt to talk to their capability-based engineering group. The same is true of sales and marketing. As part of that, we need global processes and businesses organised at divisional level."

However, he is confident that every Meggitt business will benefit from the group's investment in the right globally competitive processes, standards and systems—IT, quality, continuous improvement—that deliver what any customer wants on time. "Optimising single global systems is preferable to the expense of optimising many. We must move away from reinventing the wheel locally."

Young sees no conflict between the requirement to standardise across the group and being fleet of foot, entrepreneurial and creative—qualities that are sometimes attributed exclusively to small business culture. "If companies are well run using excellent processes and systems, leaders and others can spend time progressing their businesses rather than dealing with problems. MPS is already having an enormous impact in that respect."

Meggitt's non-aero businesses benefit from discrete financial investments: a brand new factory for Heatric and continuing investment in its expansion; a brand new product line for Piher Sensors & Controls in Meggitt's Chinese facility; a smart acquisition for Meggitt Control Systems' energy business at the beginning of the year, expanding its capability and markets.

And then there is the assurance that comes with the backing of a big group. Meggitt's piezoceramics business in Denmark has made significant inroads into its medical markets that would have been impossible as an independent. "All Meggitt businesses supply products that have to work in extreme environments or fulfil important functions. The financial security of a big company backing you as a parent gives customers confidence that you will be there tomorrow and the day after—and that should not be underestimated."

MAY'S LAUNCH OF MEGGITT CUSTOMER SERVICES & SUPPORT (CSS) demonstrates the concept of "centralisation where it makes sense". Today Meggitt's aftermarket repairs and spares services are dispersed across Meggitt. CSS will draw all those threads together. "Our customers in airline maintenance will start to see the number of Meggitt phone numbers in their address books reduce significantly and a key account management structure representing a wider range of Meggitt capabilities come to the fore." The new organisation will work with the divisions to enhance Meggitt's existing maintenance repair and overhaul operations and create new ones. Meggitt's MRO businesses in Singapore and Miami are directly managed by CSS. They represent a growing number of Meggitt capabilities either through MRO or distribution. "These are models we want to replicate across Europe and in the US. We will also be looking at partnerships in the Middle East and China."

There are other benefits to common management structures and practice. "We want to be able to move people around the group easily and having the same systems, processes and approach is very helpful.

"We want a more mobile workforce because our customers are becoming more and more international—they come from different countries and cultures and we need to be able to tune in to a range of different management styles and approaches."

Even more important than the desire for cultural affinity with customers is Young's interest in developing a cadre of senior managers not bounded by divisional, business unit or facility structures who can demonstrate a broad appreciation of Meggitt products and its customers' requirements. "Customers are increasingly looking to us to put together bigger packages of work—sub-systems that solve their problems. These solutions are increasingly less dependent on component A or component B but packages of components and sub-systems sourced from across our group, not just one facility or business unit or division."

Meggitt Sensing Systems' tyre pressure monitoring system which works with Meggitt Aircraft Braking Systems wheels and brakes is the prime example of that—two divisions working together to provide a brand new product line that has won many new contracts. Most recently, a cross-divisional collaboration transformed a capability in flexible fuel tanks for military aircraft into one associated with complete fuel systems, now the centrepiece of a significant contract with Sikorsky.

A mobile workforce is also a spur to connecting our capabilities. "Our central engineering and technology function is helpful in a 'top down' way," says Young. "It highlights opportunities but you still need conversations to take place on the

In terms of where we are in the food chain, we are out in front

More energy ploughed into energy

At the start of the year, Henry Reinmann (top) was appointed VP, Strategic Account Management, Siemens after a significant career at Meggitt promoting Meggitt Sensing Systems' condition-monitoring systems to the global turbine provider. He is already making essential connections for the group beyond MSS.

In March, further appointments were made to increase Meggitt's impact with GE substantially.

Meggitt's GE Aero Engines' interests have been very well-served by Key Customer Account Director Charles Riccardella for many years. "Now we are increasing the scope of the Group's engagement, says Group Sales & Marketing Director Peter Huber. "Meggitt needs to be involved more deeply and earlier with GE in technical roadmap discussions. We must also satisfy its long voiced desire for stronger on-site technical support and co-ordination."

Accordingly, given Riccardella's extensive technical background and, in particular, knowledge of Meggitt control valves, he is now covering a new divisional role—Local Engineering Representative to GE. He is working closely with Steve Wichtendahl(top right), who was appointed VP, Strategic Account Management, GE. This combines the role of GEAE KCAD forged by Charles, with additional responsibilities representing Meggitt's interests across GE Energy.

Wichtendahl's long career with MSS, latterly as President of MSS's facility in Maryland, USA, makes him ideally suited to grow the group's business with GE in high and low temperature sensing as well as MCS valves. Other roles, including UTC key account management at Meggitt, have given him a good knowledge of the group's key markets and capabilities over all, essential qualities for key account direction.

ground amongst people in the businesses where the specialist knowledge resides." He cites the 'Eureka' moment shared by two graduate programme engineers. After rotating through Meggitt Polymers & Composites and Meggitt Sensing Systems businesses, they realised that combining a certain composite with a certain piezoceramic material could create a new strand to Meggitt's world-leading capability in advanced ice protection. This idea earned its place in an industry consortium concerned with more electric technology and attracted an extremely high rating in a recent successful bid for public funding(see page 32). "Many nuggets of technology across the group are waiting to be exploited in this way. Circulating people is one aspect of facilitating essential connections that lead to creative thinking."

Time to invest in technology again

Meggitt has won an unprecedented number of new programmes from the current bid cycle. In 2014, new product introduction was accelerated, ready to meet the manufacturing ramp-up that will drive financial returns for the next decade and more. Industrialising new products will continue for the rest of this year and into 2016.

Young is looking ahead. "Aircraft in the next major bid cycle will be developed for a world that is more hungry for resources and more regulated in environmental terms. We are locked into a cycle of ever-decreasing operating costs requiring hyper-efficient engines and low-weight components and airframes that must be designed using a new generation of different technologies and different materials. We need to make sure that we continue to remain relevant to our customer's efforts by building on our core capabilities."

Traditionally, aerospace has been very conservative. The technology on consecutive generations of aircraft has been broadly similar. While aerospace engineering has always been demanding, it is a known quantity in terms of the design challenge. "Every now and again, however, you see bigger, bolder steps," says Young. "And in the past, sometimes the industry has come unstuck when it changed from one technology to another. In consequence, our customers want to see products developed to a higher state of readiness before they award programmes."

To balance the requirement for the incremental development of traditional technologies and the development of future products and technologies, Young instituted a central budget of several million pounds to create a central AR&T—Applied Research and Technology—function when he became Chief Executive.

"The central AR&T team acts as my portfolio manager, identifying the technologies we are capable of pursuing and where we think we have a good idea."

The budget is being used to collaborate with external partners, customers and government institutions on a variety of technology projects which include pioneering intelligent workbench and intelligent factories concepts, advanced ice protection, thermal management solutions for next generation ultra-high bypass engines and silent bleed valves.

He is very pleased with the team's efforts at consolidating Meggitt's approach to key technologies like additive layer manufacturing and working with major customers and other industry partners to maximise those efforts.

Now he wants to do more of this at the division level. "I want the divisions to take the same approach—to continue to ask what technologies we need to invest in to make ourselves invaluable to our customers.

"We have a very capable central technology team but the businesses will always know at least as much and more about their own technologies and how they might be developed to the customer's advantage. They have regular access to our customers' engineers in their capabilities and what are they thinking about. They know what problems they are trying to address and how we might help them. That cannot be done as well by the central team as it can by those who have that regular contact."

Meggitt takes a dual approach to filling gaps in its portfolio of technologies. If it is one that exists in the market and it is possible to do so, it will acquire it. August's acquisition of complex aerospace composites businesses from Cobham PLC demonstrate (see page 55).

New OE nodes

With the establishment of Meggitt Customer Services & Support to focus

The businesses have had to work very hard to please customers while building the group's infrastructure behind the scenes. Inevitably, there have been growing pains but we have learned many valuable lessons

Demand for Meggitt parts unprecedented

>1,800

New production introduction at Meggitt—involving over 1,800 new part numbers—is running at three times the historical average.

Research and development expenditure was up 10% to £148 million in 2014.

Some 15 new aircraft platforms are due to enter service over next five years (the historical average is 1.5 platforms per year).

Meggitt Production System creates teams at group as well as site level and enhances the planning, prioritising, sequencing and resourcing of projects across large organisations

exclusively on Meggitt's aftermarket, Young has created a dedicated OE 'node' for customers. This includes key account management under the leadership of former divisional President Peter Huber and responds to the requirement for increased senior level engagement with customers in aerospace and energy. The major turbine producers are centralising procurement and new key account managers have been appointed to grow existing business and look at the long-term migration of Meggitt aircraft technologies into energy. In the short-term, Heatric, Meggitt's compact, high integrity etched plate heat exchanger business, largely focused on oil and gas, is already benefiting from the strength of our new ambassadors' existing OE relationships with the ground turbine producers.

As far as aerospace is concerned, customers were quite fragmented in their approach to the supply chain until relatively recently. Now they are becoming much more joined up. They are more demanding contractually, operationally and in terms of communication. Multiple points of contact on bids and programme management have been replaced by central procurement and engineering teams. So Meggitt must respond using the same structures. Huber will strengthen account management and look at risk/revenue sharing partnerships. With his team, he will coordinate the supply of cross-group product packages and ensure Meggitt engages early to understand our customers' technology road maps, swap ideas and identify the investments we need to meet or even further our customers' thinking.

Young is also providing dedicated programme management attention at group level to enhance customers' confidence in the systems and processes that underpin timely delivery of products to specification.

Given the increasing influence of aftermarket service metrics on the reception of bids, Meggitt Customer Services & Support, OE key account management and programme management functions will work in lockstep. They have to ensure there are no chinks in Meggitt's reputation for predictable delivery and technology vision.

In answer to questions from the group leadership team on where Young sees the group's future, his vision lies in pristine operations, intelligent manufacturing, exerting our technology prowess in our chosen fields and creative collaboration from global Meggitt citizens. Meggitt's growth trajectory can match that of his first decade at Meggitt when he served the business as Group Finance Director. The group can double in size every five or so years through a combination of organic growth and acquisitions. Organic growth will come from two sources: becoming "MPS Gold everywhere", making Meggitt one of the most sought after suppliers in all our markets for cost, quality and delivery performance; and from Meggitt people thinking beyond the boundaries of organisation and capability to create new products, sub-systems and packages. New products will be made in factories that will be showplaces for low volume, hi-tech production.

Aerospace is an especially exciting place to be for Meggitt, says Young. Aircraft will become very complex with high technology linked to everything in which Meggitt is expert now—sensing, monitoring, control and thermal management, for example.

The group will continue to evolve its brake control systems, gradually encompassing more safety and monitoring functions across landing gear. It will continue to further the aims of its non-aero speciality businesses. Meggitt will also be known as a major force in gas turbines for aero and ground-based power generation. "The OEs will look after the core and we will do as much of the rest as they will let us," he concludes. ●

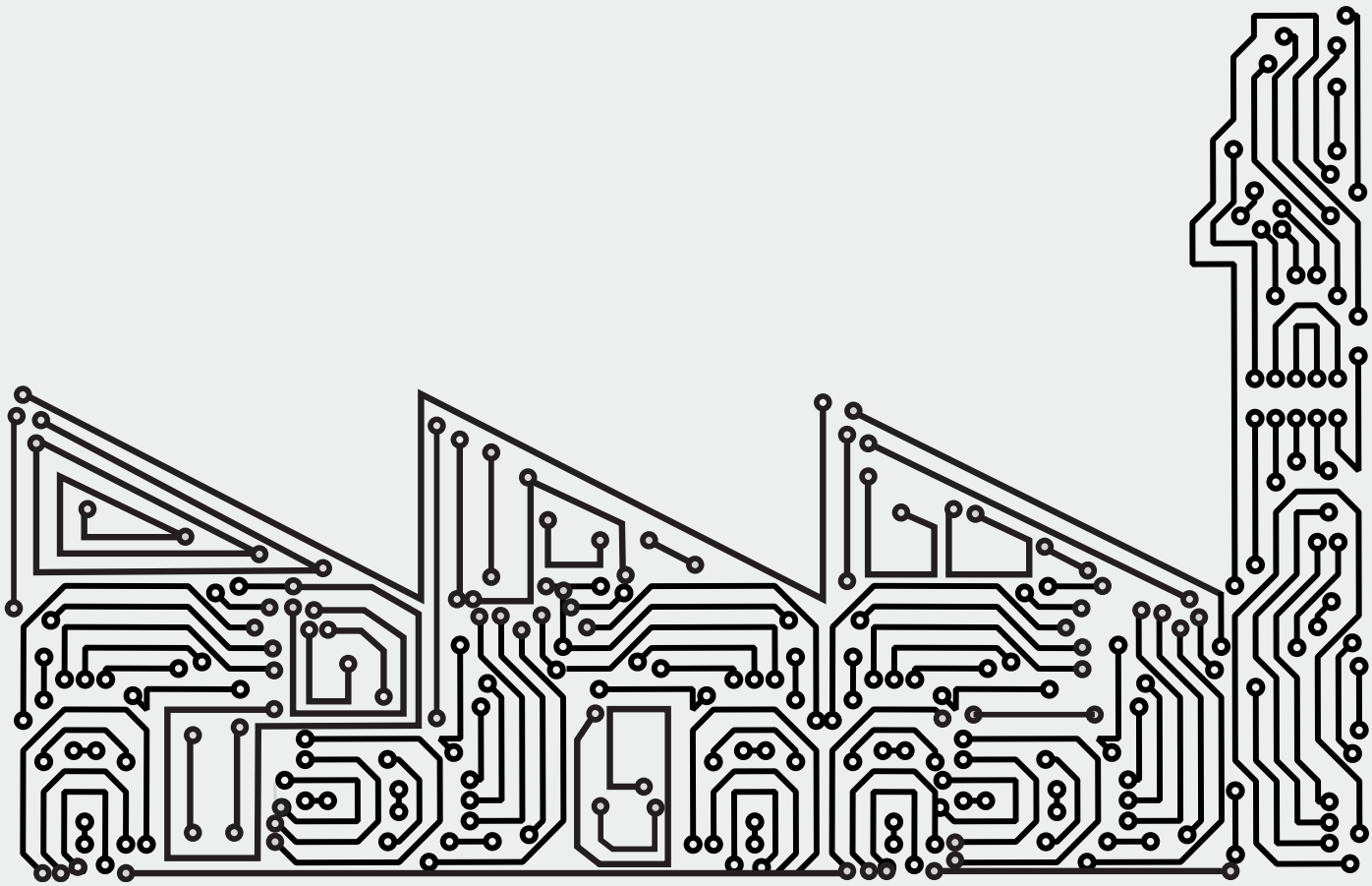
Programmed for success

Gary Poole joined Meggitt as Group Vice-President, Programme Management in March to provide group-wide functional leadership and direction to all Meggitt's programme management efforts. An experienced programme and project management professional, Poole joined from Fokker Aerostructures in The Netherlands where he served as Vice President of Program Management. He brings additional knowledge and experience from aerospace, automotive and industrial sectors through Rolls-Royce, Goodrich and Johnson Controls.

Poole has a mechanical engineering degree from Birmingham City University with an MSc in Programme & Project Management from The University of Manchester. He reports to Chris Allen, Group Director of Engineering & Strategy.

Factories **of the future**

The Meggitt Modular Modifiable Manufacturing (M^4) project will reinvent the factories of the future with ideas that could bring profound changes to the product manufacturing landscape. Combining existing and future technologies, factories will become intelligent, responsive units, revolutionise component assembly and transform operators' working conditions. This isn't just some flight of fancy—the first stage of the project, an intelligent workbench, is already well under way. In the following pages we explore M^4's radical vision for the future and, in *Benchmark of the future*, find out more about the workbench that is making the vision a reality.



M4 The **power** of intelligent manufacturing

First there were hybrid cars. Then there was hybrid manufacturing, combining additive layer manufacturing with subtractive machining. What comes next might come as something of a surprise: hybrid factories.

The three-year Meggitt Modular Modifiable Manufacturing project, known as M4, will turn the traditional understanding of factory layout and flow on its head with a ground-breaking combination of existing and future technologies. The project was launched at the beginning of this year, prompted by the specific challenges of aerospace engineering.

Everyone knows how an aerospace factory works. Components are put together in an assembly line dedicated to that product and operators become highly skilled in assembling that one product.

Producing complex products in low volumes does not necessarily make for the most efficient business model,

> M4 isn't just a one-off improvement. It's giving us the tools we need to drive improvements, year on year

however. Manufacture can be labour- and capital-intensive, with equipment lying idle for long periods of time.

Automation, as used in the automotive industry, is not an option: to make a business case for it there have to be production volume and repeated operations. Even the rising demand for aerospace components is not enough to make conventional, automated methods of manufacturing financially viable.

M4 meets this challenge with the concept of the smart factory. Unlike the static, passive collection of machines and components found in a traditional factory, the smart factory is an intelligent, interactive environment that will capture data from each build, analyse it and communicate it to design and manufacturing engineers, allow different components to be made on the same assembly line, increase operators' skills and improve their working environment. Parts will move around the factory, possibly via an automated system, according to the optimal flow.

M4 involves a partnership between Meggitt and the Advanced Manufacturing Research Centre (AMRC) in Sheffield, UK, been creating the Closed Loop Adaptive Assembly Workbench (CLAAW) which could revolutionise component assembly, increase operators' skills and improve their working environment.

SPEED READ

Break with tradition
M4 is an intelligent factory concept that will turn a traditional factory into a responsive and efficient environment that optimises flow. Meggitt's partners in the project are Advanced Manufacturing Research Centre, Sheffield, UK, Manufacturing Technology Centre, Coventry, UK, Innovate UK and IBM.Old problems, new solutions.

M4 addresses the challenge of how to deal with low volume manufacture of complex products that do not lend themselves to automation.

Moving parts
Parts might move around the factory on an automated delivery system such as an overhead gantry. Eventually they will be self-aware and able to choose the best route through the factory to maximise efficiency and flow.

Knowledge is power
Information about products, assembly, flow and operators' preferences will be gathered and stored in a private cloud. Data analytics will close the loop between operations and engineering and be used to optimise flow, identify faults, improve design and provide better working conditions.

New tricks
New technologies such as additive layer manufacturing will be introduced to improve product design and allow previously unachievable product features to be incorporated.

Stand and deliver
An intelligent workbench (see page 14) is the first step towards realising the M4 vision. A Meggitt team at the Advanced Manufacturing Research Centre (AMRC) in Sheffield has

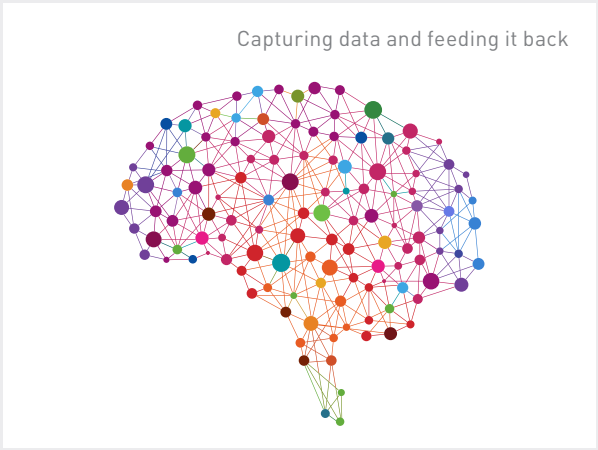
Coming soon
The workbench, designed to assemble an eBrake® actuator and featuring smart, flexible fixturing, laser projection and data capture, started touring Meggitt's UK factories from end-July.

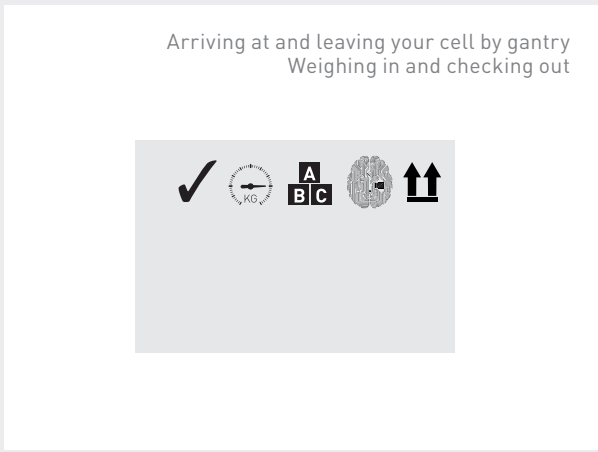
Smart goals
The CLAAW team has been researching machine vision, smart tooling, smart parts bins and wireless technology to identify the component and the operator. Future technologies include wearable technology and hands-off devices to allow touch-free use of a keyboard or screen.

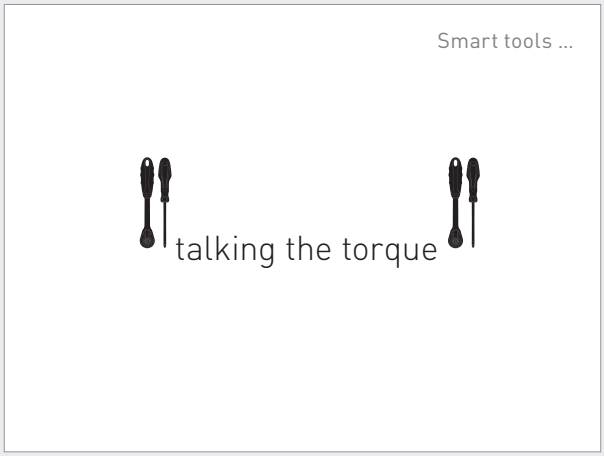
CLAAW II—the sequel
Once CLAAW is completed the project will move into its next phase—CLAAW II—under the umbrella of the M4 project. The emphasis will be on human factors —ergonomics and data capture— and adapting the workbench for different components and a real factory environment. Research will include lightweight desktop robots and advanced machine vision.

Money talks
Eventually the workbench should be adapted to assemble any product coming through the factory. The improvements in efficiency, output and productivity should justify the initial investment in the new factories and products.

Watch/listen
Meggitt is bringing Industry 4.0, the German manufacturing concept for advanced automotive production, to aerospace. See our video: **www.meggitt.com/M4**







M⁴ FILM ▼ www.meggitt.com/m4

M⁴ FILM ▼ www.meggitt.com/m4

the Manufacturing Technology Centre (MTC) in Coventry, UK and IBM (which is researching the best way to model the data generated by a smart factory). It is receiving matched funding of £2.5 million from Innovate UK, the UK's innovation agency as part of a funding call initiated by Britain's Aerospace Technology Institute.

Central to M⁴ is the intelligent workbench, known as the Closed Loop Adaptive Assembly Workbench, or CLAAW (see Benchmark of the future, page 12) which has been developed by a team working at the AMRC. Designed to assemble an eBrake® actuator produced by Meggitt Aircraft Braking Systems in Coventry, the workbench uses smart, flexible fixturing to make assembly quicker and easier, laser projection to identify the steps in the assembly and data capture to increase understanding of the assembly. The CLAAW team has researched future technologies such as machine vision, smart tooling and wearable technology.

ONCE CLAAW HAS BEEN COMPLETED, the project will move into its next phase, CLAAW II, and will become part of the M⁴ project. There will be an emphasis on human factors, with a team from Cranfield University looking at ergonomics and data capture.

The CLAAW II workbench will, under M⁴, be adapted to assemble a bleed valve and a heat exchanger as well as the eBrake® actuator. The idea is that eventually the same machines and stations could be used for any product coming through the factory so all machines are in constant use, making the additional investment economically justifiable.

Although the workbenches will initially be introduced into existing factories without changing their layout or delivery systems, M⁴ is researching the idea of components and parts moving around the factory on an automated delivery system, perhaps using an overhead gantry support system or an autonomous ground vehicle that will move through the factory delivering items to where they are needed (although the team acknowledges it may equally conclude the traditional forklift truck or trolley works just as well).

The long-term aim is to make products self-aware so they respond to the factory's current state and intelligently direct themselves to the route that will produce the optimum flow. This feature is known as object-oriented manufacture, or OOM. If, for example, a point or machine were to fail, the product

would know to re-route itself to a working one. It might even be able to predict problems in advance and take corrective action before they occurred.

Information about the products and the assembly process will be stored in a private cloud. Data will be independently analysed to identify faults and pass feedback on to engineers to improve design and analyse trends. The individual operators' preferences about their environment (such as the height at which they like to work and the light levels they find most comfortable) will be recorded and remembered.

The factories will incorporate new manufacturing technologies such as the rapidly-growing additive layer manufacturing (see *The print addition*, page 34), allowing engineers to design previously-unachievable product features such as lattices, hollow structures and surface finishes without joins and time-consuming finishing processes.

New features will be introduced in stages using a combination of simulated and actual environments: there are no plans to demolish existing factories and replace them all with futuristic, gleaming citadels. In the first instance, M^4 technologies will be deployed for new products on lines running alongside the traditional, serial flow lines, in a hybrid factory model. Each step will be assessed and proved before the next step is taken.

"M^4 isn't just a one-off improvement," says Director of Engineering, Steve Parker. "It's giving us the tools we need to drive improvements, year on year."

The three-year Meggitt Modular Modifiable Manufacturing project, known as M^4, will turn the traditional understanding of factory layout and flow on its head with a ground-breaking combination of existing and future technologies

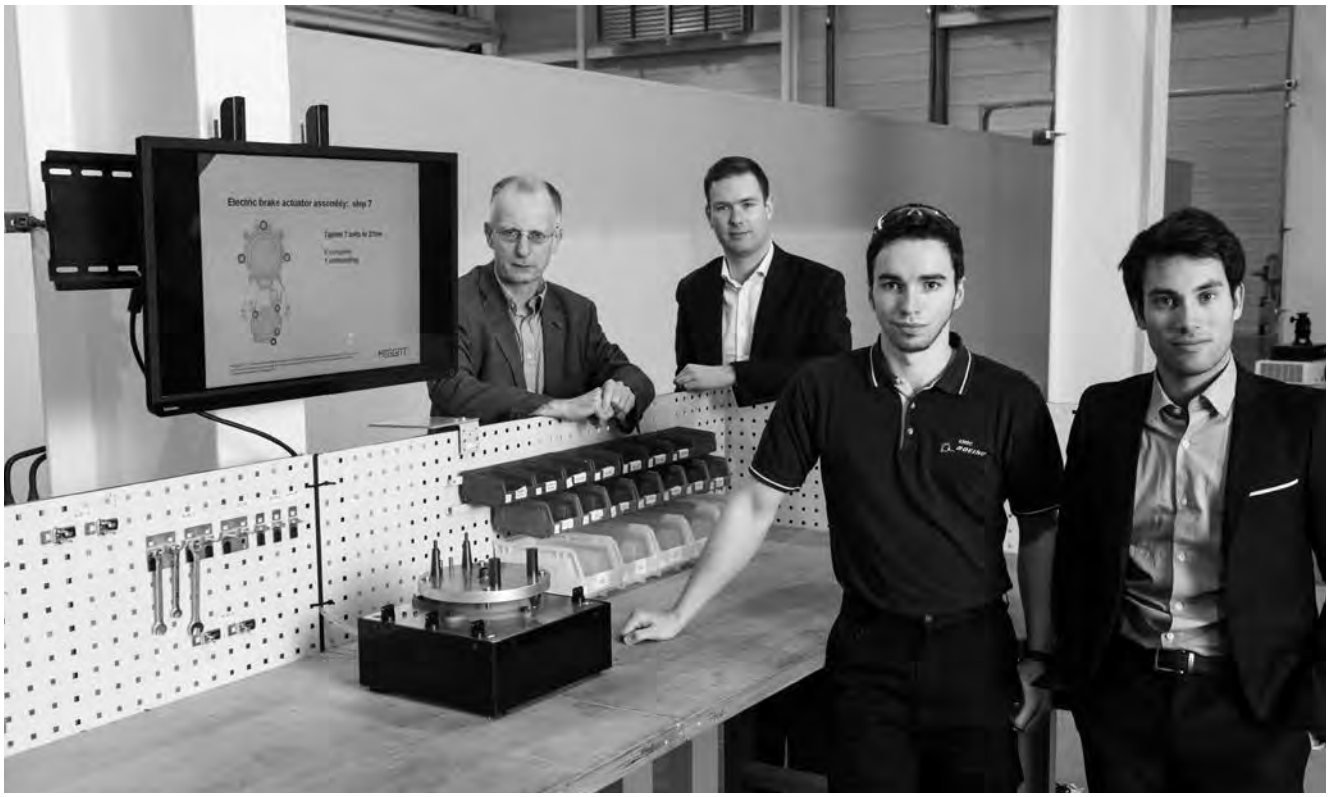
If all of this sounds expensive, the research team believes it will be worth the investment. Because a wider variety of components will be made in each factory, equipment will be fully utilised, providing a better return on investment. The improvements in efficiency when flow is optimised—and in design as lessons are learned from data capture—will make each factory significantly more productive. M^4 should enable Meggitt to double revenues in UK civil aerospace and increase employment by 50% by 2025.

According to Parker, "M^4 will optimise factory performance by responding to changes at the micro level, like late customer demands, and at the macro level, like buying more efficient equipment. It supports investment in people and equipment by maximising our resources." ●

Benchmark of the future

—the Closed Loop Adaptive Assembly Workbench

The first step towards bringing M⁴ to life, the CLAAW workbench, has been designed by a Meggitt graduate team at the Advanced Manufacturing Research Centre. With its smart features and new technologies, it will bring radical changes to component assembly. We meet the CLAAW research team and find out how their work is pushing the boundaries of technology.



Team CLAAW: Chief Technology Officer, Keith Jackson with graduate engineer Tom Newman, AMRC technician, Jon Hall and graduate engineer Rémy Trang

Imagine a world where an operator assembling a product is more like a highly-skilled surgeon in a state-of-the-art operating theatre. His—although of course it's just as likely to be her—working environment is adapted to his individual needs and preferences. He's slightly long-sighted so the light is set a little brighter, just as he likes it. He's taller than most of his colleagues, so he is working at a greater height to save his back. As he's an experienced operator, the assembly instructions on his screen scroll down at just the right speed, faster than for a beginner. When the screen is switched off he sees an image that he chose himself. Parts are handed to him at the correct time and in the correct order by a desktop robot that knows exactly which nut or bolt is needed next.

This operator is skilled in assembling more than one product. The workbench on which he is assembling it is adapted to multiple components, so whilst that morning he will be assembling an electric actuator (Meggitt's eBrake®), later in the day he'll be building a bleed valve. The workbench allows him to work quickly and accurately. All the information from the build is recorded and logged electronically and fed back to the engineering team. This may sound fantastic but it is not as far off as you might imagine. A Meggitt team based at the Advanced Manufacturing Research Centre (AMRC) in Sheffield has been hard at work for the last year, creating an intelligent workbench, called the Closed Loop Adaptive Assembly Workbench—or CLAAW. It is the first step in a project to improve production output, quality, flexibility and traceability in component assembly.

The first workbench model, which features smart, flexible fixturing, laser projection and data capture, was completed and ready for demonstration in July. In the second phase—CLAAW II—which will last three years, the workbench will be refined, new technologies will be brought in and the concept proved in a production environment.

CLAAW was the brainchild of Chief Technical Officer Keith Jackson and Graduate Programme engineer Tom Newman. On a visit to the annual Tech Fellows event at the AMRC, they were shown an intelligent workbench concept addressing many of the issues faced by Meggitt: complex products manufactured in low volumes, which do not lend themselves to automated production.

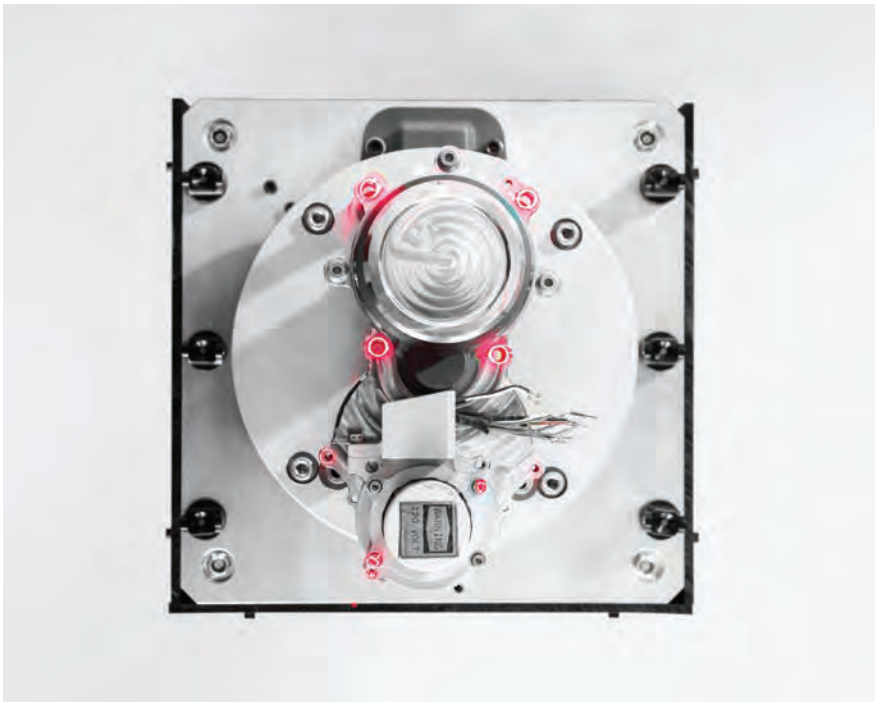
"They had come up with an intelligent workbench concept where they were using off-the-shelf, office multimedia projectors to project markers onto components to show where a hole needed to be drilled," says Newman.

The components in question—aircraft wings—were much larger than anything manufactured by Meggitt. Jackson and Newman wondered if they could take the concept and apply it to the kind of components produced by Meggitt.

"Keith said, 'If you can find the funding for it, you can go ahead and get on with it'," says Newman. So began the CLAAW project.

Newman got the ball rolling, putting together a funding package and conducting the initial research. He and Jackson

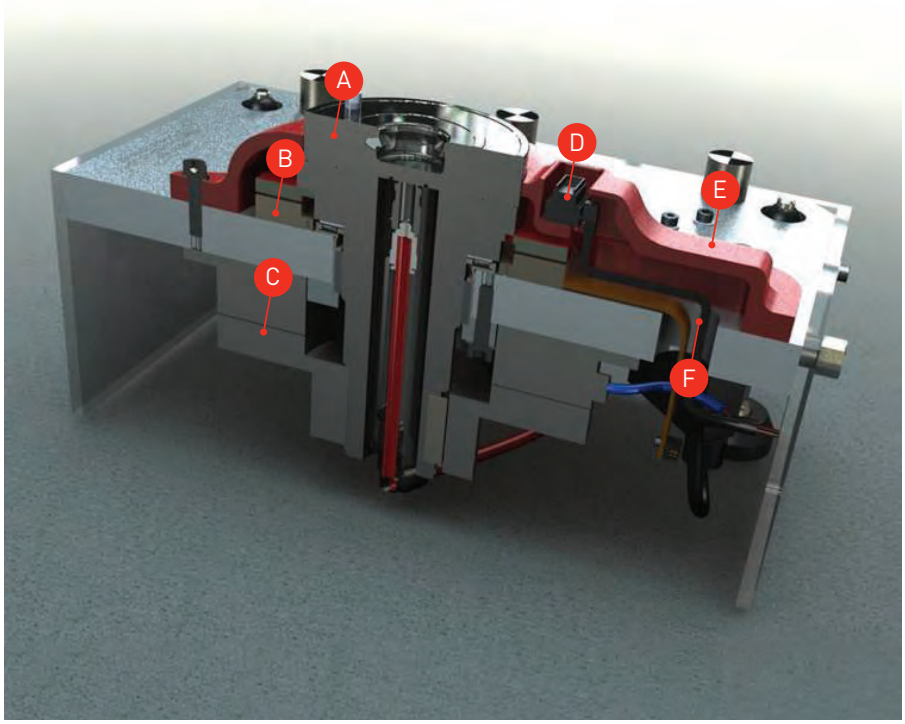
Left and below: CLAAW's fixture includes targets to guide the calibration of an overhead laser. A shaft is encoded to enable precise rotation measurements. A power-on brake provides stability for torque operations. Product assemblies can be mounted and removed swiftly using a pneumatic easy-click clamp.



It is the first step in a project to improve production output, quality, flexibility and traceability in component assembly

travelled to Germany to observe intelligent workbenches in action. A few months later two more Graduate Programme engineers —Matt Scovell, Gevorg Hovakimyan and Rémy Trang—joined to take the lead on the hardware side.

As Jackson had identified, the first step was to secure funding. This came from InnovateUK (formerly the Technology Strategy Board), funded by the UK government and tasked with furthering new technologies. "This project came under Enabling the Internet of Sensors," says Newman. "There's a big drive for



Top left: **Inside story: a cross-section of the workbench**
A) Easy-click clamp
B) Incremental encoder
C) Power-on magnetic brake
D) IR sensor
E) 3-D printed cover
F) Pneumatic solenoid valve

Top right: **Intelligent workbench:** AMRC Technician, Jon Hall examines a flexible fixturing solution, a product of Meggitt's Closed Loop Adaptive Assembly Workbench (CLAAW) project, the aim of which is to achieve a quantum leap not only in production output but quality, repeatability and traceability using guidance via lasers and display screens and 'smart' tools. The sample part is Meggitt's electric brake.

The smart, flexible fixturing solution

Matt Scovell, who designed the fixturing elements of CLAAW, talks us through them.

The aluminium base plate, the steel shaft and the top plates were machined by Meggitt Avionics. The 3-D printed cover was manufactured to our design by a 3-D printing company. All other parts were bought off the shelf.

Top plate
This is the standard fixture that holds the part being assembled rigidly in place. The part sits on the red pillars on the top plate so it doesn't require any clamps or bolts to keep the part on the fixture.

IR sensor
This tells you whether the top plate is attached to the bottom. When you lift the top plate off it tells the electronics that it is no longer in position and returns the clamp back to its neutral position, ready to accept a new top plate.

Easy-click clamp
This is the clamp that holds the top plate down. It is a very robust, quick-release system, rather like the seat-belt release in a car.

3-D printed cover
We needed an organic-shaped cover that fitted all the electronics we wanted in it. ALM was the obvious process to use for a bespoke part in a volume of one, with a unique geometry, in a short lead-time. The design element was important, too: we wanted it to look neat, robust and uncluttered. We consciously chose Meggitt colours. It took 10 days between approving the CAD and having the part in our hands.

Pneumatic solenoid valve
This valve takes an electrical signal instructing it to open and shut by changing the air flow. It allows us to remotely select if the operator can take the fixture on or off. If, for example, you're not 100% happy that the part is correctly built, you can have an override in the system that won't release the part until a senior operator has approved it.

Power-on magnetic brake
Again, this lets you control the mechanics through an electrical signal, giving you flexibility. There's an on-off-switch that stops the plate rotating, so if you're doing up a nut if will hold the whole fixture still and let it spin again if you're doing something that needs movement in the part.

Incremental encoder
This tracks the rotational position of the part being assembled, which is important when the operator has to spin the part around a number of times to achieve a particular task. If you rotate the part the laser markers will no longer be where they should be, so this enables you to update the laser projection on-the-fly.

getting sensors into components as part of the Internet of Things, where everything is becoming more connected. Internet-enabled appliances such as fridges and central heating controls are becoming more commonplace, so we're looking at how we apply that to our manufacturing environment.

The project involved three partners: Meggitt, the University of Sheffield (which owns the AMRC) and a small-to-medium-sized enterprise, Visio Ingenii, specialising in machine vision technology.

responsible for designing the solution (see panel left), which incorporates a cover made using additive layer manufacturing and smart features to make assembly and product interchange easier and more efficient.

As with the model showcased at AMRC, several lights—in this case lasers—are projected on to the component to provide guidance to the operator. "You could highlight where a component needs to be placed and verify the orientation of the component using machine vision, all whilst

The nice thing about this project is that there are a number of quick and immediate efficiency gains right now, but we're also looking at how we could really push these using future technologies

The workbench was designed to assemble the eBrake® manufactured by Meggitt Aircraft Braking Systems (MABS) in Coventry, although there are plans to extend it to other components. The team chose the eBrake® actuator because of the wide variety of processes involved in its assembly and demand that will raise production levels in the coming years.

As the positioning of a component is critical to the success of its assembly, the researchers proposed a bespoke, flexible fixturing solution. Matt Scovell was largely

capturing in-process assembly data for subsequent analysis," says Newman.

The flexible fixturing solution and laser projection was ready for demonstration by the end of the project, in July.

Other technologies will be ready for demonstration, testing and implementation at a later date. First is Visio Ingenii's research into reducing human error using machine vision. Newman explains: "They've been looking at on-the-fly inspection using off-the-shelf cameras—so if, for example, a seal needs to be placed around the outside of a part, it sees whether it has actually been placed or not."

The team has been researching the productivity and traceability gains achievable with smart tooling, such as an intelligent torque wrench, which can be wirelessly programmed to do up a bolt to a particular torque. That information is recorded. "It can give you feedback on how the torque and angle profiles vary over time," says Newman. "Measuring torque when a bolt is tightened will detect obvious problems like a mis-thread. It can also detect small amounts of debris which may otherwise go unnoticed—this could indicate other issues."

They are investigating digital parts bins to ensure that the operator always picks the right part and can find it quickly. If the operator needs, say, an M6 bolt, a drawer containing the correct bolt will light up to show him where it is.

Information to identify the operator and the part being assembled might come in the form of tags. "It could just come down to scanning a bar code on the part or on the operator's ID tag," says Newman, "but a neater way of doing that would be to use wireless technology like RFID [radio frequency identification] or NFC [near field contact] tags." Again, this is by no means a remote prospect: the ID passes at some Meggitt facilities already have RFID tags in them.

A less immediate prospect, perhaps, is the notion of wearable technology along the lines of the Microsoft HoloLens which the team has been researching. "The term 'wearable technology' is being bandied about at the moment in a lot of industries outside manufacturing," says Trang, who continued the project when Newman rotated to his next graduate placement. "You could envisage augmenting a person's vision with information. Instead of having to look up at a screen you could just keep your eyes on the part and the work instructions would be displayed in front of you. It may be that you can actually visualise the completed part by itself, show an animation or point out with arrows the order in which certain components have to be installed or tightened. Any information that is relevant could be flagged up in your immediate vision."

The team has also been looking at hands-off devices like LeapMotion, which allow people to interact with their computers without touching the screens, using gesture recognition. An operator could move his hand from left to right, instructing the workbench to move to the next step in the assembly process. The appeal of this isn't hard to see. "The nice

thing about that is that you don't want to touch a keyboard or a screen when you've got your hands full," says Trang. "It's a good way to interact with the system without actually having to touch it."

Trang acknowledges that elements like this are rather futuristic but considers this to be part of the appeal. "The nice thing about this project is that there are a number of quick and immediate efficiency gains right now, but we're also looking at how we could really push these using future technologies."

One of the most important elements of the project was the idea of closing the loop between operations and production engineering and between operations and design. The workbench has data capture features, feeding information back from operator to design engineer and even from operator to operator.

"Data integration is key," says Trang. "We've been asking how we can integrate all these disparate data sources. If we're gathering information from intelligent torque wrenches and a flexible fixturing solution and if we're gathering information on the timing it takes for each step, the question is then how we pull all that information together and conduct analysis work on it."

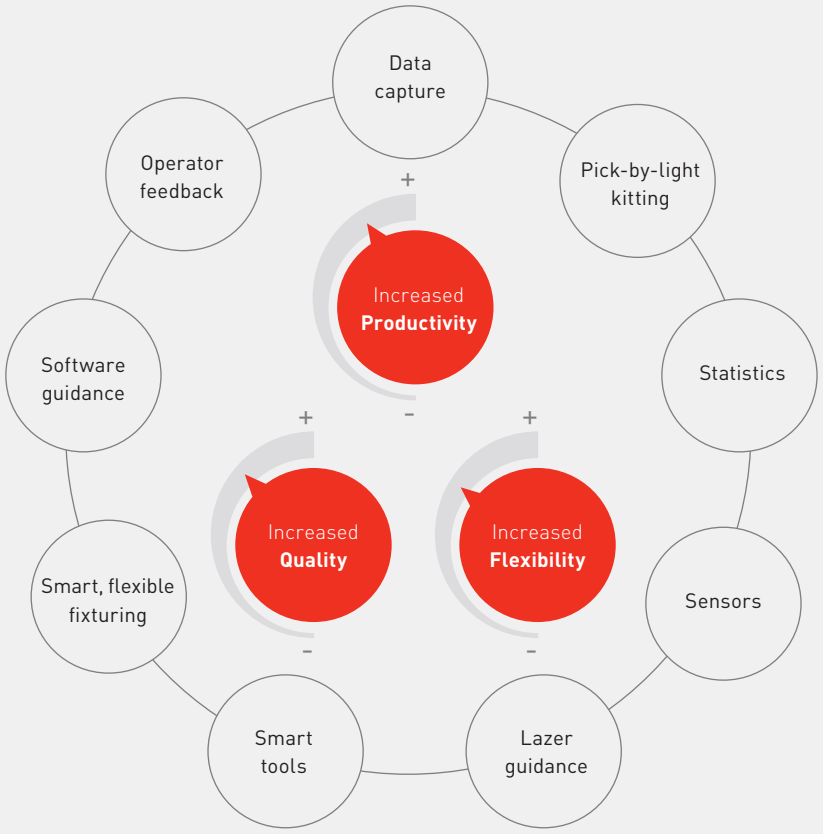
CLAAW II is a microcosm of the M⁴ project

The team has carried out initial demonstrations of CLAAW to MABS and Meggitt Control Systems (MCS) in Coventry and to the Meggitt Applied Research & Technology (AR&T) Board, all of which received the idea favourably. It is now working with operators to prepare the workbench for final demonstrations around Meggitt's UK factories.

With CLAAW completed, the project will move into its next phase, CLAAW II, which forms part of the three year M⁴ intelligent factory project (see *Factories of the Future*, page 8) . It will focus on bringing the workbench into the Meggitt factory environment, and developing further technologies to work alongside it. "CLAAW II is a microcosm of the M⁴ project," says Newman.

The workbench will continue to be developed for the eBrake® actuator but in line with the aims of M⁴, it will be designed to build other components—a heat exchanger for MCS in Birmingham and a bleed valve from MCS in Coventry. Gevorg Hovakimyan, who is taking the project forward into the next phase, explains.

Closed loop adaptive assembly workbench



Techniques and technologies deployed in the intelligent workbench

"The idea is to create a factory that will be more flexible. "Often we don't produce enough components to create an assembly line so if we need to produce 50 components in a month, we don't want to produce all of them in the first week, only to gather dust on a shelf. We want to produce them when we need them. With the CLAAW II station, operators would be able to assemble, say, two eBrake® actuators in the morning and an electrohydraulic servo valve in the afternoon."

The partners in M⁴ are Meggitt, the Manufacturing Technology Centre (MTC), the AMRC and IBM (which is researching control software). Some of the research has been subcontracted to Cranfield University, which is looking at human factors: ergonomics and data feedback.

"We would like the operator to feel comfortable when he works," says Trang. "The CLAAW station will adapt to working speeds, heights and preferences.

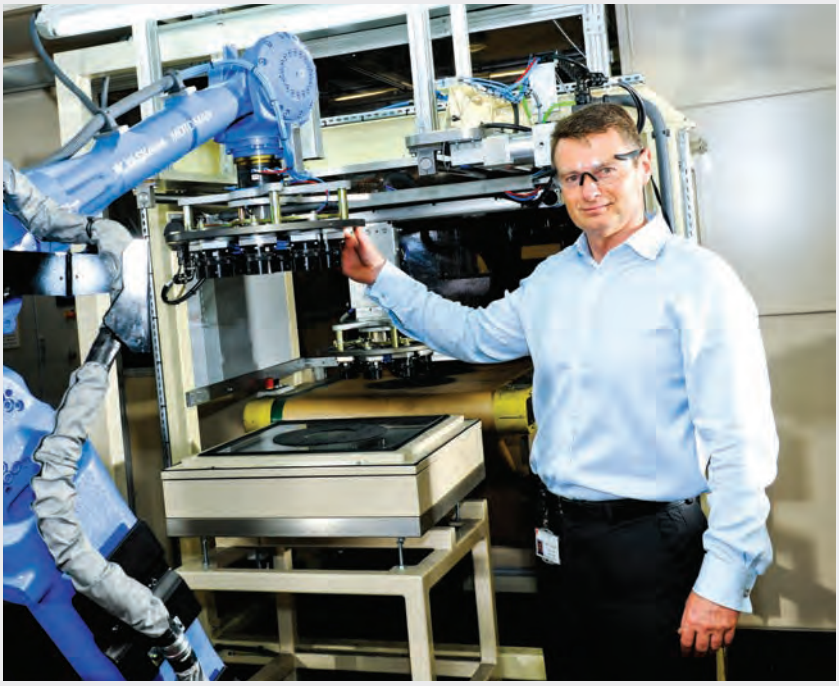
Data capture, which will be recorded in the Cloud (allowing for the centralised storage and processing of 'big data'), is central to CLAAW II. "The software will be a big part of the CLAAW II project," says Trang. "It's really exploring the closed loop. The operator will be able to give information to the software and the workbench will remember what the operator says to it. This information will be recorded and go back to the design engineers, and it will increase the traceability of our manufacture."

"It will be a way to learn about the way the product is made because we'll have so much data we can get answers to a lot of the questions that arise," adds Scovell. "For example at the product development stage you could see where a team from design and manufacturing would confer on part assembly. It could certainly be a two-way process."

Data capture will enable knowledge-sharing between operators, according to Trang. "If one of the operators was tightening a sequence of bolts in one order and another operator was tightening them in a different order, if one sequence proved to be more efficient than the other, this information could be passed on to all the operators."

In line with M⁴, CLAAW II will look at how to deal with the complexities that arise in a production environment. As Meggitt has a significant maintenance, repair and overhaul capability, operators will be guided through disassembling as well as assembling parts.

Made [better] in the UK



Roy Deakin, Senior VP Operations, Meggitt Aircraft Braking Systems: is excited that MABS operators will be part of this historic journey towards the UK's next generation factories

It's taken the length of Roy Deakin's 36-year career in manufacturing for time and motion experts to spend as much time optimising workbenches for humans as optimising machines.

"CLAAW is a subject very close to my heart," says the Senior Vice President, Operations for Meggitt Aircraft Braking Systems, referring to the first phase of the Closed Loop Adaptive Assembly Workbench project started by Meggitt at the Advanced Manufacturing Research Centre in Sheffield, UK and part-funded by the UK government to boost manufacturing in Britain.

Deakin started as an apprentice in hydromechanics (valve assembly included), becoming a full-time hydromechanical fitter. Since then he has seen numerous projects focusing on machine improvements but never one that really concentrated on assembly work.

CLAAW (mark one) is an 'intelligent' workbench concept designed to help operators raise quality and productivity in the assembly of complex aerospace products which cannot be automated cost-effectively due to low-volume demand. The 'Closed Loop' refers to a feedback capability—information recorded during assembly that could result in product designs that are easier to make without compromising functional specifications.

CLAAW will be soon trialled on electric brake actuators at Meggitt Aircraft Braking Systems (MABS)' Coventry facility. Deakin is confident it will help ensure consistent methods of assembly, supporting operators to improve build accuracy, decrease build time and iron out potential quality wrinkles.

AND HE'S ALREADY THINKING BIGGER. Brakes which are large and difficult to move could be mounted on tripods creating 360-degree access. He explains: "We need a fixture that gives you full access to a part without the physical labour involved in moving a hydraulic braking system that might weigh over a hundred pounds. Think about the operator today working with flat benches, twisting that brake in multiple positions and turning it upside down to fit a heat pack."

And he sees opportunities in repair and overhaul (R&O). As the Meggitt workbench includes a laser light to guide individuals on which parts to pick, place and fit in sequence for assembly, the same approach could be taken for disassembly. "Of course, there is no reverse button because it is not exactly reversing a process. It is very hard to take a product apart for R&O without scrapping parts. The process would have to be redesigned but all the benefits of better benches and better sequencing of actions apply, minimising this risk."

He points out that once a business unit achieves over 90% on-time delivery, getting to 100% involves attention to detail at a microscopic level. "Even reducing the time spent touching up paintwork because you can manoeuvre products more easily without scratching them would be a gain worth having."

Deakin is equally enthusiastic about the value of CLAAW to experienced operators responsible for training. CLAAW would enable MABS to take *Standard Work*, a key Lean tool in the Meggitt Production System, to a higher level, increasing the efficiency with which trainers pass on their experience to youngsters. "We could consolidate and standardise the very best techniques from our top trainers who could bring training time down significantly with fewer variations on the way products are assembled. Laser guidance would reinforce that training.

All this would free up time to train more people and, of course, design and calibrate more intelligent workbench processes for brand-new lines."

Deakin is interested in anything that makes MABS, Coventry more competitive and therefore more marketable. Right now, industrialising products won from the last bid cycle to meet imminent ramp-ups on customers' production lines is today's key priority. "Customers want zero quality escapes and they want their products on time. It's what they are paying for. We must manage our processes to minimise risk to their programmes. Pioneering projects like this are exactly what we need."

CLAAW's future fault-finding capability inspires him. "Intelligent fixtures that help operators today by making physical activity easier will eventually collect data during product assembly making quality issues quicker to trace. Over all, I am tremendously excited that MABS operators will be part of this historic journey towards the UK's next generation factories."

Right now, industrialising products won from the last bid cycle to meet imminent ramp-ups on customers' production lines is today's key priority. Pioneering projects like this are exactly what we need

Researchers at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg, Germany are working on networked manufacturing concepts and smart work systems that will be an integral part of factories of the future. Only when humans and robots can safely work side-by-side at the same time will protective barriers disappear from manufacturing facilities, thus paving the way for Industry 4.0. *Picture: Fraunhofer IFF*

Machine vision will be involved once again, with more advanced part recognition. This could be straightforward—checking that all the parts are present and correct—but might go further, noticing when a part is complete but scratched and can be released to the customer as a concession.

The way components move around between machines and workbenches will be looked at. "It's very much an investigation into the best way of moving our parts around the factory," says Newman. "Is it through an autonomous ground vehicle (AGV) that's able to make its way around the factory delivering parts to respective locations? Is it via an overhead gantry support system—little robots attached to the steel beams at the top of the factory?

Or will it just be the conventional operator moving parts around the factory on trolleys and forklift trucks?"

> As the positioning of a component is critical to the success of its assembly, the researchers proposed a bespoke, flexible fixturing solution

Components might be kept in a smart box. "The idea is that we have a kitting area in a new factory where all the individual components required to build a part are placed into a smart box," explains Newman. "This would be able to weigh all the individual nuts and bolts and screws as they are placed into the box, and it might measure temperature and humidity using sensors. This smart box will be placed on the automated delivery system and make its way around the factory to its next step. The first step might be the machining centre where it is machined into a shape that then moves on to a CLAAW cell."

Intelligent software may take this idea even further, according to Trang. "All the data will be captured and fed to the software and the software will give the best instructions possible to optimise flow through the factory. The software might say it's better to make the eBrake® actuator this morning and the bleed valve this afternoon."

The final—and most ground-breaking—element of CLAAW II involves robots assisting operators to assemble components, handing them parts, for example, or holding a part in place. "It makes the operator a bit like a surgeon," says Newman. "When he says, 'torque wrench', it has the tool ready for him because it knows that's the next step." Eventually the CLAAW system could be trained to act as smart assistant, copying instructions from an expert and learning as it went.

Traditionally robots have not worked well alongside humans: their moving parts can catch fingers, and they have an unfortunate habit of swinging around and knocking people so tend to be encased in metal guards. Co-operative robots, such as the German-designed KUKA lightweight robot, addresses these challenges with smooth surfaces and feedback sensors to stop if it knocks into someone.

As with the rest of the project, ergonomics will be taken into account. Having identified the operator through his or her bar code or tag, the robot's arm should be able to move into the person's preferred orientation. As Trang says, "The robot will recognise the operator and adapt to his height."

Although the technology is cutting edge, the team is keen to emphasise that it should be user-friendly and easy to programme. Indeed, the enhanced software will help operators train new apprentices more effectively: instructions can be made more detailed and could appear on the screen more slowly for novice operators.

Everyone involved in the project is enthusiastic. "It's a chance to be creative, which is sometimes difficult in the industry we're involved in," says Scovell. "Aerospace technology is a very risk-averse culture—there's a tendency to repackage the same technology over and over. This is really a chance to take out a clean sheet of paper, come up with your best solution and work back to take the risk out." ●

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Attracting new talent is essential to the success of any competitive enterprise and Meggitt is no exception. We find out how the Meggitt graduate programme identifies the new stars in the engineering firmament and look at how they are putting their bright ideas to work.

Talking about a new generation

Since Jenna Becker arrived at MSS in Simi Valley in September 2014, fresh from her studies at Cal Poly, she has been pushed far out of her comfort zone. Becker is in the most recent cohort of graduates on the Meggitt graduate programme. She has already developed a new piece of equipment to improve the versatility of a device for measuring the effectiveness of a fire suppression system—a vital component in an aircraft engine. It's been hard, demanding work, but Becker loves the challenge. "I'm having a ton of fun," she says.

The Meggitt graduate programme came into being in 2011, not long after the start of Meggitt's organisational transformation. Starting a group-wide graduate programme was a natural step for Meggitt to ensure that all businesses in the group had access to the best talent, according to Robin Young, Group Organisation Development Director.

"Individual businesses left to their own devices wouldn't necessarily set their sights on real, game-changing talent," he says. "They might not know how to get it, they might not think they needed it and they might not think they could afford it.

"At the same time, looking at the overall demographic, we realised that there were so many experienced engineers who were just about to retire. Where was our next generation of great ideas coming from?"

So the first cohort of graduates started on a structured, three-year programme, moving to a new placement every nine months and experiencing at least one international placement.

There are only 10 graduates in each intake and considerable resources are invested in them. "It costs a lot of money and a lot of management time," says Young.

To justify this level of investment, recruitment is carefully targeted to ensure Meggitt finds the brightest and the best from around the world. Contacts are fostered with the most dynamic engineering universities and talented students encouraged to apply.

The graduate profile is an international one. "We've got people of all sorts of nationalities," says Young. "We've had people from Côte d'Ivoire, Israel, Switzerland, Romania, France, Great Britain, America, Bangladesh and Denmark, amongst others. We're very lucky."

What Meggitt is looking for in a graduate recruit is not just academic talent,

although about one third has a PhD. "We're not specifically after technical excellence or managerial facility—we're after a blend of both," says Young. "If we can find a mad scientist who can manage, so much the better. I would hope that somewhere in here we've got future chief executives."

Chief Technical Officer, Keith Jackson, agrees. "We assume they're all bright engineers because they've got good degrees from good universities but the real thing that's going to set them apart as future leaders is how they conduct themselves and how they can operate in the business."

> We challenge them, take them right out of their comfort zone and pile the work on by volume and difficulty

Once on the programme there's no room for complacency. "You do have to prove yourself," says Young. "The point at which you start with us is the point at which we really start noticing your contribution. Expectations are high."

Graduates are, accordingly, put to work as soon as their induction week is over. "You get dropped straight into something very real and very business-like," says Jackson. "Some can take it and some can't."

Those that can seem to relish being put to the test. "I hope I can add a little thing out of the box that somebody else couldn't think of," says graduate Blaise Guélat, who has a PhD in biomedical micro-engineering and is currently based at Meggitt's aircraft safety and security facility (Securaplane) in Arizona, working on next generation lithium ion battery systems.

Charged with developing a new algorithm for secondary flight displays, he was given free rein in his research. "I have been given a lot of independence—in my current project I was given carte blanche to look around the scientific literature, starting from nothing and developing algorithms. It's very exciting."

Neither can graduates necessarily draw directly on their existing knowledge. Jamie Marshall, who rotated through Securaplane in Arizona, explains that his project there, working on a camera-based system, was unfamiliar territory.

"Although my other placements were quite familiar, the flavour of the engineering there was completely new to me, but my manager was happy to let me dive in."

Whatever their field, graduates are all agreed that the transition week between placements presents a particular challenge. In addition to lectures each day from 9 a.m. to 5 p.m., the graduates are set an assignment to be completed by the end of the week.

"We challenge them," says Jackson. "We take them right out of their comfort zone and pile the work on by volume and difficulty."

In one transition week, graduates were called back urgently from lunch to be told that Meggitt had an opportunity to buy a company making advanced mechanical systems and electronics for storing energy in flywheels. They were told to work out technically whether Meggitt should go ahead with the purchase and put their case, in opposing teams, in a presentation to Chris Allen (Group Director of Engineering and Strategy) and his direct reports the following day.

SPEED READ

Talent show
The graduate scheme was founded in 2011 to give all businesses in the Meggitt group equal access to new recruits and bring on a new generation of talent.

Casting the net
Recruitment is carefully targeted at centres of engineering excellence around the globe, and the graduate profile reflects the international search for talent.

Best of both worlds
Graduates are expected to demonstrate both engineering skill and managerial potential and are thrown in at the deep end right from the start, applying their knowledge to cutting-edge projects.

In transition
In between each placement, graduates receive training and are set an assignment designed to push them out of their comfort zone.

All change, please
The programme is evolving as time goes on. Graduates pursuing a career in operations are now included, their ultimate destination is more flexible, and demand for graduates is rising across the group.

What's the story? The graduate programme

3
year programme

x4
nine month placements

1+
At least one placement abroad

The programme begins with an induction week where graduates meet their business mentor who will oversee their training.

Each graduate starts in a "home" business division and spends at least one placement abroad. The emphasis is on project work.

In between placements, graduates train together in transition week. At the end of three years, graduates all have a qualification such as certified engineer.

Hats off to Meggitt's mainstream engineers

GRADS ARE GREAT, AFFIRMS MEGGITT'S CTO, BUT LET'S NOT FORGET THE ENGINEERS GIVING THEM THE CHANCE TO EXCEL.

Keith Jackson, Meggitt's Chief Technology Officer, says that graduate programme successes prove the value of giving engineers the time and space to drill into thorny topics or expand their knowledge without immediate commercial pressures. " I envy them," he says.

At the same time he pays tribute to the quality of young engineers coming into Meggitt, filling permanent positions in individual divisions and business units and already contributing to the achievements of Meggitt's established 1000-strong engineering team at all levels. Some of these achievements are commercially-sensitive and, en masse, the list of high performers is too long to enumerate on this page.

Jackson also highlights the work being carried out today industrialising the design successes that have won contracts in the current bid cycle. "It commands great respect. It is complex work," he observes, "and it's paying for our future."

ART for ART's sake

THE GRADUATE PROGRAMME IS CONTRIBUTING TO A MUCH BIGGER RESEARCH EFFORT involving Meggitt's Applied Research & Technology (ART) teams who are in business to provide mainstream engineering with the opportunity to work with new manufacturing and product technologies. The function has the highest backing, with Chief Executive, Stephen Young, ring-fencing budgets to ensure that programmes are isolated from the effects of economic cycles. The response across Meggitt has been positive. Says Jackson: "We butt into the space of some pretty busy people and they say, "interesting. Have you thought about ... " or "Could we add ...". They bring focus and momentum to our efforts. It is very refreshing. Hats off to them."

There is plenty of exciting new design work to go round to ensure that Meggitt is ready for the next wave of development programmes. "This is likely to be as transformed by original thinking as new manufacturing technologies," he says.

And it is not just AR&T's call. He believes that some 1000 engineering brains working together through the *Meggitt20* innovation forum alone could deliver outstanding products for Meggitt's customers and professional development opportunities for all those involved inside the business. Meggitt20 invites responses to topics relating to Jackson's technology roadmaps for the next decade majoring on Meggitt's core capabilities such as fluid mechanics, heat transfer, sensing and monitoring, material science and power and control. "I know," says Jackson, who is relatively new to Meggitt, "that we really can make a difference. I've seen it happen elsewhere and from my experience to date at Meggitt, it can happen here—no question."

Having heard the presentation, Allen would ring Stephen Young, Meggitt's Chief Executive, and give technical advice on whether or not to buy the company.

"That made them sweat," says Jackson. "I made it all up, but as far as they were concerned it was real. Chris's first line came in to receive the presentation—they were in on the scam—but it really got them."

During the week, the more experienced graduates are expected to deliver training to the other graduates on an engineering subject. "You have six months to become an expert, create the course materials and be ready to give an introductory lecture," says Marshall, a transition week veteran.

> You get dropped straight into something very real and very business-like. Some can take it and some can't

Jackson is unapologetic about the demands. "When you go into transition week, you should know it's really hard and that expectations are really high. I expect people to be motivated and driven. Those are the characteristics of good engineers—they are always stretching themselves."

Unsurprisingly, the programme has undergone some changes since the first intake. In the first two years the graduates were all engineers, but the latest cohort included some graduates with an engineering background who were hoping to make a career in operations.

The final destination of the recruits has become more flexible, too. "Initially," says Young, "the expectation was that we would place you for the first assignment with the business where we thought you would end up. Now you're just as likely to end up somewhere different."

As the programme becomes more visible, more businesses within the group are bidding for graduates to join them, so the way placements are assigned is changing. "People have got used to the idea that these people are great resources," says Young.

Indeed, some graduates make themselves so indispensable that their temporary bosses are unwilling to release them to their next placement. "It messes up the programme," says Jackson, "but it's really good. It shows that what they are doing is wanted." ●

Meet the graduates

Farhana Zaman

Studies:

PhD in micro-electronics at the Georgia Institute of Technology in Atlanta, Georgia

Why Meggitt?

Zaman liked the breadth of experience offered by the programme. "As my PhD was very specialised I wanted to branch out." The international element was a further attraction: "I am fortunate to have the opportunity to visit totally different places."

Placements so far:

MPC in Rockmart, GA, MSS in Irvine, CA, MCS in Birmingham, UK, OECO in Milwaukie, OR

Making an impact:

Zaman used Design of Experiments (DOE) in work to improve the yield and accuracy of sensors.

DOE is a standard engineering technique used where there are many combinations of factors affecting a process. It involves working out which elements can be tested together and which separately, at a few points on the curve or at many.

Zaman discussed its application to this project with her mentor. "I received guidance and resources from Meggitt but a lot of it was my own motivation and initiative." She went on to develop training materials and delivered an introductory course in DOE to fellow programme participants and now looks forward to offering the training to the wider Meggitt community.

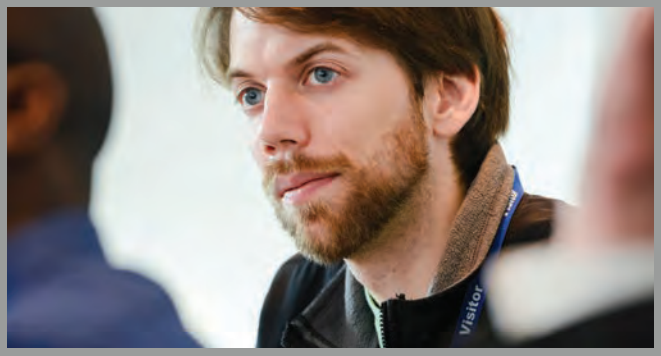
Impressions of the graduate programme:

"It's very stretching—there's never a dull moment. It is focused with the formal training modules, but I like the flexibility it offers."

What's next?

"I would like to continue in a project management role. I want to work on a site with a lot of diversity—not just in one aspect of the business." Managing a high-impact R&D project on next-generation heat exchangers at MCS, Birmingham reinforced my interest in pursuing project management in a permanent placement.

Jeffrey LeHew



Studies:

Milwaukee School of Engineering, then a Masters and PhD in aeronautics at the California Institute of Technology (Caltech)

Why Meggitt?

LeHew wanted the opportunity to try out a lot of different things—"to find out where I fit in the company"—with non-technical placements as well as engineering work. "The major difference was the international placements."

Placements so far:

MDSI, Irvine, CA, MSSI, Simi Valley, CA, MPC, Loughborough, UK, MCS, North Hollywood, CA

Making an impact:

At Meggitt Safety Systems (MSSI), LeHew developed a prototype device for certifying water mist fire protection systems based on the Particle Image Analysis (PIA) technique – a non-contact measurement technique for extracting droplet size and spray density from images of a spray or mist. "The goal was to create a low cost system using an LED light as the illumination source. I designed and assembled the instrument, developed an interface between the device and computer system, and wrote the image analysis software. This sort of technology exists but until now it hasn't been applied to certification so we're changing the paradigm."

At MPC, LeHew went on to work on a simulation for a de-ice and anti-ice control system for aircraft wing leading edges. His non-engineering placement involved developing a software tool to aid aftermarket and spares sales forecasting.

Impressions of the graduate programme:

"I've been able to make an impact on projects fairly early on. I thought I would just be learning, but I proved some results which I think were useful. In a lot of cases I became the expert in something very quickly which was very good.

"Looking back as my final rotation concludes, I have been given many opportunities for professional development from acquiring different skills to undertaking diverse activities. The programme is a good opportunity to try your hand at a lot of different things and to make an impact."

What's next?

I was offered several fascinating roles and have chosen a position in MSSI's R&D team which enables me to work on optical system design and heat exchanger design and analysis, while continuing to contribute to Group-wide AR&T initiatives.

Jenna Becker

Studies:

Mechanical engineering at California Polytechnic State University (Cal Poly San Luis Obispo)

Why Meggitt?

Becker was attracted by the opportunity to try out a lot of different types of engineering, and by the prospect of travelling to different places and seeing different parts of the world.

Placements so far:

MCS in Simi Valley, CA, OECO in Milwaukie, OR

Making an impact:

At MCS in Simi Valley, Becker worked on test engineering for the research and development of a green fire suppression programme for aircraft engines.

"I worked on testing an addition to a tool we use called a Halonyzer—a device that measures the concentration of extinguishing agent in an area of interest (the aircraft engine). The Halonyzer is designed to measure concentration when the agent is in a gaseous state, but we are also interested in testing agents that become more of a mist at very low temperatures.

"My goal was to test an addition to the Halonyzer that we call heated probes. A lot of it involved building an apparatus so I was using hands-on skills that I hadn't really been able to put into use before."

Impressions of the graduate programme:

"So far it's been an amazing experience. It's a really interesting programme—it definitely gives us a lot of opportunities. I have had a lot of independence. I have been seeking help, but it's pretty much me on the project so it's very exciting and also pretty nerve wracking.

What's next?

"I'd like to spend a rotation in the UK at some point. As far as projects are concerned, I'm not really sure yet. Part of the reason I went for this job was because I really had no idea what I wanted to do when I got out of college."

Blaise Guélat

Studies:

École Polytechnique Fédérale de Lausanne, Switzerland: degree in micro engineering, PhD in microsystems, specialising in miniature sensors

Why Meggitt?

Guélat was interested in applying his PhD to a new area and gaining industry experience. He was also keen to work abroad. "This programme was a perfect opportunity to develop myself and get experience abroad with challenging projects."

Placements so far:

MSS in Archamps, France, Meggitt Avionics, Fareham, UK, Securaplane, Tucson, AZ

Making an impact:

Guélat has been working on the development of a new attitude computation algorithm for secondary flight displays showing the orientation of the aircraft.

The Integrated Secondary Flight Display (ISFD)—a flagship Meggitt product—integrates all the sensors it needs to compute the attitude of the aircraft, using data from an inertial measurement unit. "The goal of the project is to fuse data to provide the best, most accurate data and to make use of other data sources such as magnetic data and GPS when they are available.

"My first task was to learn and research the state-of-the-art methods for attitude algorithms. I developed and later improved a first algorithm in Matlab for fusing the data of the various sensors and I built sensor models which allowed me to simulate the algorithm following different scenarios.

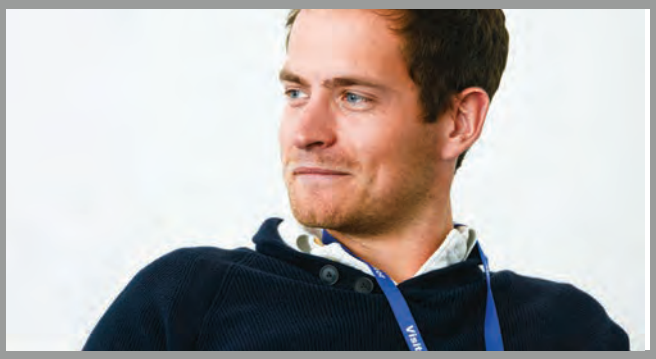
Impressions of the graduate programme:

"It has been challenging and interesting. If you apply for an engineering job you would expect them to take someone with previous experience, but my work has not been directly aligned with my background. It's different but it makes it very interesting."

What's next?

My last placement sees me return to Switzerland, my home country, for a non-technical assignment in Operations before looking forward to hearing about the future opportunities within Meggitt when I conclude my Graduate Programme rotations.

Jamie Marshall



Studies:

Aeronautics and astronautics/spacecraft engineering, Southampton University, UK

Why Meggitt?

Marshall was already a Meggitt employee when the graduate programme started—he joined the programme straight from Meggitt. He was attracted by the prospect of working on diverse projects.

Placements so far:

MSS, Basingstoke, UK, MSS, Fribourg, Switzerland, Securaplane in Tucson, AZ, MCS, Coventry, UK

Making an impact:

At Securaplane, Marshall worked on a wingtip protection system, integrating cameras and sensors into aircraft structures and practising the project management skills, largely involving customer relations, needed to progress his engineering chartership. Now, in his final non-technical placement, he has moved into programme management for a multi-million pound, multi-organisation research project into technology for Meggitt's factory of the future.

"M^4, Meggitt Modular Modifiable Manufacturing, moves conventional production line systems to smarter, internet-enabled alternatives. It is a paradigm inversion for aerospace, never mind Meggitt, and I am proud to be playing my part in a truly ground-breaking project."

Impressions of the graduate programme:

"I have really enjoyed it and would recommend it to other engineers. It has opened my eyes to understand how different businesses work. Being sent to different places and living away from the UK for 18 months has developed me as a person as well."

What's next?

I will be graduating from the scheme towards the end of the year and will be taking on a permanent role. The programme has taught me that my strengths lie in technical creativity with leadership elements.

The AR&T of the future

From the world's first altimeter 150 years ago to the electric brakes and next generation sensors of today, our history of innovation is formidable.

With a group-level board, increased funding, a regular programme of seminars and a new online forum, Meggitt's Applied Research & Technology (AR&T) strategy continues that tradition, developing tomorrow's technology today.

In the beginning was the (Meggitt) altimeter

The first commercial e-brake—by Meggitt

Our silent bleed valve—in development

If we're going to capitalise on the Meggitt legacy and create one of the great engineering firms of the 21st century," says Group Technology Director, Keith Jackson, "we need to look ahead over the next 20 years and concentrate our efforts. That's what AR&T is all about."

"In the last few years, we've seen time and again how successful the Meggitt Production System is in getting people at every level to innovate," says Chris Allen, Group Director, Engineering & Strategy. "So when it comes to researching and implementing new technologies, we're very clear that all our engineers can and should contribute."

"But it's no good working alone," says Jackson. "We need to harness ideas from across the Group, focus our efforts on the most promising and collaborate across disciplines."

Meggitt's AR&T strategy is designed to do just that. The aim is to increase growth and value by identifying and developing product and manufacturing technologies to Technology Readiness Level Six, the point where new technologies are ready to be offered to a customer.

Representatives from each Meggitt division and expert technologists from key capabilities sit on the 10-man AR&T Board (see box right). Members feed through insights from their part of the business and gathered from many Meggitt partners—leading universities, innovative start-ups, OEMs and government bodies. Right now, these range from next-generation manufacturing technologies to key Meggitt capabilities such as high-temperature electronics, integrated vehicle health management and the wireless technologies underpinning our smart sensors.

> It's always fascinating and it's always hard to choose: there's so much going on, it's not possible to green light everything

work with each other to refine technology roadmaps for each of our core capabilities.

Board members give updates on cutting-edge developments from across the business and the latest research they've

"Once we've reviewed and updated our roadmaps," says Jackson, "We prepare and approve the budget and discuss which individual projects should be funded. It's always fascinating and it's always hard to

Group Technology Director, Keith Jackson, capitalising on the Meggitt legacy and creating another for the 21st century

choose: there's so much going on, it's not possible to green light everything."

One of the biggest AR&T projects underway is a €7 million gas turbine sensor programme funded by the European Union.

"Engine efficiency is more critical than ever," says project lead Mark Langley, Research & Technology Manager, Meggitt Sensing Systems. "In addition to intense commercial competition, there are increasingly tough environmental targets such as those set out in Vision 2020 and Flightpath 2050 by the European Union. Engine manufacturers are looking to eke out every last drop of performance and efficiency."

"Take higher temperatures, for example. In very broad terms, if you can increase the heat of the gas entering the turbine by 50°C because your sensors are more accurate, that could yield about a 1% reduction in fuel consumption. And that means thousands of tonnes of kerosene saved every year."

Meggitt participates in and coordinates STARGATE, as the project is known (Sensors Towards Advanced Control and Monitoring of Gas Turbine Engines). Now in its final 12 months, it has 16 partners ranging from the large OEMs like Rolls-Royce, SNECMA, GKN and Siemens to universities such as Cambridge and Loughborough and cutting-edge small businesses.

"The technologies we're evaluating include advanced gas path sensors, novel optical methods for surface and structural measurements, as well as wireless and less-wired systems," says Langley. "We're on track and hope to deliver some very exciting new sensing technology that can contribute to improving engine efficiency." Meggitt is participating in a number of other EU and national research projects in Denmark, France and Switzerland and the UK government's £2 billion Aerospace Technology Institute.

Seeding knowledge, harvesting ideas

While the AR&T Board oversees strategy development and implementation, two other initiatives have been launched to share our latest advances, encourage debate and generate new ideas.

One is a programme of monthly online seminars where experts from across the group are invited to discuss key topics (see over). The other is Meggitt20, the company's digital forum for future technology which is open to all of the group's 1,000-plus engineers.

"It's been proven time and again that collaborative forums can have a huge impact on productivity and revenue. But you've got to create a forum that works for your culture. " Jackson explains. "Some companies just have to make a platform available and conversations take place immediately. Others need to lay out a highly structured approach to generate ideas. Meggitt20 is somewhere between the two."

The intranet site is structured around the technology roadmaps approved by the AR&T Board which relate to key next generation platforms and Meggitt's core capabilities. This helps to seed discussions in key capabilities but there's

> Being open is essential if we're going to get really free thinking. We'll share our mistakes. It's a vital part of the learning process.

Meet the AR&T masterminds

Meggitt's new AR&T Board brings together technology leaders from across the business with recognised experts in key areas to develop and implement group strategy.

Chairman

Keith Jackson,
Chief Technology Officer

Board members

Doug Moseley, Vice President of Research & Technology, Meggitt Aircraft Braking Systems

Ian Campbell, Director, Advanced Technologies, Meggitt Control Systems

Velma Brooks, Vice President, Technology, Meggitt Polymers & Composites

Dr Dominique Vez,
Director, Applied Research & Technology, Meggitt Sensing Systems

Aircraft systems:
Dr Mike Boost, Vice President, Technology, Securaplane

Composites and ice protection:
Mark Hancock, Technical Fellow, Meggitt Polymers & Composites

Non-Executive Director

Dr Richard Greaves,
Chief Technology Officer Emeritus, 2015 SAE President

Secretary

Jamie Marshall,
Graduate Engineer, Meggitt PLC

sufficient flexibility to allow users to start up new conversations and evolve the site as necessary. The most popular topics so far range from model-based systems engineering and carbon fibre aircraft wheels to the application of big data principles in brake operations and maintenance.

Commercial sensitivity prevents publication of project details but engineers can log on to find out more and catch up with regular updates on the latest industry trends and news. Users can also now create profiles detailing their experience and interests so like-minded spirits can find one another and feed off each other's enthusiasms and knowledge.

We each have a unique contribution to make. So log on to Meggitt20 today—there are insights only you can give, ideas only you can have

"It's the most effective way of binding together the threads of innovation that span the business," says Allen. "It helps us push ahead by giving individual engineers the inspiration and opportunity they need to broaden their thinking and drive their careers ahead."

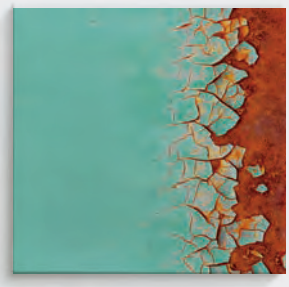
"There's PLC funding available for good ideas so I'm really looking forward to seeing all our engineers getting stuck into conversations that could lead to offline projects."

The first offline results from Meggitt20 are already feeding through. Additive layer manufacturing discussions that started in the forum, for example, have led to a fully-financed project leading to prototype parts in a matter of months.

"That's how quick it can be if an idea has relevance. The doors are open. Any of our engineers can come and contribute." ●

Meggitt20
The future starts here

www.Meggitt20.com



What's the cost of corrosion?

From inspiration to application—AR&T seminars at work

What do fir cones and bleed valves have in common? Where's our additive layer manufacturing (ALM) strategy heading?

Every month Meggitt experts give online seminars to bring our engineers up to date on key extreme environment topics. "The ALM session was fascinating—a powerful dose of cutting-edge technology and commercial insight," said Meggitt Chief Executive Stephen Young.

The seminar programme has run since 2012. Topics are selected by Meggitt's AR&T leaders to ensure the strategy remains tightly focused on key commercial opportunities. Very often PhD engineers on the graduate programme are asked to give the seminars to broaden their outlook and develop their thinking.

Take corrosion, for example. When you know that the direct cost of corrosion in the US comes to $276 billion a year (3.1% of U.S. GDP)*, it really focuses the mind—particularly if you're a materials engineer with a PhD from Georgia Institute of Technology.

"That's the figure for just one country," says Dr Yair Korenblit, one of two post-grads from Georgia Tech to join us in 2012. "Tackling corrosion is a huge and fascinating challenge, particularly in the kind of extreme environments we specialise in."

"So I was delighted to give a seminar on the subject. It's not often you get the chance to spend time assessing the latest research and discussing commercial opportunities on a topic like this with some of the industry's leading experts."

In the seminar, Korenblit gave an overview of the nine major kinds of corrosion and the complexity of real world situations before reviewing key lessons from Meggitt Aircraft Braking Systems and making suggestions about improved design and how to work more effectively with suppliers.

Another big challenge facing the aerospace industry is noise reduction, particularly for those who live near airports. In a recent seminar on lateral thinking in ALM, Dr Jeff Lehew, who has a PhD in Aeronautics from the California Institute of Technology, told how a Meggitt team drew inspiration from a fir cone to redesign compressor bleed valves.

"They're used to control engine pressure at landing and take-off and prevent stalling. But high pressure air passing through valves cast or machined in the traditional way is extremely noisy," he explains. "ALM allows you to create much more complex geometries which could potentially reduce noise."

The ALM seminar examined other prototypes that use complex shapes to improve performance before discussing the possibility of producing small custom components on demand. There was also a review of how ALM is changing manufacturing best practice on the Meggitt shop floor.

"There were about 25 of us online from all over the Meggitt network," says Lehew, "From senior figures like our CEO and Group Engineering Director to new joiners. We had some very interesting discussions."

"Technologies like ALM are so new that often it's our young engineers who can take their application furthest," says Jackson. "They have a fresh perspective because they're not so steeped in traditional manufacturing."

Engineers who want to find out more about the seminars should visit Meggitt20 today. You'll find:

- details of forthcoming AR&T topics
- recordings and minutes from every seminar
- follow-up discussions
- newsletters

* NACE International, The Worldwide Corrosion Authority
http://www.nace.org/uploadedFiles/Publications/ccsupp.pdf

Quality management goes global

The development of the Meggitt Global Quality Management System (GQMS) represents another step forward in Meggitt's maturity journey.

Led by Global Quality Systems Manager, Graham Crighton, who has developed similar systems at Honeywell and other diverse international corporations, Meggitt's first global quality management system will promote global compliance, reducing risk by eliminating the group's multiple quality management systems.

"The system will help us continue in our quest to become easier to do business with, presenting one face to our customers with a common approach, common language and, even, common branding," he observes, referring to the "Right First Time. Every Time" campaigns pervading Meggitt factories.

Supporting the all-important Meggitt Production System, the GQMS implementation is on track, with several live global procedures, several dozen in development, a manual undergoing external review and compliance assessments scheduled with external parties for Q4. System implementation is being piloted at several key Meggitt facilities in Jan 2016, with further implementations throughout the rest of year. 'Q Pulse', a world class audit, corrective action and documentation management system is being implemented at all facilities led by Siholi Dasgupta, Global Business Process Lead, Quality.

The GQMS is based on ISO9001 aerospace and automotive standards, structured in three levels: a single Meggitt quality manual superseding all those held by the sites today; one set of primary procedures for divisions and business units; and facility-based procedures and work instructions where unique requirements exist.

Crighton is working with senior Quality leaders Mark Keal, Brett Withington, Laurent Glinel-Montreuil, Rob Crocker, Steve Kahm and Sanjeev Sen to ensure that the system will cover the requirements of every function and facility and the regulatory requirements of all our markets. Tec Transnational, an external quality systems provider and training organisation, plus the British Standards Institute, are involved in development and review and will assess the GQMS before its launch in Q4 2015.

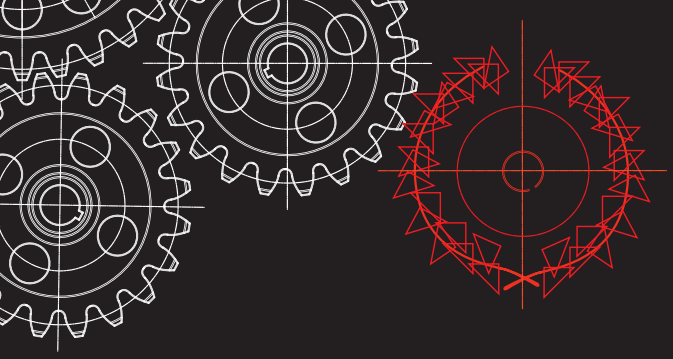
> We can only work together if there are no process and system boundaries. The implementation of single systems like the GQMS enables us to move resources around the group because we work the same way everywhere

Ensuring there are no weak links in quality control to damage the group's reputation is reason enough to implement such as system. However, Ian McMurray, Group Quality Director emphasises the GQMS's contribution to collaboration. "We can only work together if there are no process and system boundaries. The implementation of single systems like the GQMS enables us to move resources around the group because we work the same way everywhere." McMurray's 'rapid read across' theme is strong too. "System updates will be significantly easier to make without 40 disparate systems. Sharing best practice won't just be a nice aspiration. It will happen."

The Admirable [Graham] Crighton

Chief Executive Stephen Young has described the GQMS as 'critical'. "This programme not only promotes profitable operations but builds and protects our all-important reputation, the key to being invited to bid on important new programmes." ●

QUALITY
RIGHT FIRST TIME. EVERY TIME



Permission to be an engineer

Until last year, expert engineers who wanted to rise to the top had to take on more management and commercial responsibility, in many cases cutting back on their first love: engineering.

"Now we have a dedicated technical path to senior level," says Group Director of Engineering and Technology, Chris Allen. "The new roles of Technical and Associate Fellow are for the experts who lead the technology development that keeps Meggitt ahead."

Meggitt's first Technical Fellow, Mark Hancock, has specialised in keeping aircraft ice-free for 30 years. "Being a Fellow gives me permission to be an engineer again and concentrate on keeping us in the lead."

The key to Meggitt's advanced electro-thermal ice protection is the provision of the right amount of power in the right place at the right time.

The traditional solution still works—bleed air from the engine is ducted along the leading edge of the wing. But with today's emphasis on efficiency, the demand on engine power is too high a price to pay, no more so when it comes to 'more electric' aircraft. Hancock observes: "Electrical solutions have become a critical 'enabling' technology. If ice protection requires too much energy, the future of more electric is limited."

Hancock has been instrumental in the evolution of our capability which today combines advanced competencies in power conversion and smart control, sensors and internal connectors. Meggitt's expertise in precision-mechanical chemical etching is key too, enabling complex heater elements to be 'printed' with integral sensors and advanced connector solutions.

"Our systems can now provide ice protection on exposed leading edges of fixed wing aircraft," he explains. "We can deliver energy savings by varying the heat intensity depending on the environment and aircraft flight envelope. And thanks to the reduction in temperature compared to bleed air systems, we can use lighter composites in leading wing edges, further improving overall efficiency."

One example is the electro-thermal slat developed for a Bombardier 'more electric' demonstrator programme, successfully proven in icing wind tunnel testing and flight trials. Hancock and team are also working in the European Union's Clean Sky 1 programme, developing an electro-thermal solution for a laminar wing.

"Looking ahead, we want to trial other potential configurations including a hybrid bleed air-electric solution as well as new coatings that could help prevent ice formation," he says.

How does being a Fellow help?
"My new role as a Fellow is helping us push ahead in a number of ways. First, I'm back to focusing 100% on technology. I enjoyed the challenges of earlier roles such as Director of Engineering but I definitely had less room for the technical side."

As a Fellow, I'm back to engineering full time. It's what I'm best at and enjoy most.

"Second, I now sit on Meggitt's Applied Research & Technology Board. That means I get a bird's-eye view of what's happening technology wise across the group and where the commercial opportunities are too. As a result, I can bring all Meggitt's expertise to the projects I'm working on and make sure all our specialisms can be maximised elsewhere."

"Third, part of my brief as a Fellow is to champion our expertise in the industry by giving papers, working with universities and other research bodies."

Hancock sits on the Regional Advisory Panel for the National Aerospace Technology Programme, a £40 million UK-government backed development programme. He is also a member of the Industrial Advisory Group for Nottingham University's Aerospace Technology Centre and has given many papers including to The Royal Academy of Engineering.

"These roles keep me right up to date with what's going on in my field, opening up possibilities for funding, partnerships and commercial opportunities."

"Ultimately being a Fellow gives me more time and more resource and raises my profile across the group. People know where to find me if they have any ideas or issues related to ice protection or composites. And because I am kept informed about Advanced Research & Technology developments across the whole of Meggitt, I can see where we can push ahead most profitably in the areas I know most about." ●

Champions of technology

Our technologies play a lead role in our success," says Chris Allen. "We need expertise at the highest level to make sure we continuously rejuvenate our technology portfolio, both in our own R&D and by working with other leaders in our specialist areas."

The roles of Fellow and Associate Fellow ensure we do that by creating a dedicated career path for senior engineers who want to focus on developing and championing their technical expertise.

Meggitt Technical Fellow

What does a Fellow do?

Operating at the same level as a head of engineering for one of Meggitt's five divisions, Fellows fly the flag for technical excellence within their domain and are given the time and resources to work across the group. They contribute to an annual technical review to identify trends and risks and opportunities in emerging capabilities.

As trusted ambassadors for Meggitt, they develop and maintain external relationships with research institutes, government bodies and the like.

And they play a key role in nurturing Meggitt's engineers of tomorrow as nominated experts in problem solving, staff development and mentoring and vision setting across the group.

Fellows generally report to the head of their division and functionally to Meggitt's Chief Technology Officer (CTO).

How do you get to be one?

Candidates will be well-known subject matter experts, within Meggitt and industry. You need at least 15 years' experience, an impressive record of commercial impact and the respect of your peers, internally and externally.

Unlike most roles, it's peers who nominate you rather than bosses who appoint you. Candidates with the right level of experience can also apply formally for the role.

Nominations are reviewed by all existing Technical Fellows as well as CTO Emeritus and SAE 2015 President, Richard Greaves and Wanda Wolny, recently retired Materials Director at Meggitt Sensing Systems and former President of The Piezo Institute.

Boost for power

In June, Mike Boost was appointed Technical Fellow, Power Conversion & Energy Storage.

A PhD in Electrical Engineering, Boost began his career in telecommunications before joining Meggitt in 2001, rising to become Securaplane's Chief Technology Officer from 2006. His pioneering work includes the first certified wireless safety critical system, the first lithium battery charger, the first application of novel power conversion topology and the first application of power harvesting technology. Securaplane's *System Lithium* would not exist but for him.

Boost's expertise is sought by third parties including the Federal Aviation Association, the National Transport Security Board and various standards committees. He contributed to the RTCA standards for energy storage, including the new DO-311 standard for lithium battery systems which forms the basis of the FAA's Technical Standard Order for battery-based emergency power. He is widely published and cited by organisations such as IEEE, SAE and various power electronics journals and is the named inventor on many Meggitt patents in power electronics, energy storage and security.

Chris Allen, Meggitt's Group Head of Engineering & Strategy commended Boost in two ways. "Mike's work always has commercial purpose. He has consistently sought to stimulate organic growth through technology innovation. At the same time, he always makes time for mentoring. The ability to develop others is an essential quality of the Meggitt Technical Fellow."

The appointment represents both an honour and a privilege, says Boost. "I welcome the opportunity to push technology innovation to higher levels within an engineering and technology-driven company like Meggitt.

"The revenue we reap from new products is an indicator of corporate vitality. At Meggitt, given its diverse specialist technologies and products, our vitality is limited by our ability to link thousands of talented, technically-oriented employees into a continuous innovation framework and to integrate open innovation, where we can, with universities and industry. I welcome the opportunity to speed our growth rate by harnessing this innovation." ●

A system not a battery.
Dr Boost with Meggitt lithium

Electric combination breaks the ice

Meggitt Polymers & Composites in Loughborough has just beaten the industry's odds-on favourites in a competition to lead a state-of-the-art de- and anti-ice systems research project funded by the European Union

Late June saw Meggitt Polymers & Composites, Loughborough (MPCL) accepted as a "Core Partner" in a European Union Clean Sky 2 (CS2) Joint Technology Initiative covering 'green' aircraft ice protection systems. Core partners commit to programmes for the long term, bring key capabilities and have the opportunity to shape research strategy. The project will cost around EUR 6.2 million, of which Meggitt's share is EUR 2.76 million. The EU will refund 70% of that investment.

> Our existing smart ice protection solution cuts around 50% of the energy consumed by a bleed air system. We are targeting a massive 90% with smart materials actuation

The award is the culmination of several years' intensive research led by Meggitt Technical Fellow, Mark Hancock into smart electro-thermal aircraft ice protection systems for civil aircraft at Clean Sky 1 'Partner' grade. This built on significant expertise in electro-thermal ice protection for helicopter air inlets from Meggitt, plus the cutting-edge actuation control systems capability that came from the newly acquired Pacific Scientific Aerospace business, Artus.

MPCL is now leading a consortium of fellow core partners including Meggitt Sensing Systems' Artus and Danish facilities, plus the University of Nottingham, Ultra-PALS, which is supplying the cable translation mechanism, AeroTex, supplying the icing analysis and CIRA, the icing test facilities. The consortium will deliver solutions to "Work Area Leads" (industrial sponsors and specifiers of the requirement), Dassault Aviation and Airbus Spain.

Known as GAINS (Green Airframe Icing Novel Systems), the consortium brings together the capabilities needed to provide a complete ice protection solution for business aircraft, including smart hybrid bleed-air and electro-thermal systems

for de-ice and anti-ice and a novel ultra-low power de-ice system using exclusive Meggitt intellectual property.

Ice protection is mission-critical and very far from a niche capability. "You cannot fly without a system that checks the formation of ice deposits on aircraft surfaces. If you did, the risk of the aircraft becoming impossible to control in cold weather is very real," explains Steve Parker, the Group Director of Engineering who has been successfully coordinating multiple bids for UK government and EU funding following the establishment of a central Applied Research & Technology budget two years ago. "Today, most anti-ice systems on civil aircraft heat surfaces using bleed air. De-ice systems allow a thin layer of ice to form before it is removed , typically using pneumatic rubber 'boots' which inflate and cause the ice to break off. It really is time for more next generation thinking in this field and Meggitt's credentials make it the obvious leader for such a project."

Even higher GAINS

Expulsive systems have been available for a number of years using heavy electromechanical actuators to apply impulses to an aircraft's structure causing the ice deposits to break away from the aircraft skin. Meggitt's system will use alternative actuation strategies to provide the mechanical impulses, providing a route to low-power, very lightweight de-icing systems for next generation aircraft. says Hancock. "Our existing smart ice protection solution cuts around 50% of the energy consumed by a bleed air system. We are targeting a massive 90 per cent with our smart materials actuation."

Alongside active ice protection systems, research will be conducted into passive ice protection using advanced ice-phobic surface materials to inhibit ice accretion and promote ice shedding. Hancock observes: "Passive ice protection combined with active systems promises the lowest power possible ice protection system. The GAINS project started formally in early July and will continue until 2022 with the objective of demonstrating the flightworthy advanced hybrid system and a laboratory demonstration of the novel ultra-low power alternative. ●

All the options in an era of change

Meggitt has been keeping critical aerodynamic surfaces and engine air inlets ice free without limiting flight range and safety for over 50 years. It is uniquely experienced in the primary technologies—bleed air and electro-thermal systems—and its engineering team, many of whom have aircraft constructor experience, know how to design, integrate, manufacture and qualify them in ways that minimise programme risk.

Meggitt has trialled its latest innovation—electro-thermal ice protection with advanced smart control—with Bombardier, a leading manufacturer of fuel-efficient, more electric fixed wing aircraft. While decreasing drag on engine power, our technology will also become critical for ice protection on composite wings.

Meggitt is confident that it will become the first manufacturer worldwide to use smart materials to actuate expulsive systems. To date, such systems have focused on less-than-elegant solutions

Meggitt wins Scout ammo handling

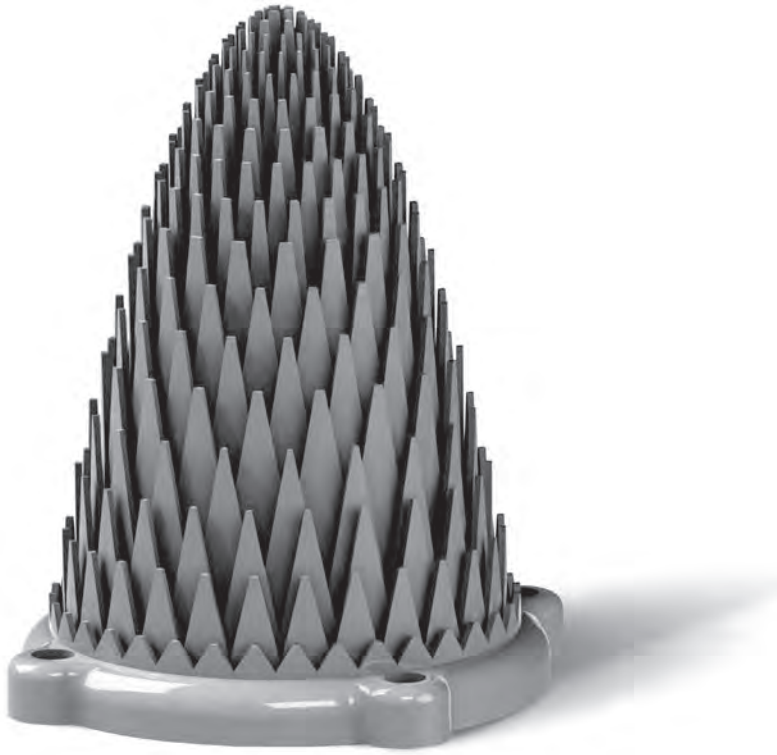
Meggitt Defense Systems of Irvine, California, has been awarded a $42.1 million contract by Lockheed Martin UK (Ampthill) to produce 245 automatic ammunition handling systems (AHS) for the British Army's Scout armoured vehicle programme. Production deliveries from Meggitt's Irvine, CA facility will commence in 2016 and continue through 2021.

The Meggitt cased telescoped ammunition handling system will be incorporated within Scout's 40mm cannon. Rounds are translated laterally about one metre at high speed and handed off to the gun for loading into its unique rotating breech and firing. The action is based on Meggitt's "linear linkless" technology in which a round travels from the magazine along a linear track until it reaches the gun's breech. Each round is handled individually, with no belt or link to snag or jam. Despite the 'linear' part of the name, which implies rounds are stowed in a straight line, they are actually stored in a serpentine configuration to maximise utilisation of available space.

The Scout's weapon system showcases another of Meggitt's specialities: volumetric efficiency—packaging an ammunition system in such a way that it takes up the minimum possible amount of internal space.

According to Charlie Panasewicz, Senior VP, Business Development, Meggitt Defense Systems, Irvine said: "Creating a system with the fewest possible moving parts means that reliability rates skyrocket. There is simply less to go wrong. In fact, the design of Meggitt's medium calibre ammunition handling systems eliminates 90% of the ways a gun can fail." ●

Smart engineering is second nature to us
High pressure air travelling through the geometry of bleed air valves cast or machined in the traditional way is extremely noisy, something that will be familiar to those who live near airports. In future, air could flow more quietly through a radical new concept from Meggitt based on a fir-cone design, an organic structure made possible through additive layer manufacturing. The bold use of innovative processes forms part of Meggitt's centrally coordinated and highly focused technology strategy.



The print addition

With hysterical headlines screaming about its latest antics, additive layer manufacturing—or 3-D printing—has been known as the bad boy of the engineering world. We find out how the bad boy has come good and is the subject of a major Meggitt research project.

Scott Lathrope (left) leads the ALM project with co-graduate programme participants, Matt Scovell (back) and David Skolnik (centre) whose responsibilities include the generation and evaluation of new concepts enabled by ALM. This activity includes assessing commercially available software solutions, devising guidelines to standardise the Meggitt ALM design process and creating prototypes on a desktop 3-D printer for design verification. Interfacing with suppliers, customers and academic institutions becomes a day-to-day task for ALM team members as they define milestones for aerospace Technology Readiness Level advancement.

It's been the new kid on the block for a while now—and a pretty troublesome one at that. If you ask most people about additive layer manufacturing— better known as 3-D printing or ALM—the chances are they will tell you a wild story about printing your own IKEA furniture or warn you about the dangers of the 3-D printed gun.

Well, it seems the new neighbour has finally put the gun down. Additive layer manufacturing is all grown up.

A team at Meggitt Control Systems in Coventry has been working with General Electric (GE) to develop a fully-optimised bleed air valve that will reduce noise emissions, decrease weight, improve reliability and advance the group's understanding of this emerging technology

Meggitt has chosen the ALM powder bed process for the GE project. A laser melts fine metal powder onto a part and sinters it, layer by layer, in the exact shape required. It can be used to make complex, lightweight parts with a geometric freedom that would not be possible or economically viable using other techniques. Hollow and sparse structures, lattices, webbing, surface finishes and hidden facets can now be created without joins or lengthy post-machining processes. Structures will be significantly lighter and stronger.

The other strand to the group's research involves heat exchangers and an alternative form of ALM. Group Director of Engineering & Strategy, Chris Allen, explains. "We are exploring two forms of additive layer. One is printing and melting thin layers of alloy powder and the other is stacking thicker sheets and mechanically bonding them together to form a monolithic structure. We are already world leaders in composite structures, so we are combining this with the chemical etching capability we acquired with Precision Micro to develop shaped and structural cooling technologies for next-generation ultra-high bypass engines.

> ALM enables a radical rethink of every aspect of the valve's design and materials

"'Shaped' means we can build additive layer in any shape to fit in and around the free space in the engine-nacelle integration—take a look at the windshield washer tank on any modern car. They are

SPEED READ

New beginnings
Additive layer manufacturing (ALM) was the subject of hype. Now it is the subject of a major Meggitt research project.

Quiet, please
The research team is creating an ALM bleed air valve that will reduce noise pollution and weight, improve reliability and increase knowledge of this emerging technology.

Strength in depth
The technique—laser melting—enables complex, lightweight structures to be made as one solid piece, increasing strength and decreasing weight.

Gold rush
The possibilities of ALM are so great that several companies are actively pursuing it. Although it is a future technology, it is thought it will be widely used within a decade.

made into increasingly complex shapes to fit into some odd places.

"'Structural' means additive layer in a multi-functional device. This could be a strut, for example, which carries the weight of the engine and has cooling galleries with fluids flowing throughout."

Bleed compressor valves are used to prevent stalls by controlling engine pressure. As high pressure air passes through the valve, it emits the high pitched scream on landing familiar to anyone living near an airport. Future engines will require lighter, smaller valves with increased performance and reduced noise pollution. ALM enables a radical rethink of every aspect of the valve's design and materials.

Scott Lathrope, a Graduate Programme engineer who studied mechanical engineering at Stanford University before joining Meggitt as an intern and later a project engineer, is leading the ALM project. He explains why this particular valve was chosen as an exemplar.

"It was a combination of keeping it simple and exploiting the design freedom of ALM to improve the valve. The noise is a unique opportunity. As the air exits the bleed valve it immediately creates noise downstream, depending on its flow rates and the perturbations the air encounters. We have been exploring ways of managing the effects. It is easy to make a valve quiet but conventional methods of doing this would make it big and heavy, which would not suit our applications."

The target is, says Lathrope, to reduce the noise as much as possible where it matters and where it will have an effect. "We are focusing on noise reduction at certain flight stages, working in sympathy with the rest of the design. It's especially important to do this work with an engine company, so we are really pleased to be working with GE."

The team is aiming to reduce the weight and part count of the valve.

"Weight reduction is the other main aim so we are looking at the fundamental design and reducing the parts count. Fewer parts mean fewer fixings, which is good for reliability and weight. It may also mean complex parts that are difficult to inspect, but there's always a trade-off.

"We could make it much more complex—we have ideas for future designs that could take us to another level—but for now we are sticking to our main goals of noise, weight and parts count reduction."

The low noise bleed valve is not, in fact, the first ALM valve the team has worked on but is the latest in a series. "With this one we are pushing the design freedom harder than before," says Lathrope.

It will be a while yet before the valve is ready for testing—according to Lathrope the team is aiming to test a complete valve by January 2016—but they are already evaluating elements of it. "We are moving into the exciting stage," he says.

"Throughout the ALM programme we have been tasked with 'making it real' and developing our capabilities using real exemplars," says Lathrope. The low-noise bleed valve is one. "It's much more of a challenge to develop a capability with real products." In time, Meggitt intends to develop a general ALM capability for use on other high technology components. The potential is huge. Valves, heat exchangers, brake manifolds, integrated metal matrix composites and integrated sensors housings could all benefit from its sophisticated properties.

So great is the potential of ALM that manufacturers are hurrying to get in on the act. GE has developed an ALM fuel nozzle with Parker-Hannifin and UTAS has a design and manufacturing ALM centre at the University of Connecticut.

Lathrope is excited to be working with GE. "They're the experts in the industry and the closest to production. It really couldn't get any better in terms of customer involvement."

Lest excitement at this gold rush build unrealistic expectations, Chief Technical Officer, Keith Jackson, is at pains to emphasise that this is a future technology. "There is an awful lot of misinformation on the subject and people are going to be disappointed when their expectations are not met. My team at Meggitt is taking a well-structured approach, thinking carefully about where and when to use the technology. It should be treated as a new material, of which the industry has limited knowledge. If care is taken and the applications are thought about, the risks around the new material can be balanced against the advantages offered by the manufacturing techniques.

Lathrope agrees. "It's been pitched as a technology that is ready today—some of the media stories are really bad. It really should have been pitched as the technology of 2018 to 2020."

In the meantime, though, ALM's build technology is evolving rapidly and machines are constantly being improved. It will move from a specialist technology to a volume one.

Lathrope believes the possibilities will be endless. "I see it as something that can apply almost everywhere," he says. "What you can get out of the process is much more than you can imagine today. If you just sit at your desk and think about it for 15 minutes, you are not going to be able to come up with the full potential of the process. It takes a time commitment to make the thought shift." ●

Valves, heat exchangers, brake manifolds, integrated metal matrix composites and integrated sensors housings could all benefit from its sophisticated properties

It's been pitched as a technology that is ready today—some of the media stories are really bad. It really should have been pitched as the technology of 2018 to 2020

Who's who in the ALM project

Lead
Meggitt, working with Manufacturing Technology Centre

Partner
Ashton & Moore (UK aerospace finishing supplier)

End user
GE

Additional sub-contractors
Within Labs & 3TRPD

Powered up

Meggitt's expanded range of all-electric engine controls lights up with PECC acquisition

Meggitt's long standing interest in Precision Engineering Controls Corporation (PECC) of California took tangible form in January when PECC joined the group. A greatly expanded horizon for gas turbine control systems beckons following the acquisition of PECC's actuation systems and fuel metering valve capacity from United Technologies Corporation. San Diego-based PECC has been integrated into Meggitt Control Systems (MCS).

The capabilities of MCS and PECC complement each other nicely. "In terms of product development, we benefit from PECC's electronics engineering capability and PECC benefits from our valve engineering," notes Rob Baker, MCS Vice President, Energy. This raises the prospect of cross-selling products between the two companies' customers.

"PECC gives us a much wider portfolio of electric valves and actuators to sell into the turbine market," explains Paul Normand, MCS Sales Director, Energy Products. "It really kicks up our discussions with existing and prospective customers several notches with this wider portfolio of products and increased technical capabilities."

PECC's products enable the integration of valves and actuators with electronic turbine controls, rather than packaging them separately on the turbine

In making actuators and controls for the industrial gas turbine (IGT) industry, PECC has focused hitherto on the 1-30MW range of IGTs. However, a new product will allow it to expand that range to 50MW.

"It's a rotary gas valve, a new piece of technology we've been working on for several years," says PECC general manager Sherri Stack. "This gives highly precise control and a wide flow range. It has a compact planetary gear that's also very reliable and smooth in operation.

PECC's products enable the integration of valves and actuators with electronic turbine controls, rather than packaging them separately on the turbine. This eliminates the need for wiring between the electronics and control units, a potential weak spot.

As well as its technical capacity, PECC has another quality that customers rate highly, namely a strong delivery performance. "We run at over 98% on-time delivery," says Stack, "and our quality signature is very strong." That delivery record counts for a lot among customers. "Our primary customer says 'We don't have to worry about you.' A couple of companies are doing business with us because they don't have to manage us."

Reliability, high quality and delivery were cited by customers in a feedback exercise as the most important factors on which they judged PECC, with good communication coming first and price, fifth only.

In reliability terms, the aim is to attain 40,000 hours mean time between failure (MTBF). That is essential because of the vital roles played by IGTs in domestic life. For example, a valve failure could effectively cut off the flow of natural gas to homes in a remote community. The valves must be proof against fires, explosions and leaks.

The much wider product portfolio really kicks up our discussions with existing and prospective customers several notches

"For some years, Meggitt has admired our design capabilities, our understanding of electronics and the complexity of those electronics," says Stack. "In buying us, Meggitt has gained a key component which fits group strategy."

"PECC's market share of electric valves and actuators in the <30MW segment and its relationships with IGT volume manufacturers added to the company's attraction for Meggitt," adds Baker.

The markets in which the combined businesses operate now effectively double in size. "We have major market share in two key industrial gas turbine market segments: aero-derivative [30MW-60MW] and small frame [<30MW]. And we have now have a much broader 'all-electric' product portfolio."

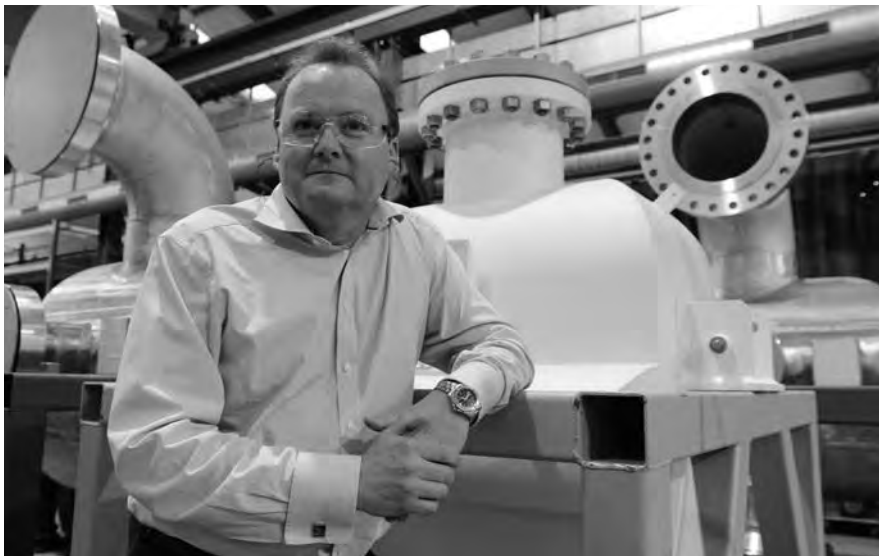
PECC is unusual in operating in both the original equipment manufacturer (OEM) and aftermarket sectors. "We don't have other companies out there doing our aftermarket [work] for us," says Stack. "When you need to know anything about our product, or do something to it, you come to us. Nobody else can match what we bring as the original designers and manufacturers of the equipment.

"We are proud to manage the entire life cycle of our products, delivering excellence to customers from cradle to grave." ●

New fields of energy

Months of close cooperation with a pioneering carbon capture consortium have led to a ground-breaking application and a multi-million pound contract win for Heatric's printed circuit heat exchangers (PCHEs) in this promising new market.

Business Development Director Nick Johnston explains how balancing innovative R&D projects with continued growth in the company's established markets is bearing fruit while also staying true to Heatric's roots.



Nick Johnston places many small bets in emerging technologies

"We try not to be too judgemental about crazy business propositions because we used to be one," says Nick Johnston. "And we respect disruptive technologies because we used to manage one of those too."

NET Power (see right) is a prime example.

NET Power was originally without funding, partners or customers. Heatric nonetheless set engineering time aside to support the embryonic enterprise. "The concept made sense and we followed through from a patent application around three years ago to this year's commissioning of a major power plant." NET Power's big idea may increase CO_2 capture dramatically and reduce the world's power bills.

Not all projects involve extraordinary technologies. "We are always looking beyond the hydrocarbon economy but we take care to track bridging technologies

Such a sympathetic approach to entrepreneurs with technically interesting concepts that depend on Heatric's specialised heat transfer engineering has produced some highly practical applications. The recent major order from

However, not all emerging technologies will progress this far so Heatric places many small bets. Beyond its traditional heartland of gas exploration and production, it is nursing around 30 projects of varying stages of technological and commercial maturity. "In a structured way, we put resource in commensurate with each customer's progress with his particular big idea. This includes a gap analysis. If the customer has worked with all components bar ours, we are comfortable. Clearly, we become less comfortable if the customer's experience of other technologies within a process is weak."

Not all projects involve extraordinary technologies. "We are always looking beyond the hydrocarbon economy but we take care to track bridging technologies," says Johnston.

In power generation, Heatric develops concepts for household names such as GE to make conventional gas turbine technology more efficient—just like Meggitt's control and actuation and engine health monitoring businesses. Again, the efficiency and high integrity of Heatric's heat exchangers are key enablers of any process involving very high pressure and requiring very high integrity to prevent leakage between, say, streams of steam and fuel gas.

The next generation of power conversion cycles will make use of supercritical CO_2 as a working fluid to recover more energy and generate power more efficiently than today's steam cycles. These new cycles need the same high pressure capability and high integrity construction as the hydrocarbon processing industry but at much greater levels of energy efficiency, all of which can be delivered in a small compact package with Heatric's microchannel technology.

Heatric is working with renewable energy suppliers to address the peaks and troughs of power generated by sun and wind. One solution is to store surplus renewable power, so it can be released when needed. British company Highview Power Storage has a pilot plant that uses off-peak electricity to cool and compress air to -196°C, the temperature at which the air's main component, nitrogen, becomes liquid. This is stored in tanks. When electricity is needed for peak demand, the liquid is warmed up, causing it to expand and drive a turbine. Once again, Heatric's high integrity, highly efficient technology is critical to the process.

There are other projects on which Johnston is tight-lipped. Interview over. He will trail those when the time is right, he says. And off he goes, back to the incubator. ●

CO_2

Multi-million pound contract paves way to low-cost power, zero CO_2 emissions

Carbon capture is widely touted as a key weapon in the battle against climate change. But there are very few power plants showing how it could work commercially. In a major new contract, NET Power has commissioned Heatric to help prove it at a new demonstration plant in Texas.

Most carbon capture systems are parasitic: they increase capital costs and reduce overall plant efficiencies, making them uneconomic.

NET Power, a new consortium of engineering and energy firms, is trialling a new approach with a revolutionary gas-fired plant that will be able to produce energy, store it when demand is low and provide 100% carbon capture.

Heatric is to supply the plant with four PCHEs by the end of April 2016, in a multi-million pound contract. The 50MWt demonstration plant, delivered in partnership with Chicago Bridge & Iron Company (CB&I), Exelon Generation, Toshiba and 8 Rivers Capital, should be commissioned later that year.

Using supercritical CO_2 as its working fluid, the system's major by-products will be water and a pipeline-quality, high-pressure stream of CO_2 ready to be stored underground permanently or compressed and liquefied for industrial use.

Environmental performance is further enhanced as oxyfuel combustion gives near zero pollutants—no nitrogen oxide, or sulphur dioxide, for example.

However, the heat exchanger required in this cycle needs a very large specific surface area to allow for the high flows of CO_2 and the large temperature range, between 50 to 950°C. That's why NET Power came to Heatric: its diffusion-bonded PCHEs can capture and recycle a significant proportion of a given waste energy flow at very high pressure and temperature, making a critical contribution to the economic viability of these pioneering green processes.

www.netpower.com

NETPOWER

Meggitt technology entrepreneur celebrates four decades' service

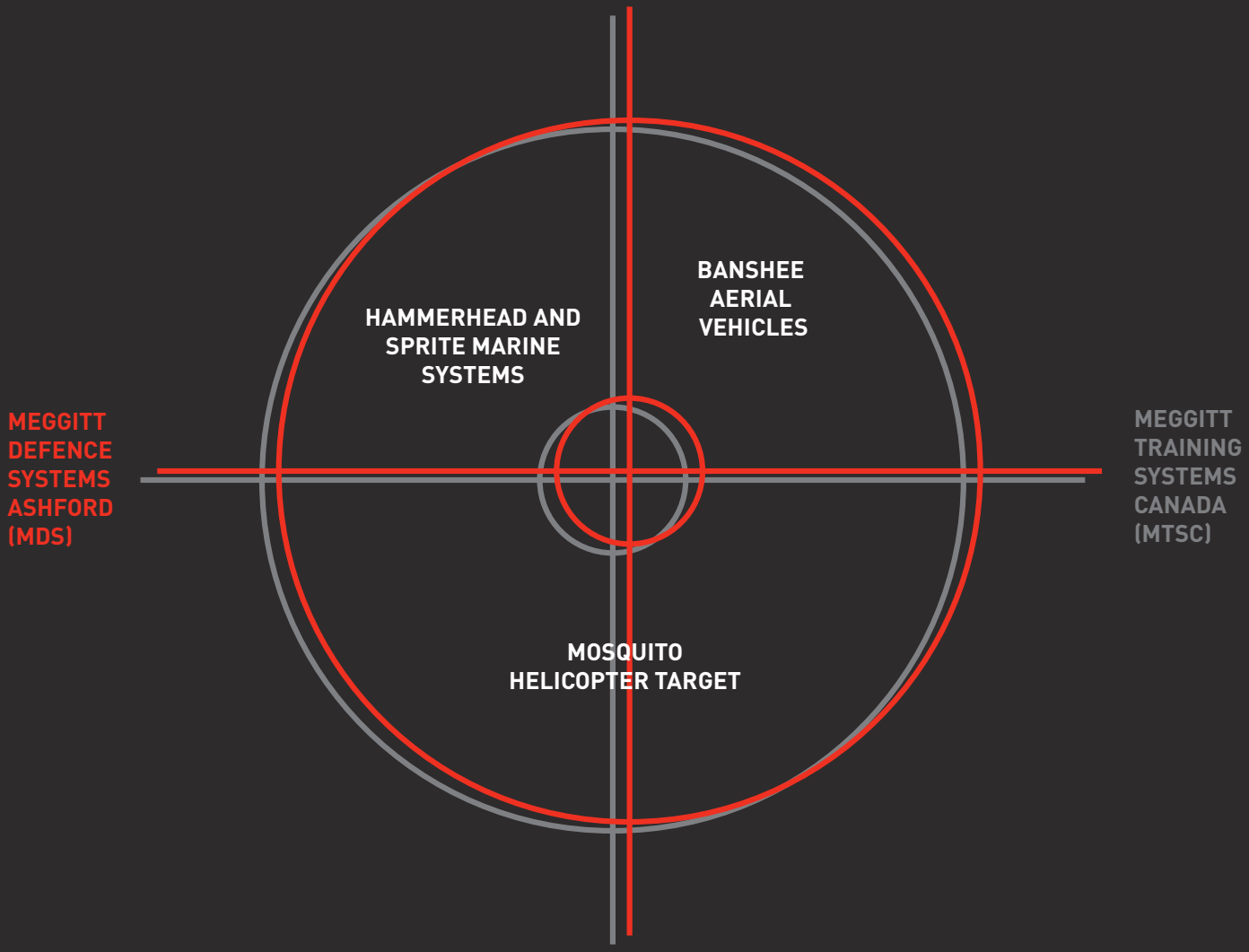
Dr Roger Brum's 40 years of service at Meggitt Defense Systems, Irvine, California, was marked by Meggitt's new Chairman, Sir Nigel Rudd and Chief Executive Stephen Young when they toured the facility in June. Brum has been President since 1995 but his involvement with the company dates back to the mid-1970s.

Dr Roger Brum's career started in 1975 with Prototype Development Associates, whose airborne target assets he acquired as part of a small consortium in the early 1980s. At this time, Brum was earning his PhD in Engineering —and teaching—at the University of California, Irvine, an institution with which he remains strongly associated, serving on the Dean's leadership council and providing careers guidance to graduates. In 1996, he completed an Executive Program in Business Administration at Stanford Business School.

With Brum as Vice President of Engineering for what had become Southwest Aerospace Corporation, business grew steadily according to colleague and chief marketer, Charles Panasewicz "through innovative engineering and active worldwide marketing." Meggitt agreed with that assessment and acquired the corporation in 1992. Two years later, Brum became President of what is now known as Meggitt Defense Systems.

Brum has combined the role of technical leader with mainstream management and financial disciplines enabling the business to achieve a virtually unassailable position in countermeasure deployment and recovery systems. This included the development of the ALE-50 towed decoy, the largest selling system of its type in history. He was the principal inventor on seven patents in this domain alone. In 2007, he combined this business with several other Meggitt enterprises specialising in automatic ammunition handling equipment, Doppler radar scoring, and military electronics cooling into one systems house.

In the eight years since, Brum has continued to oversee the steady growth of the enterprise by capturing numerous development and production programmes of increasing complexity, scope and visibility at the highest levels of prime contractor customers and the United States Department of Defense. Panasewicz summed up Brum's talents during a ceremony attended by Meggitt's chairman, Sir Nigel Rudd and Chief Executive Stephen Young: "Roger's technology-oriented leadership is a model for the rest of the group and we look forward to his continuing leadership for many years to come."



Transatlantic alliance a new force in target systems

A single, world-class organisation—Meggitt Target Systems—providing training for threat scenarios on land, sea and air, has emerged from integrating two of the Group's companies in the UK and Canada.

Targeting new customers with end-to-end solutions.
Meggitt Target Systems' new managing director, Peter Longstaff

Herculean task: Meggitt Target Systems' 6,000 kg, 9 x2 metre Hercules pneumatic catapult is designed to launch an aerial target weighing up to 250 kg at speeds of up to 55 metres per second with a launch pressure of between 2.5 to 10 bar.

The new outfit brings together the expertise and production capacity of Meggitt Defence Systems UK (MDS) and Meggitt Training Systems Canada (MTSC).

The expanding range of *Banshee* and *Vindicator* aerial vehicles, *Hammerhead* and *Sprite* marine systems and the new *Mosquito* helicopter target now benefit from a single management structure. Ashford-based MDS and Medicine Hat-based MTSC will retain their individual sites. However, vastly increased co-operation between the two organisations is already evident just weeks after coming together.

Meggitt Target Systems' Managing Director, Peter Longstaff, explains: "There are cost-efficiencies for Meggitt but the whole is becoming greater than the sum of its parts." The technical synergies and expanded product range mean that customers can be offered a far greater range of target options.

He adds: "From the operations point of view we will now implement the Meggitt Production System in both facilities. It's been a very positive experience for Meggitt as a whole and we're looking forward to deploying as one integrated organisation."

The merger will mean potential opportunities for cross-selling equipment to each other's customers. For example, one Asian user of the Banshee aerial target is already enquiring about the Hammerhead remotely-piloted boat.

The Asia-Pacific region will continue to provide an intense marketing focus for the new organisation's growing profile. Several of the region's navies use the *Hammerhead* and *Barracuda* systems. The Indian Navy last year ordered 160 Jet Banshees to satisfy its requirement for an expendable aerial target.

The Banshee and Jet Banshee built at Ashford exemplifies Meggitt's progressive product design. Initially produced as an aerial target in the Falklands aftermath, it has been steadily updated, with its single piston engine replaced successively by one, then two jet engines, boosting its speed from 200kts to 350kts. Further improvements are in the pipeline. Those Banshees that do not take a direct hit from units practicing their air defence skills can be used many times over after parachuting to a soft landing at the end of a sortie.

> We're going to push the technological boundaries. Our engineering team is twice as big in terms of people and capability. That's some order of magnitude, it really is

Naval targets evoke major interest. "If you look around the world there's a huge amount of capital ship building," notes Longstaff. "Navies across the world are building new ships and upgrading and modifying existing ones. Validating their systems creates a demand for targets."

The fast-moving, Canadian-built Hammerhead and Barracuda remotely-controlled boats are used to simulate swarm attacks by speedboats on warships, a tactic tried on western navies for more than a decade. Iran's heavily-publicised naval exercise in February in which a mock-up of a US aircraft carrier was attacked by dozens of small, armed vessels highlights their concern.

The Canadian operation is looking forward to marketing Mosquito, a new multi-role unmanned free flying helicopter that can pop-up to replicate an enemy aircraft suddenly appearing within missile firing range of friendly troops.

Meggitt is one of the top three providers of aerial targets globally. The merger means increased emphasis on the vital American market. "We believe our ability to provide very high quality but lower cost target solutions will give us an advantage."

"We do a lot of work out of Medicine Hat with the Americans on the AEGIS [naval missile defence] programme, plus a couple of other programmes I can't really discuss." It's no secret, however, that Meggitt personnel are undertaking missions for the US Navy with the Vindicator aerial target —slower than the Jet Banshee but capable of performing high-level diving attacks on warships, mimicking the flightpaths of certain anti-ship missiles and UAVs.

"We can offer more to existing customers and with a more integrated

The new Mosquito pilotless helicopter target should enter full-rate production by the end of 2015. It sharpens troops' reactions during training by undertaking pop-up manoeuvres, replicating the sudden appearance of enemy helicopters at short ranges and the emerging UAV helicopter threat. Early models are in service in the US and Canada.

range of products, we can go to new customers with end-to-end solutions," says Longstaff.

Meggitt Target Systems' long-term, intensive focus on its market gives it certain advantages over competitors, he believes. "Other producers of avionics for unmanned vehicles usually attempt to enter a very broad market. When we design the autopilot and avionics we do so very specifically for that target market. Basically ours do exactly what we need them to do and no more."

This tight focus on a specific role means that: "We are much more efficient and there are cost savings in doing that." Meggitt Target Systems sets great store by its field service. Its teams operate, maintain and, if necessary, repair kit during training exercises. This is vital. If a Jet Banshee goes sick, an entire, highly-expensive naval exercise could be put at risk or be seriously diminished in training value.

"If a navy is only doing one or two of these exercises a year, the skill-fade is high," says Longstaff. That risk is minimised when Meggitt's highly-skilled field teams are at the controls. "In any given week, we will have teams on ships from two or three different navies or on bases around the world, operating the equipment for our customers."

If the guys in the field are stumped, Meggitt has another card up its sleeve: "If something doesn't behave, we can send telemetry back. This is going to be really neat: we're looking at having real-time telemetry feeds from the field to Ashford and Medicine Hat and between the centres by the end of the year. If something happens that we don't understand, we can have the experts look at it in real time." It's a development that will leave competitors trailing in the new company's slipstream.

On the ground, the systems used to control the company's targets are getting a makeover. Discussions are taking place about optimising Meggitt's multiple ground control stations by utilising the best features of each station. "In a perfect world we will look to operate all Meggitt Target Systems' targets from a single control station. Architecturally, there it is likely to be modular approach to accommodating them."

"We're not resting on our laurels. We're going to push the technological boundaries. Putting Ashford and Medicine Hat together creates an engineering team that's twice as big in terms of people and capability. That's some order of magnitude, it really is.

"We've got some incredibly good people feeding off each other and we're putting in shared resources. There are two very talented engineering teams with complementary areas of expertise. In Canada, the control theory side is very strong. In the UK, this is matched by an extremely strong capability in R/F and datalink technology."

Meggitt Target Systems made its trade debut at the CANSEC defence and security trade show in Ottawa in May. The European launch will take place at September's Defence & Security Equipment International exhibition in London. "It's an exciting time for the business. Working together is always great. Just in the first month we've been doing this, the ideas and the enthusiasm have been beyond my expectations.

"The next year or two is going to be really, really interesting for everyone involved on both sides of the Atlantic."

Two very talented engineering teams with complementary expertise. In Canada, the control theory side is very strong. In the UK, it's all about R/F and datalink technology

Jet-setter: the new twin-engine jet Banshee is the latest addition to the low-cost aerial target family developed over 30 years, in service with every NATO defence force amongst others. With significantly more powerful power plant, this latest Banshee variant makes high-g turns for even more challenging threat scenarios for personnel and anti-aircraft weapons systems development.

L-R top: Ian Watts, Composite Design Technician, prototyping a part.

Andy Maynard, Airframe Technician, undertaking a final quality check on a Banshee target wing.

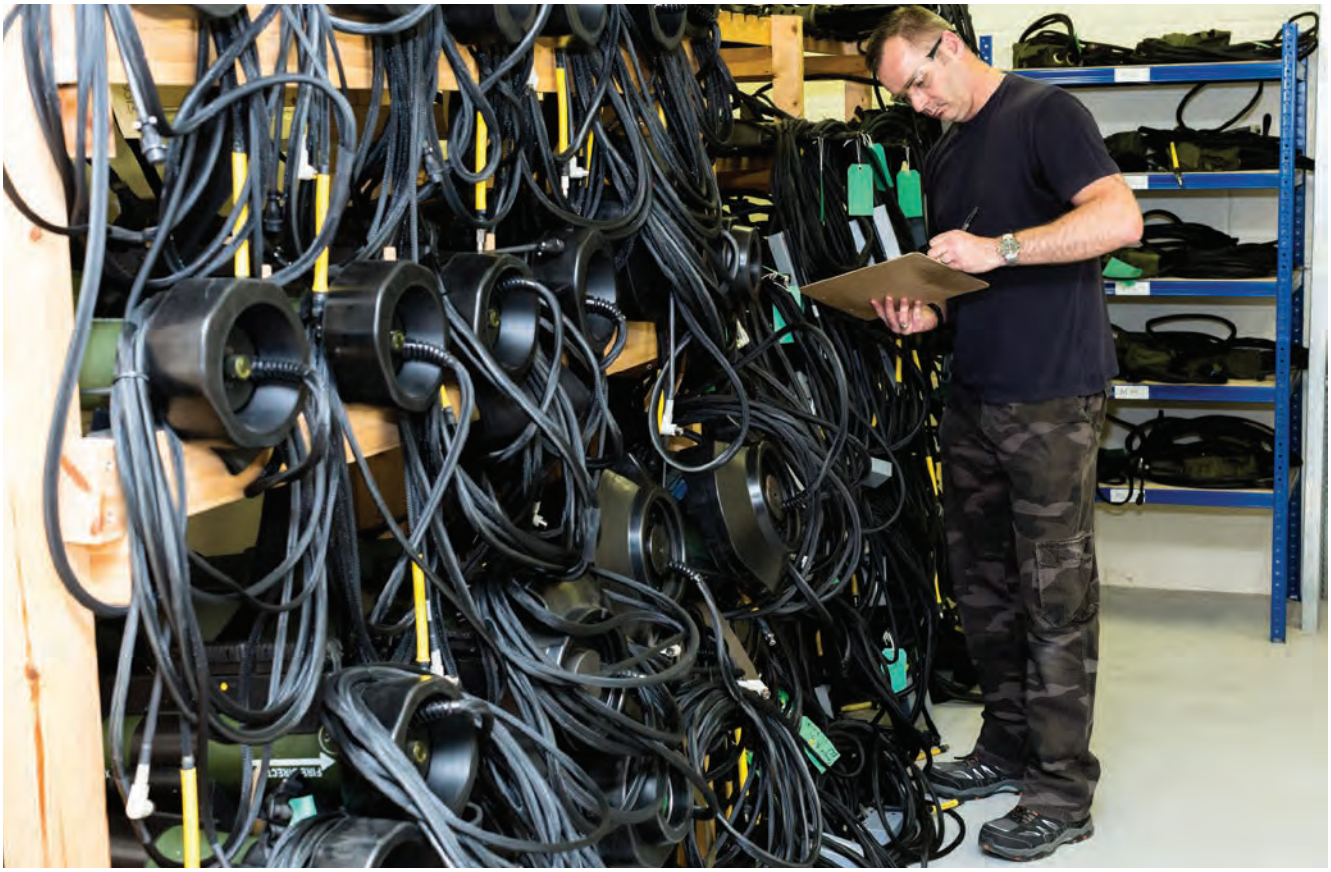
L-R bottom: Meggitt Target Systems' Ashford airframe assembly floor. Around five trades are deployed for the assembly of the target airframe and the manufacture of engines, fuel tanks, avionics, recovery systems and payloads. Some 20 targets on the line at any one time. It takes around 10 hours to conduct the final assembly of the basic Banshee model.

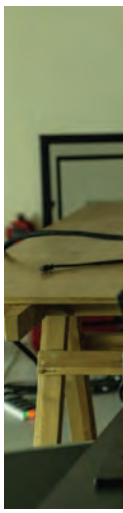
Tony Poynter, Electronics Design Technician, manufacturing a prototype printed circuit board, part of a drone autopilot system in which Meggitt Target Systems specialises.

Wing of a Banshee Jet 80, with carbon fibre servo cover, forebear of the new Banshee Twin Jet.

Dominic Melville, Engine Technician, preparing to test-run an engine.

Paul Rogers, TIG welding an aluminium fuel tank.

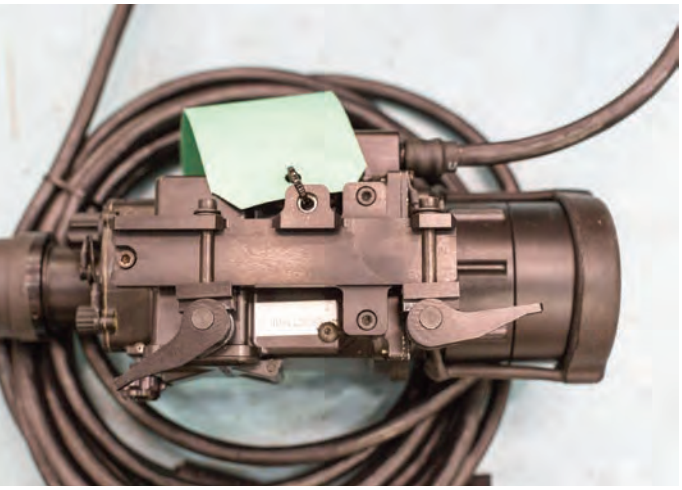




Meggitt Target Systems Ashford is the UK's maintenance, repair and overhaul (MRO) arm of Meggitt Training Systems' small arms virtual trainers and associated BlueFire wireless and tethered weaponry. In addition to the trades needed for drone manufacture and operation, the facility employs weapon technicians and service engineers to maintain all aspects of the UK's small arms training capability.

Top: Ken Irvine, Weapons Systems Supervisor books in shoulder launch weapons for repair.

Bottom: Rory Hougham tests a small arms system involving a highly realistic Middle Eastern scenario.



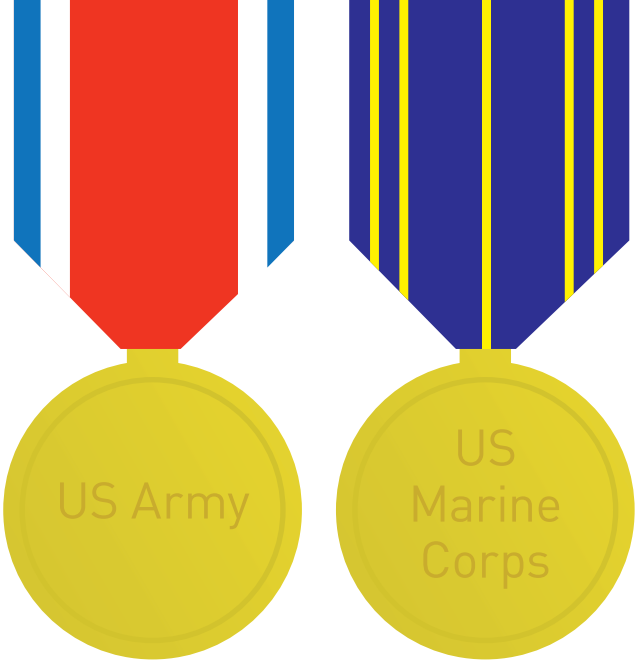
Middle top: Thermal sight for simulated weapon.

Middle: SA80 rifle repair. All small arms weapon simulators used on training systems are decommissioned firearms featuring pneumatic and micro-electronic components simulating the feel of weapon recoil, true ballistics and even the effects of weather conditions.

Bottom: Rory Hougham (foreground) and Louis Hilton-Jones (background) test weapons using a Meggitt small arms training system scenario.

Top right: Ken Irvine maintains an SA80 rifle, a deactivated version of the British Army standard. Over 150 Meggitt small arms training systems are in service in the UK.

Bottom right: This SA80 rifle features a tether. However, the majority of Meggitt's simulated weapons utilise wireless technology for ease of use and greater realism.



Doubling up

Two major orders from the US Army and US Marine Corps for Meggitt's virtual small arms trainers will see a step forward in marksmanship training for US military personnel and open up the prospects of significant foreign military sales for Meggitt.

The resolution of new systems increases target clarity and detail allowing even more realistic training at greater distances for optical sights and weapons of which there are an increasing number in the Meggitt inventory of simulated equipment.

Two major orders from the US Army and US Marine Corps for Meggitt's virtual small arms trainers will see a step forward in marksmanship training for US military personnel and open up the prospects of significant foreign military sales for Meggitt.

Imagine the situation: you're a US Army clerk. Your unit is short-staffed and you get an instruction from your company commander that you're the only person available to take charge of marksmanship training the following morning. Tutoring troops in the finer points of this craft really isn't your strength, so what do you do? Get back to your barracks and grab your tablet computer on which the 'automatic coaching' application for Meggitt Training Systems' new-generation small arms training system has been installed.

The automatic coaching app will give you the appropriate syllabus for the day, then walk you through the relevant lesson plan. You familiarise yourself with the details the evening before the training session, then head to the range in the morning with much greater confidence that you can provide a competent lesson for the troops.

That's just one of the advantages of Meggitt's Engagement Skills Trainer (EST) II, for which the US Army announced a $99 million contract last October covering a five-year, Indefinite Delivery/Indefinite Quantity deal that will see more than 1000 new and upgraded virtual systems, plus simulated weapons, being delivered to Army facilities across the globe.

A $31.7 million contract from the US Marine Corps for around 670 similar systems and weapon simulators—the Corps refers to them as the Indoor Simulation Marksmanship Trainer (ISMT)—followed in January.

This is the first time for a single provider to have held such contracts simultaneously.

This is the first time for a single provider to have held such contracts simultaneously

Both the Army and Marine Corps virtual simulators are based on a new architecture developed by Meggitt. "The backbones are very similar but the

Pictured from L to R: **Meggitt's Angels.** Mark Parr, Program Manager, US Army EST with fully-sensored wireless "Bluefire" M4, Darren Shavers, Subject Matter Experts Manager, with tethered M240B machine gun, Kathleen Wilson, US Marine Corps Program Manager, with M72 light anti-tank weapon

specific requirements for each contract are different," says Phyllis Pearce, Senior Vice-President, Strategy Sales & Marketing at Meggitt Training Systems (MTS) in Suwanee, Georgia. The applications employed by the two services on the EST and ISMT are slightly different—the Marines' version, for example, has an indirect fire [firing without relying on a direct line of sight] application, which the Army does not require.

The two contracts have become the 'system of record' for the US Army and US Marine Corps - the acknowledged standard system for small arms training.

This opens up potential new markets under the US Foreign Military Sales (FMS) system, by which the US government finances defence equipment exports, says Pearce.

"When you become the system of record the US government will finance the [export] opportunity. Generally they will recommend the system they've chosen themselves. That's where you have your multiplier effect. We believe that could be worth $200-250million to us over the next five to 10 years."

The first export contracts may not be far away: "FMS cases are being worked on now with the State Department. We have to continue the development of our system so when it is actually ordered, we're ready to deliver."

The Army and Marines determined that the Meggitt system represented 'best value', yet it was not the cheapest option in the competition. "It was very significant for us that they appreciated the features and equipment we were offering as value for money," said Pearce.

So, what constitutes 'best value'? "The Army said that our knowledge of army training was a 'best value,'" said Darren Shavers, Manager, Subject Matter Experts, at MTS. That knowledge of precisely what is required to get the best results out of training comes from people like Shavers, a former Army staff sergeant who served three tours in Iraq and two in Afghanistan and periods in Haiti and Somalia.

> This opens up potential new markets under the US Foreign Military Sales (FMS) system

His group of subject matter experts acted as an interface between the prospective customer and the engineers designing the system.

Shavers was about to retire from the US Army when MTSI swooped and brought him on board. He was influential in helping MTS determine what both military procurement personnel and individual soldiers 'at the sharp end' were looking for in a new small arms trainer.

What they were looking for were new levels of virtual reality and flexibility. And that is exactly what the Army and Marines will get. The 'fully sensored' weapon simulators used on the EST and ISMT training systems detect factors as fine as as the degree of cant that soldiers impart to the weapon and even how tightly they hold it against their shoulders. "All these things feed into inaccuracy in a shot," explained Mark Parr, Program Manager, US Army EST. The sensors in the weapon provide this data to the instructor so he can correct errors in individual shooters' technique quickly and effectively.

Of the weapons used by the soldiers, more than 300 types can be converted from live-fire firearms to simulated versions for use with Meggitt's small arms trainer. These offer flexibility

Top: The US Army and US Marine Corps' future small-arms training systems supports a wide variety of tethered weapons and state-of-the-art wireless alternatives.

Bottom: During marksmanship exercises, the new tablet feature allows instructors to move around training areas and interact with individual trainees, changing scenarios on the fly to improve performance and proficiency. Smart automatic coaching is available through PCs and tablets.

through being freed from the physical constraints of earlier generation practice weapons.

"In the past, the weapon was on a tether that provided electronic connections, and a hose with the pneumatic system to compressed air [to produce 'gunfire' and recoil]. We use our Bluefire® technology to communicate with the weapon electronically and wirelessly, and have modified the magazine to provide a compressed charge and highly realistic experience of recoil," said Parr. That means he can move without restriction, engaging new targets on the screens in front of him or her without having to haul around the connecting tether.

Simulated reality is further helped by high-quality computer graphics which can illustrate just about any weather scenario—just ask Kathleen Wilson, Program Manager for the US Marine Corps, who recalls spending two weeks with government officials debating the differences between fog and haze. We're working with high levels of detail, not only in our graphics and 3-D capabilities but with the shooter's aim point, depth perception and range dimensions.

Every element is scrutinised to ensure realism, accuracy and the best possible training environment to ensure battlefield readiness."

The instructor can also introduce 'wind' and 'rain' to the scenario—both of which affect the ballistics of shots going down-range, so the soldier learns how to compensate when aiming.

The ballistic accuracy of Meggitt's wireless Bluefire weapons used on the EST and ISMT simulate that of the real weapons they represent. "We refer to that as 'true ballistics,'" said Pearce. We match the ballistics not only to the weapon but to the ammunition used. We can simulate real-world ballistics through our algorithms. Our system is unique in being so accurate. That's a huge selling point over competitors." That ballistic accuracy was cited by the armed services as another example of 'best value'.

Taking the accuracy and heightened appearance of reality together, Pearce believes the previous incumbent's rival system was similar in capabilities to what Meggitt was developing five years ago.

The sophistication of Meggitt's offering allows customers to incorporate 'serious games', such as Virtual Battle Space (VBS), into the system to give troops added scenarios in weapons training. "We adopt a neutral stance on the type of gaming engines the customer prefers ," says Pearce. "We build an interface that allows them to use any on our system. It puts us light years ahead of what any other company can do, not just in the US but around the world."

With marksmanship, consistency of approach in teaching is obviously vital. "It's important that everyone is taught the same way. We make sure all the fundamentals are there," explains Shavers. "That automatic coaching tool facilitates putting everyone on the same level when they're doing their training."

The coaching tool offers additional advantages when the troops are training on the system. The instructors used to sit at a computer to the side of the troops. The mobility gained by migrating the system to a tablet means they can collect data transmitted from each instrumented weapon used by shooters as they move along the firing lanes behind each soldier and then show the individual his or her performance in real time. "It multiplies the instructor's effectiveness because he or she can provide instant instruction and guidance," explains Parr.

Even if you are a clerk. ●

Meggitt CTO Emeritus appointed SAE President

Dr Richard Greaves, Meggitt PLC's Chief Technology Officer Emeritus, is this year's President of SAE International, the global association that unites more than 138,000 engineers and technical experts to build knowledge and expertise throughout the engineering profession.

"It is a great honour," said Greaves. "I've been working with SAE for 35 years and the organisation is achieving more than ever in its three key areas: education, training and connecting engineers and experts from all areas of mobility engineering and standards development for commercial vehicles, automobiles and aerospace."

First appointment from the aerospace sector for nine years

Greaves, the first SAE President from the aerospace sector in nine years, has held ground-breaking roles at Meggitt.

He established the group's expertise in piezoelectric vibration accelerometers from 1972 when he joined Vibro-Meter (now Meggitt Sensing Systems, Fribourg) in Switzerland. His 10-year presidency of the division culminated in the development of a comprehensive condition-monitoring capability based on measuring multiple parameters. The on-engine condition monitoring units for the Boeing 787 and Airbus A380 have provided the most accurate image of engine condition ever achieved, boosting the engine providers' diagnostic and prognostic capabilities and ability to manage power-by-the-hour contracts economically. Meggitt condition-monitoring products can boost the operating economics, performance and safety of any aircraft.

Meggitt's first Group Director of Technology & Engineering, Greaves remains a world expert on condition monitoring and has served on the SAE Board since January 2012.

"As an aerospace man, I'm keen to promote awareness of the organisation within our sector," he says. "More than 60% of all aerospace standards are SAE standards and the 10,000 people who work on our technical standards boards and committees cover every aspect of aircraft."

Other key areas of interest are promoting SAE as the global leader in integrated vehicle health management and flying the flag for the organisation's science, technology, engineering and mathematics (STEM) outreach programmes.

"One of the best parts of my work here is meeting young people with an interest in engineering. Their enthusiasm and knowledge is a great inspiration. I want to do everything I can to build on SAE's efforts to help people all over the world build on their understanding and expertise."

About Richard Greaves

Dr Greaves has played a significant role in one of the most technologically advanced areas of Meggitt.

His publications centre on piezoelectric technology and condition monitoring. He has held and continues to hold a wide range of international posts:

- Member of the Board of the IVHM (Integrated Vehicle Health Management) Boeing/Cranfield University Research Institute since 2008 and Chairman (2010 to 2012).
- Member of the Brussels-based Aerospace and Defence Industries Association of Europe Supply Chain Commission (2004 - present)
- Member of the Civil Aviation Committee of the United States Aerospace Industries Association (2007 - present)
- Chartered Scientist, Chartered Physicist, Chartered Engineer
- Fellow of the Royal Academy of Engineering (UK)
- Fellow of the Institute of Physics (UK)
- Fellow of the Royal Aeronautical Society (UK)
- Fellow of SAE International

As well as his Meggitt CTO Emeritus status, Dr Greaves is an Honorary Meggitt Technical Fellow.

About SAE

SAE International is a global association of more than 138,000 engineers and technical experts in the aerospace, automotive and commercial-vehicle industries. Driving knowledge and expertise across a broad spectrum, the organisation acts on two priorities: encouraging a lifetime of learning for mobility engineering professionals and setting the standards for industry engineering. SAE's philanthropic SAE Foundation includes programmes like A World in Motion® and the Collegiate Design Series™..

The organisation celebrates its 110th birthday this year.

smart reporting

Standardisation and integration are essential to Meggitt's operations excellence vision. Now management reporting gets the treatment.

The maturity of Meggitt's SAP (enterprise resource planning) implementation is enabling more *One Meggitt* infrastructure improvements such as state-of-the-art management reporting—a global business reporting tool will be launched before the year-end.

According to Derren Smith, Business Leader, Meggitt Business Intelligence System, the management reporting (MRep for short) solution will be "best of breed", capable of enabling timely decision-making based on "one source of truth" from a single central data repository.

Supported by IBM, a dedicated MRep team based at Meggitt Avionics, Fareham, UK will deliver *SAP Business Objects* reporting tools in the initial launch phase.

Units running the SAP enterprise resource planning (ERP) global template will be the first to benefit: around 80% of the group's civil aerospace-oriented businesses and some 70% ofMeggitt's top revenue generators.

MRep will be one of the first applications to be hosted in Meggitt's new data centre in the UK, preceded only by the Meggitt Master Data Governance (MMDG) project, the foundation of the 'clean' data on which the success of Mrep, in part, depends.

Ultimately, the system will consolidate Meggitt data silos whether residing in enterprise resource planning, customer relationship management, human resource or time and attendance systems.

Smart reporting

Why we're globalising

- "One Meggitt". One source of truth
- Data entered once, consumed many times
- Quality decisions from quality data
- Quantum leap in forecasting and planning capability
- Consistent comparators
- Better informed negotiations
- Sustainable inventory control
- Flies Meggitt Production System higher

Anyone who wants to consume data will do so from one source. Data must be maintained within core systems

The first data to be centralised will be operational including performance on delivery, quality and health, safety and the environment, followed, among others, by transactional, including sales and inventory.

Smith and teams will provide rich, multi-dimensional data. On-time delivery figures, for example, are facility-based today. "Tomorrow, we'll have granular data on how we perform by customer, by product family and by market," Smith explains.

"And we will use historic data with greater agility and accuracy, contributing to 10-year revenue forecasts for say, aircraft platforms and emerging build-rates."

The commercial advantages of better and more relevant data are obvious and will be a gift to anyone focused on *Continuous Improvement* and committed to taking the group's Meggitt Production System (MPS) to the next level. Smith explains: "MPS has

had enormous success on the factory floors wherever it has been launched but as our capabilities mature we will increasingly rely on insight from all aspects of our business if we are to sustain world-class performance. MRep is central to delivering that insight."

The programme has direct financial benefits too: inventory dashboards, in particular, will help unlock value. Smith asserts: "We think we can reduce inventory substantially across the group, savings we can reinvest in new technologies. But those reductions have to be sustainable."

Smith is referring to the limitations of inventory spring cleaning. "It's a commonplace in our industry to drive down inventory within working capital but reductions often lapse.

"We need a system that enables us to understand what a world-class inventory level should be for Meggitt so that we maintain our reductions while continuing to exceed our customers' delivery requirements."

There is no shortage of investment opportunities for Meggitt's *smart engineering for extreme environment* technologies. Smith reminds us: "Investment in AR&T [Applied Research & Technology] secures the future but financial returns are not immediate. This requires sustained investment, often over many years, and such investment must be justified based on sound information, which is what MRep is all about."

Establishing one source of truth: Derren Smith, Business Leader, Meggitt Business Intelligence System

Smith is already running workshops across the group to ensure the reporting design is optimal. It will look good too: the MRep team has been quick to develop an attractive visualisation standard based on Meggitt branding (see below right) and is applying it where customisation is permitted by the system.

Co-development is key. "We want everyone adopting the new tool in the initial launch phase to be able to turn off their existing information source with complete confidence."

AND REPORTING IS JUST THE START. MRep will also deliver new forecasting and planning solutions to businesses no matter what ERP systems are in use. The days of laborious spreadsheet forecasting are numbered.

Smith confirms: "Today most of our businesses pull together forecasts in Excel. It takes a lot of man-hours. That burden will be lifted with new tools that are easier to use and integrate readily with all other aspects of the MRep programme including its new reporting capabilities." While the new tools will have significant benefits for business units in terms of user-friendliness and greater business insight, the greatest value will undoubtedly be reaped by divisional and group management.

"To optimise group performance, our management teams must have insights across functions from data unlocked from individual repositories. They want actionable management information that is not dependent on the onerous reconciliation of data between sources.

"Running many different reports and manually manipulating them to get one view of a division's performance, for example, is subject to error and lack of repeatability. Soon group and division will get more consistent and higher quality data at the press of a button."

Back to the one source of truth. The system will report information based on data that created from Meggitt's transaction processes. There is a *read-my-lips* steeliness to Smith's tone when he asserts: "We are going to report the data we collect, not collect the data we report."

The distinction is critical. The data in an ERP system is the information that will be reported. The data cannot be transformed at the point of reporting because it will be acquired at source. He spells it out: "If you are about to make a last-minute shipment to a customer to make your month-end numbers and the customer agrees to accept the shipment early, the customer's agreement must be entered into the system. If it isn't, the system records early delivery. There will be only one window of opportunity to change data before you have dispatched the goods. The system will prevent retrospective modification."

With MRep, facilities and business units will no longer be gatekeepers in the chain of reporting. Anyone who wants to consume data will do so from one source. Whether master or transaction-oriented, data must therefore be maintained within core systems.

"We will all assume the data is correct so it is in everyone's interest to ensure items such as sales order lines are corrected if true on-time delivery is to be reflected. Tomorrow's decisions and performance reporting depend upon it."

Smith is fully aware that some business process reengineering needs to be undertaken for a successful implementation and he will work with global business process owners accordingly.

Facilities and business units will no longer be gatekeepers in the chain of reporting

We are going to report the data we collect, not collect the data we report

"It's about working as a team and using our systems correctly. We don't want the guy in dispatch to be rebuked because he shipped the goods before the sales team corrected the sales order line. We want the sales team's correction of the sales line to trigger the shipment."

Smith and team will be working with the SAP Way Forward team accordingly. The SAP Centre of Excellence has, to date, focused on implementation. Now, through the Way Forward team, the emphasis is on helping businesses use the system better. "It's about Meggitt's standardisation agenda at the end of the day. *One Meggitt*. One set of consistently-presented, accurate data."

Looking ahead, Smith sees the establishment of a business reporting competency centre. He wants to bring back some of the agility of business unit data analysts slowed lately by essential governance procedures.

The centre will be the place where reporting requirements needed to meet a specific requirement can be developed and, if not unique, then shared. "It will be more akin to having that traditional analyst down the hall," says Smith, "while maintaining the standardisation agenda."

Part of the change management approach will be the enforcement of discipline early on. Smith says: "We can expect senior management to say: 'But this report is in Excel—please use the MRep report with the *smart reporting* logo on the top right hand corner.' And once MRep is launched, people will no longer be prepared to make decisions without the data they *really* needed." ●

Really centred

Our new data centres: another step on Meggitt's maturity journey

Until now, Meggitt used individual Meggitt facilities to deploy global IT applications.

In May 2014, Meggitt deployed its first dedicated professional hosting location in the UK. This high performance, highly secure data centre will be followed by another in the United States in the second quarter of this year.

Both support the growing need for Meggitt's integrating group to deploy standard applications and business processes.

Adrian Knight, Meggitt Information Services' Global Infrastructure Services Manager, says: "We are now able to provide access to single data sets that will allow standard reporting across the business. The whole group can now benefit from any investment we make from standardised IT services and applications that do not require onerous, site-by-site installation."

The US data centre is being constructed to meet rigorous US government procurement standards known as DFARS (Defense Acquisition Regulations), providing certainty that contract data is strictly controlled.

Cleaning up

Another step on the road to corporate maturity

MRep, Meggitt's new global management reporting tool, depends on 'clean' data. Enter Meggitt Master Data Governance, a group programme spearheaded by Fareham-based, Group Master Data Services Manager, Bradley Smith. Aim? To realise the value of business information and intelligence by harmonising data standards, controlling the integrity of information and governing and improving data quality.

Smith (Bradley) explains: "Incorrect or duplicate master data such as customer and vendor account information, product descriptions and finance 'objects' impedes customer service, creates confusion and wastes effort. This programme will identify and eradicate erroneous data and set up prevention processes and systems."

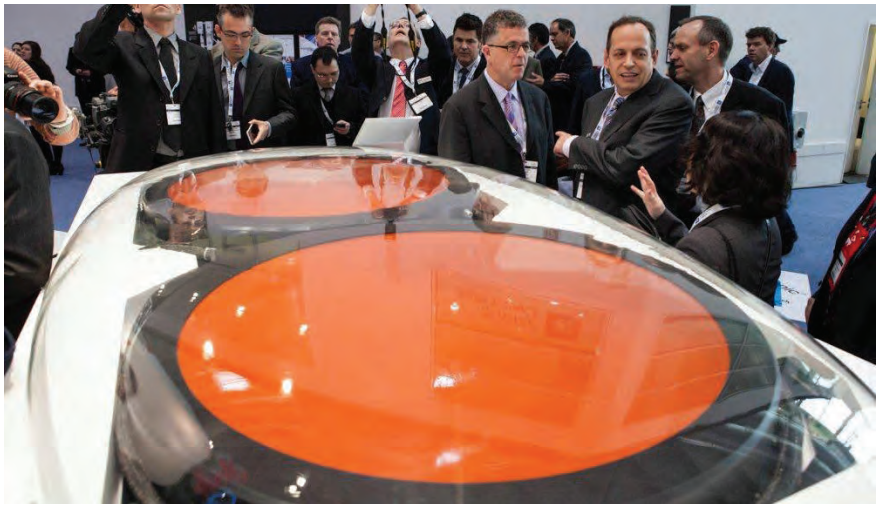
Data standards and data quality will be addressed through functional information governance councils which will facilitate, for example, the simplification and standardisation of product hierarchy structures and the automation of change authorisation processes. All activity will be based on actively managing and improving data based on accuracy, conformity and completeness.

Software tools including SAP Master Data Governance, Information Steward and Data Services will identify and correct errors, providing the foundation for more advanced master data management.

However, in pursuit of excellence, we cannot rely wholly on software and governance. We must all acquire new habits, Smith (Bradley) asserts. "Every day across the group, thousands of decisions are supported by information—data—within systems. That's why data accuracy should be regarded as the personal responsibility of every Meggitt employee.

Meggitt materially advances strategy with composites acquisition

Meggitt's smart materials capability just got smarter after it agreed, in August, to acquire advanced composites businesses from aerospace and defence manufacturer, Cobham PLC.



2Ku, Gogo's next generation satellite technology, enabled by Meggitt super-aerodynamic radomes, should deliver 70 Mbps-plus peak speeds to aircraft

Meggitt Polymers & Composites (MPC) is upping its game, showing ambition and flair in the execution of its market and technology strategy. "We're determined to take a leading position in extreme environment composite secondary structures," says MPC President, David Horner "and the acquisition of Cobham's advanced composites businesses creates a rock solid foundation for our campaign." He enumerates the new weapons in his armoury: "Now we'll have critical mass, new capabilities, first-class customer relationships in this product category in Europe and North America and peerless mastery of advanced process technology."

By the end of the year, Meggitt will have welcomed a workforce of around 500 employees from plants in Stevenage and Loughborough in the UK and Baltimore and San Diego in the US. Collectively, they produce highly specialised extreme environment radomes, engine components and aircraft structures such as air-to-air refuelling fittings, rotorcraft fairings and munitions housings for military and civil aircraft. Unmatched know-how in multi-axis high temperature compression moulding, in particular, has enabled the production of intricate structures for mission-critical components on the engines that power the A320neo, C-Series and the Mitsubishi Regional Jet.

MPC will not be resting on these hardwon laurels. Horner intends to deploy the process further into more new products for commercial aircraft. However, while there is no doubt that Meggitt's markets are hungry for lightweight, rugged components, the group is looking to build these, plus expand on the multi-functional composites in which it has some experience: embedded heater elements for electro-thermal ice protection, for example. Horner is tight-lipped on specifics but he expects his division to work closely with Meggitt Sensing Systems and other group businesses to bring new products to the marketplace. He also believes the division's sealing products can be packaged in ingenious ways that will reduce weight and part count in certain applications.

Radomes to GoGo

Amongst many new product lines that come with the acquisition, Meggitt's portfolio will now include radomes for numerous military aircraft including the Eurofighter Typhoon and F18 jets, special mission aircraft such as the Poseidon P-8 and the Apache and V22 rotorcraft. However, an innovative, aerodynamic radome for Gogo, the world's largest in-flight connectivity provider, will see Meggitt enabling communications to extend from air to ground to air to satellite, boosting the speed and reliability of WiFi services in commercial aircraft. "This skill in developing aerodynamic structures comes with a capability in RF transmissivity that has scope in other applications as the onward march in wireless technology continues," says Chris Allen, Group Director of Engineering & Strategy.

Chief Executive Stephen Young reinforces the value Meggitt can bring to composites customers: "By combining and investing in these highly complementary composites businesses, we can take them further in a market whose pace is quickening and where customers continue to look for streamlined supply chains in a very fragmented industry segment."

And it is good for the MPC workforce. "Nearly 50% of multiple next generation aircraft are already made of composite materials, the market for which is growing at 9% a year as metallic materials are displaced by lightweight composites to save fuel.

"This represents an outstanding opportunity for seasoned engineering and manufacturing teams with deep technical experience who can expand their capabilities and this acquisition will help those at our established and new businesses do just that." ●

We can take these new businesses further in a market whose pace is quickening and where customers continue to look for streamlined supply chains in a very fragmented industry segment

Celebrate yesterday's pioneers, help today's heroes

The **Sopwith Camel** was one of the most successful fighters of World War I. With its extraordinary manoeuvrability, it was a showcase for the extreme environment engineering of its day.

Today, some 99 years after the aircraft's maiden flight, Meggitt's pioneering photo-chemical etching business, Precision Micro, has created a limited edition scale model to raise money for British military veterans.

The legendary Sopwith Camel owed its extreme manoeuvrability to the placement of engine, pilot, guns and fuel tank within the front seven feet of the aircraft. Not surprisingly, with about 90% of the weight of the aircraft in such a small area, it was hard to fly.

"But once pilots mastered it, it was hard to beat," says Steve Finegan, Precision Micro's CAD specialist who designed the model. "And it was a beautiful machine, too, an icon of WWI."

That made it the perfect choice for Precision Micro's WWI centenary model.

"We've used our 2-D chemical etching production process to create the parts for a 3-D model," says Steve. "The parts are photo-etched from 0.3mm stainless steel and we've incorporated half-etch bend lines so you can put them together easily to make the Sopwith."

The advantages of chemical etching over more traditional methods such as stamping and laser cutting are its low cost, high speed and flexibility. That makes it suitable for complex designs and, most important, burr-free components whose mechanical properties have not been changed by heat or stress.

"The components we make for space, aerospace and defence are particularly suited for extreme environments," says Steve. "I often feel like we're descended from those early pioneers who designed classic aircraft like the Sopwith. But we also make medical components. So helping today's military veterans is a fitting way to commemorate those who gave their lives so courageously."

Build your own Sopwith Camel

The limited edition of 200 models available now.

1/200
LIMITED EDITION

Precision Micro is offering its scale model for £15. All proceeds will go to Help for Heroes, the UK veterans charity.

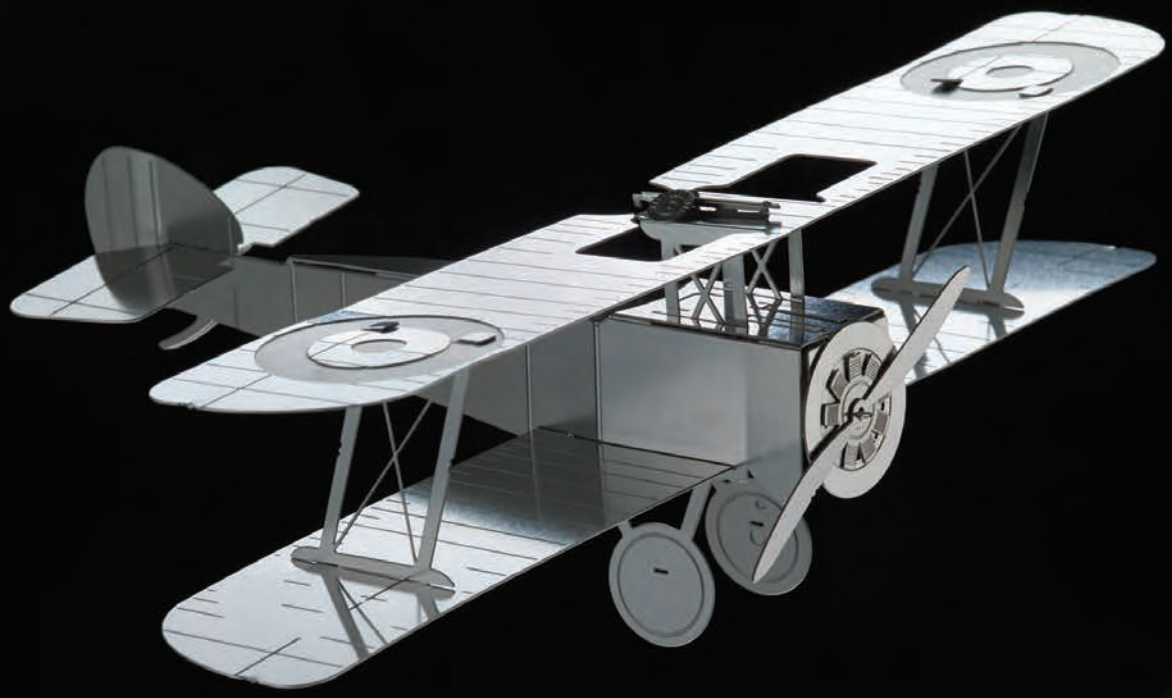
It estimates that of the 220,000 individuals deployed to Afghanistan and Iraq from the UK between 2001 and 2014, up to 75,000 servicemen and women (and their families) may need their support in future.

So if you want to donate more than the suggested price, please feel free to do so.

To buy the model, visit www.ebay.co.uk and search for "Photo-etched Sopwith Camel".

Find out more www.helpforheroes.org.uk. To find out how Precision Micro could transform every aspect of component production, see page 84.

Precision Micro



IN SUPPORT OF HELP for HEROES

MEGGiTT
smart engineering for
extreme environments

The battle for **brainpower**

To keep ahead of the competition, we need to find more of the very best people. They're always in short supply but we have some very convincing weapons in our armoury.

First, operations excellence at Meggitt is at the cutting edge. Armed with a sophisticated arsenal of tools and processes tried and tested over the last two decades, we have refocused our operational energies on the people making our products and systems, and the places they do it.

Known as the Meggitt Production System (MPS), this new approach has been developed by a crack team of Lean gurus assembled from some of the world's most advanced manufacturers. As we continue to roll out MPS and work towards the creation of a total business system, there are huge opportunities to create something that never stops getting better.

Second, our focus on new technology is sharper than ever. New and improved product designs are in the crosshairs, as well as new manufacturing technologies—everything from next-generation materials to factories of the future that combine state-of-the-art automation, intelligent workstations and big data to deliver maximum performance.

We're at the forefront of technology now and Meggitt20, our long-term R&D vision, maps out how we plan to stay there over the next two decades and beyond.

Third, thanks to an unprecedented number of recent programme wins, we are gearing up to design and produce a record number of parts in the coming years. That means more opportunities than ever to grow fast at Meggitt. The challenge is to get the word out there.

Over the next few pages, you can catch up with our latest efforts. There's a brand-new careers section on meggitt.com with insights from across the business on why Meggitt is a great choice for those who can cut it. We're tapping into social media to highlight the extraordinary range of what we do and our graduate site lays out why top talent from the world's best universities should join us. It's smart engineering in one of the most extreme environments of all: the war for talent.

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What's our story?

Making sure the ambitious and energetic understand what Meggitt can do for their careers is vital for our future success. **The Meggitt DNA**, right at the heart of the new careers section on Meggitt.com, does just that with a 30-second summary and quick links to the key chapters in our story. Go and have a look. You'll definitely learn something you didn't know.

Challenge and innovation at every turn

For more than 30 years, Margie Mattingly has been at the forefront of high-temperature accelerometer design. Working with her strongest team ever at Meggitt Sensing Systems in California, she has developed a new product line which delivers world-beating performance at a much lower cost.

Measuring success: a critical factor in Meggitt Sensing Systems' success in Orange County, California, is teamwork, says Dr Margie Mattingley, pictured (right) with Engineering Technician Stephanie Jones, who specialises in building new products.

I remember the first time I saw an accelerometer in a 600°C oven. The door opened and there was this device, about the size of a walnut. It was vibrating on a shaker and producing a flawless output signal. This thing's incredible, I thought. Even though it's glowing red hot, it can reliably measure virtually imperceptible changes in vibration. These devices have found their way onto satellites, the space shuttle, and almost every jet aircraft engine in the world.

I was hooked on the world of high temperatures and I was in exactly the right place to learn more. A number of the world's leading experts in this area worked in the building and I was fortunate enough to be mentored by them. Within a couple of years, I was overseeing projects. Later, I designed a number of sensors myself such as the first piezoelectric accelerometers.

These mission-critical components can operate continuously from -269 to 760°C and they have a lifespan of about 500,000 hours. Understanding the science to find the right materials, as well as developing the processes and assembly techniques that would allow these sensors to operate in such extreme environments has been a fascinating series of challenges.

A tradition of being first

Meggitt Sensing Systems has developed many industry firsts in sensor design dating back to 1947 when the company was founded under the Endevco name.

One of the reasons for our success is that the company invests heavily in promoting an atmosphere of creative thinking focused on unique but practical product development. That's also why we can attract such impressive talent: one of my colleagues, Bruce Wilner, recently received a lifetime innovation award from the Shock and Vibration Exchange. He has been with the company for 52 years and holds 30 patents—when you think what an achievement it is to file even one patent, this is a remarkable accomplishment. Our younger engineers aren't doing too badly either: Tom Kwa holds six patents in areas such as micro pressure and acceleration sensors, some of which are under 0.1mm in size.

Today, being the market leader is still our goal. We're focusing particularly on expanding in the test and measurement market, partly because in a recession customers monitor their equipment more closely to avoid costly maintenance and increase lifespan. To keep ahead, we're always looking for ways to reduce overall costs and to add more functionality at low cost.

Taking inspiration from the world around

I wondered, for example, if we could adapt a design from one of our sister companies as a template for a range of low-cost, high-volume sensors with very high performance. Further inspiration came as I was replacing a threaded fitting in the sprinkler system in my yard which had been run over for the nth time.

I came up with the idea of a sensor pod which threads into a variety of mounting bases. By mixing a few sensors with different bases you can create 15 different types of sensor with varying specialisms. We filed a patent in February 2014 and we launched in September. We've now expanded the design's modularity, allowing us to make many different products at a substantially lower price.

> A number of the world's leading experts in my area worked in the building. I was fortunate enough to be mentored by them

I think these developments are only really possible because of the extraordinary legacy we have. Right now, for example, we have the father of low-noise cabling coming back in to help us upgrade designs for our Swiss facility.

Overall, the strength of our current position is the result of careful but bold acquisition over the years and, today, our expertise is focused on centres of

excellence around the world: aircraft sensor and electronics in Switzerland, crystals in Denmark, test and measurement sensors, cable and connectors here in California.

Expertise and innovation isn't just about our products, though. There are interesting developments on the operational and manufacturing side too. Now we have these high-volume products, we've had to look at how we raise output because we're expecting some big sales this year. There's room to streamline and we're having some great discussions about that now.

Passing on the learning

In all the work I do here, I can see a whole new generation of talent emerging and I am delighted we are laying down the foundations for tomorrow's breakthroughs. I'm mentoring a very bright engineer and to help her and others that follow, I've formalized all I've learnt over the years in a training manual. I've also developed spreadsheets that can run the complex calculation models we need. That means new joiners will be able to take advantage of the foundation I helped create and then speed past my accomplishments to create their own.

The training I've had here has always been strong, from core skills like technical writing to obtaining an MBA. Within a year of getting that degree, I was promoted to an engineering manager and Meggitt has always allowed me to explore different paths—I've been program manager, chief engineer and operations manager, where I was actively involved in compliance issues and classifications.

Aiming for more world firsts

We have come a long way in high-temperature sensors since that oven door opened to give me my first view. We led the way back then and we're entering a new phase of firsts today. We're growing fast and we're at a point in the evolution of the group as a whole where there are opportunities for energetic and determined engineers to explore more avenues than ever, in sensing systems and beyond.

There's no doubt in my mind that if I was going to do it all again, I'd come to exactly the same place.

I can see a whole new generation of talent emerging and I am delighted we are laying down the foundations for tomorrow's breakthroughs

Fly further with the best in brakes

From cutting his teeth on hydraulic brakes for turbo props and business jets to pioneering the world's first commercial Ebrakes®, engineer David Machan has spent his career bringing aircraft of all kinds to a short sharp stop.

"If you've got what it takes, Meggitt Aircraft Braking Systems is one of the best places around to bring a career in aerospace up to top speed."

I've got more than ten years' experience in Ebrakes but my latest assignment was the toughest challenge yet. The big test for brakes is always the rejected take-off (RTO). We had to bring a 60+ ton aircraft moving at 200 mph to a stop in about 1000 metres—that's about one third the length of a typical runway. And you're not allowed any reverse thrust help from the engines either.

The brake stack temperatures reach up to 2000°C. And if a wheel locks for more than a second, the tyre will blow. That demands unbelievable performance from the materials and the design of the carbon brakes, as well as the actuator and the overall control system. They have to be of the highest quality. As we are the only experienced total system supplier, we only have ourselves to beat. But we're pretty competitive.

Take software, for example. Our customer wanted health monitoring up to a totally new level with this latest version of Ebraking. We now provide about 20 times the amount of feedback data you get from a hydraulic system.

On earlier versions we only had about 10-15 maintenance messages, similar to what you find on hydraulic systems. We now have approximately 300, covering everything from actuator temperature, force and voltage to speed, location, brake wear and current. Each one has to be very finely tuned: too tight and you get nuisance messages, too loose and you don't get the information you need to maintain performance.

Peak performance

An Ebrake actuator has complex electronics and wiring which need to stay cool to function properly. After the first RTO in our laboratory dynamometer, we parked the actuator on the 2000°C carbon brake stack

How do you stop a 20-tonne fighter aircraft coming down the runway at 200mph in under 1,000 metres? Ask a Meggitt engineer.

for five minutes to simulate the time allowed for passengers to disembark.

Thankfully, the carrier and loading plates and our stainless steel insulators did their job, allowing the actuator to hold load and then retract on command as if at room temperature—just as our engineering team designed. That was a huge moment.

But the first RTO is just the beginning. You've got to get that brake performing safely thousands of times. Our Ebrakes use a super high-performance carbon called NuCarb that we developed here. Once they're in service, we expect them to deliver for 2,500 to 3,000 landing cycles, nearly a 1000 more than the industry standard.

When the time does come for a refurb, installation and removal is much quicker than on a hydraulic brake so it couldn't be easier. And the way we've designed the discs, we can bring the brake's life back to

During an RTO, the brake stack can get hotter than a space shuttle on re-entry. We didn't know if our actuator could cope

100% by replacing just 50% of the carbon. That's a huge financial benefit, obviously. NuCarb is another area we lead the industry in and that's another good reason to work here.

And so is learning about integration. When you're relying on an actuator that's so dependent on electronics and software, the whole braking system has to be more integrated than ever.

There's always a trade-off on a brake actuator between speed and force. When you have different companies working on the control system and the brakes themselves, you may not get the proper balance. The control system developer tends to focus on response time and speed, while wheel and brake engineers want maximum force and stopping power.

We're a total system supplier so our in-house control system engineers and braking system engineers work closely together to get the proper balance.

During an RTO, the brake stack can get hotter than a space shuttle on re-entry. We didn't know if our actuator could cope.

The final test

I take a great deal of pride in helping to make our skies safer. One of the ways we do this is by designing for redundancy in our aviation equipment.

There are 16 actuators on this programme, four on each wheel. We had to bring the aircraft to a stop with just half of them working.

We'd previously demonstrated on a smaller aircraft that we could stop with just two actuators per brake but our engineers met the challenge on this one too. When I see the team succeed each time the bar is raised, I feel extremely proud—it's the best part of the job for me, especially on this programme where the challenges came thick and fast.

Overall, the project scope on an Ebrake is about three times what you get on a hydraulic brake system. We spent four years working towards the test flight, overcoming the technical challenges, staying close to the customer and coaching the younger members on the team to take the same approach.

Managing our own people was also complex as we were working across multiple sites: design work in Akron, Ohio, analysis in Akron and Coventry (UK), actuator manufacture and testing in the UK, carbon composite production and overall assembly in Danville, Kentucky.

The big day was September 15, 2013. We had about 100 people gathered here to watch and our system performed flawlessly, bringing the maiden voyage to a smooth rolling stop. We won't forget that moment anytime soon.

Learning, opportunity and choice under one roof

Customers tell us there's no other supplier like Meggitt, not just in brakes but across the board—engine components, flight controls, anything. I'm biased of course but if you ask around, I think you'll get the same answer. I think it's because we have more people here with 25+ years' experience than anywhere else.

But there's good news for younger engineers wanting to move in and take over. These people will retire quite soon. The demographics are in your favour.

At MABS, the opportunities to learn are huge: from the pilot's foot going down, to the plane hitting the runway and everything in between—electronics, software, hydraulics, wheels, brakes and composites. We've found that covers most engineering disciplines people want to choose from during a career.

You can come in to work on rolling stock, spend time on electronics or software, switch to programme management and then go back to engineering. Plus you'll learn how to collaborate across sites and across continents too. Add all that up and you see why we are so strong on choice.

If we're going to keep our lead and deliver on the programmes we've got coming up, we've got to look after and train our people properly.

Given how high our standards are, that's good news for anyone joining us. ●

We had about 100 people gathered here to watch and our system performed flawlessly, bringing the maiden voyage to a smooth rolling stop. We won't forget that moment anytime soon

Always moving, always improving

After stints at Norsk Hydro, Honeywell and Danaher, David Silverio joined Meggitt as a continuous improvement expert at Securaplane, our aerospace battery and security business. As Vice President of Operations at the business unit's brand-new facility, he's looking for talented and energetic people at every level.

"I'm very proud of how far we've taken Lean," he says. "You can hear it in the way people talk. The reason they come here every day is to beat their own record. It's personal."

When it comes to Lean, leaders have to walk the talk, literally. To understand where improvements can be made, you've got to understand what your operations people are doing first hand. You've got to get close to the action. That's what gemba means for me.

Back in 2010 I was focused entirely on continuous improvement. I expected the team to keep product flow going. I didn't want to sit idle either so out went my chair. I was amazed how much more I got done.

We'd been doing Lean for a number of years and had strong ideas in some areas, kanban and gemba management, for example. But when we started talking to Louis Chavez and the Meggitt Production System (MPS) team, they really made us stretch.

Meggitt's commitment to Lean has brought in very talented operations people from all over the aerospace world to work on MPS. We've got experts in many different areas: Amir Allahverdi came from GE via Honeywell, Bob Dirgo is a published authority on Lean and Bernie Stevens, who is now playing a leading role in the integration of our new composites business, is very strong on Six Sigma.

At Danaher, I'd had a lot of experience with Daily Layered Accountability but having to teach the MPS team what we do took my understanding to a whole new level. No matter how well you think you do something, you don't master it until you teach others.

In other areas, we had plenty to learn from the experts. When it was time to roll that knowledge through to our team, the teaching process again helped us fully understand what we thought we'd grasped.

Our leaders come to visit you in your production cell—that's where we generate

value for our customers—not in the MD's office or in the boardroom.

Designed for improvement

Our planning tools are very rigorous. Whether you're introducing a new production line or looking at training and development, the tools make you refine and refine and refine.

When it came to designing a new factory, all the work we'd done to get MPS in place gave us a much more detailed understanding of what should go where. Material flow now follows production tightly, logically supporting our system of Daily Layered Accountability. My production managers can see the entire length of their responsibility in a single line, including their daily goals and scorecards. Repair and overhaul is organised in the same way. We made other improvements too—

Dave Silverio, with operator, Dave Edens working on cockpit door security systems. The Airbus A380 is the latest platform to carry this world-class product from Securaplane.

> Our leaders come to visit you in your production cell—that's where we generate value for our customers—not in the MD's office or in the boardroom

environmental testing equipment, for example, is now easily accessible from all areas.

When it came to the move itself, Boeing, one of our key customers, thought we couldn't do it in less than three months. But four weeks after we started, we were back up and running. Boeing's response? Thank you for a seamless transition, Securaplane.

Small steps towards better

Right now, we're in a new phase of MPS, reassessing organisational development and planning for the next round of improvements. Lean never stops at Meggitt.

Over the next few months, we are selecting people who'll become our subject matter experts in areas like design of experiments, Six Sigma or planning tools. Once they're up to speed themselves, they'll guide our learning as we progress.

We're also making changes to our appraisal process to make sure we measure performance against the new values and practices we're introducing.

Cross-training for new skills, ideas

New eyes bring new ideas so we encourage our people to move around and broaden their perspective on production.

I want to see individuals as good on an emergency battery, say, as on a camera system or a battery charger. They should be proficient in three or four products, not just one.

It's definitely a win-win: our people want to get on and learn and we need to be flexible to meet changing demand.

Going for growth

At our new site, there's 8000 ft^2 roped off to expand into. We want 25% growth over the next five years which should fill it. That means great operations opportunities at every level.

The way we run things at Securaplane, you don't get pigeon-holed. All facets of the business, from engineering and R&D to operations and shipping, are here in this building. You'll touch a lot of different things, whatever your level.

And you'll find leaders who are genuinely engaged. They'll come to visit you in your production cell because that's where we generate value for our customers—not in the MD's office or in the boardroom.

They'll expect you to deliver your best, of course, but you'll get face time and your ideas will matter. Because if you can work out how to do your job better, we all benefit—that's ultimately what MPS comes down to. ●

Making the best better, one step at a time

"The Meggitt Production System takes Lean to a whole new level," says Helge Huerkamp, General Manager for Meggitt Sensing Systems (MSS) Fribourg facility.

"With what I know now, I could go back to consultancy and make a heap of money. But if you have the opportunity to make the best even better, why go anywhere else?"

In my time at Canadian Aviation Electronics, I must have done about 12 week-long kaizen workshops. Pretty much every operational problem you can imagine came up and some great solutions too. But so often, we'd get distracted by other issues before we had time to implement.

You don't know what you're missing until you've got it, of course, but what I realise now is that we didn't have the full 360° view. At the heart of the Meggitt Production System (MPS) is a set of daily interlocking meetings which cascade information up and down the business, escalating problems and good ideas so they get the attention they need.

Turning the world upside down

Daily Layered Accountability (DLA), as we call this process, is the glue that holds the many, many components of continuous improvement in the spotlight. At the Meggitt Sensing Systems (MSS) site in Fribourg, Switzerland, the first meetings kick off in each production cell every morning. We run through the same rigorous agenda of safety, quality, delivery, inventory, productivity each day. Any issues are noted down, Pareto boards—displays that highlight our key areas of focus—are updated and anything that needs escalating is taken by the cell leaders to the next meeting. That starts immediately afterwards and also includes representatives from each function.

Using the same agenda, they review and pass on what they find and so on, up to senior management who get a higher altitude view of the whole plant's performance. We start at 8.30. And we're done by 9.30.

It sounds simple but these meetings have actually turned our approach to operations excellence on its head: everyone from sales to compliance and delivery—including top management—is focused on the people who make the product. Poor process, bottlenecks and any other problems are highlighted immediately because these meetings make responsibility totally transparent. Each of us knows exactly what we have to do and how our work affects others. Making improvements and beating your own record becomes a question of personal pride.

Today, there's not a single person who wants to miss a DLA meeting. And yet two years ago, we didn't even know what they were. Fully embedding the process has been hard work and took about a year but there was full support from the start, both here at MSS and at group level.

Lean, and entrepreneurial too

That meant the necessary resources were

available and I could go out and find the people I needed. There are lots of highly experienced Lean practitioners out there but most are from organisations where implementation is at a very advanced stage. I needed people who could work in an environment where less was defined. There were only a handful I met who had the spark and energy necessary: one from a hi-tech Swiss medical business, for example, one from a smaller French aerospace business and one from Thales.

A key focus from the start was performance management. I'd seen attempts at getting this right at McKinsey but the tools we have developed here are really delivering.

The first is a monthly review of the one-year operations excellence plan for the whole site. Thanks to the quality of the data we get from the DLA meetings, we can measure where we are very precisely and fine-tune accordingly.

The second tool consists of a set of five pillars which sit right at the heart of MPS, namely, organisational development, strategy deployment, leadership culture, performance management and tools and methods. Progress is measured against set criteria defined across six levels. Before you can move up, you've got to hit all the targets across a whole site. It's seriously demanding. There's no automatic approval. You've got to prove you're ready.

You have to prove your worth but if you've got what it takes, you can move on really fast.

Big change, big results

We moved from the foundational "Red" to the next "Yellow" phase in March 2014 and all 600 of us here in Fribourg joined in the celebrations. We were three months late due to some unexpected challenges in the market but we're making progress: lead times for some products have halved and we received a supplier award from Snecma.

Considering we were the first site to formally launch MPS in the group and we invested a significant tranche of time, hiring, developing the right culture and reviewing our value streams, I'm proud of how we're doing. During that review, we realised that although we had five shops on site, we only have three types of customer—sensors and cables, energy electronics, and aerospace systems. Reorganising on that basis meant physically moving 60% of our operations around the site and about 90 people. Since then we have seen big improvements; on time delivery (OTD), for example, is up to 96%.

I believe it's the unique combination of DLA and our performance management tools in MPS that sets what we're doing here apart.

But there are other areas we're focusing on too. Take sales and inventory operations planning. We have transformed our process over the last two years and now review our three-yearly sales forecasts monthly. We are reformulating how we translate forecasts into demand for the site and our supply chain. The goal is to slash inventory by 50% but still keep improving OTD. We're about half way there on OTD and inventory is down by 10% so, again, progress is good.

You have to prove your worth but if you've got what it takes, you can move on really fast

Learn, coach, lead ... and repeat

It's an ambitious target of course, but they have pushed ahead well with this at Meggitt Aircraft Braking Systems and so we sent a planning team over there and shared our findings with other sites as we went on. My team really relish those opportunities across the group which come from having such a tight and well-resourced operations excellence network.

In terms of my own learning, I found the 12-month Oxford Leadership Programme hugely rewarding. It consists of three intensives—two at the Said Business School in Oxford and one in Silicon Valley—as well as project work focused on live strategic issues at Meggitt. We present recommendations and an implementation plan to our Board.

Both the content of the course and the networking have pushed me on far quicker than I thought possible and it's a great example of the kind of opportunities there are here. You have to prove your worth but if you've got what it takes, you can move on really fast. It's partly the culture but also because we're growing fast.

Looking ahead, operations excellence will remain a top priority for Meggitt. Investors want it and customers want it so it's high on the agenda. That focus is another gift from Pareto: we're always concentrating on the 20%—the 'vital few': it's the quickest way to the biggest gains. ●

Learning to listen

Garret Mertz, Site Director, Meggitt Control Systems, Corona, has helped bring Lean to Meggitt production lines new and old in China, England and the US. Each role he gets is bigger, more complex and more daunting than the last but the lessons he first learned as an intern at Meggitt help him succeed every time.

I managed a hydrogen reformer prototype project here as a 20-year old intern. It was a big stretch but I learned a lot. It's been the same with every role I've had since. Luckily Meggitt is full of smart people who are only too happy to guide you.

On that first job, I was the liaison between the engineers and the welders. I had to bring the design drawings to life. I'd interned the previous summer in the Meggitt Sensing Systems machine shop, running mills and lathes to produce test equipment. But I'd not managed anything before and the prototype was pretty complex.

I'm a quick learner though and I soon felt more confident. It was a great moment when I realised I could do what I was being asked. Thanks to my mentors at the time, I understood that the most important thing was to listen to to the concerns and needs of the welders and the engineers, and talk to them in ways they could relate to. You've got to tailor what you're saying so people understand and, crucially, trust you.

That's probably the most important lesson I've learned here.

Learning Lean in Japan

Whether it's off-site training or mentors and bosses who love to teach, Meggitt has been very strong on career development.

After I switched to operational excellence in 2006, I spent two weeks at Shingijutsu Global Consulting in Japan. It was set up by one of the original members of the Toyota Autonomous Study Group—the group who first developed lean production practices.

We visited Toyota and Hitachi and learned the principles of kaizen—standard

Creativity on the factory floor: Garrett Mertz, Site Director, Business operations, Judy Bunch, Lead Assembly Technician and Derek Harris, Lead Test Technician eliminating scrap at Meggitt's control systems facility in Corona, California.

work and operations as well as how to lay out a factory properly.

The first flow cell I ever helped build was on our heat exchanger production line for the Pratt & Whitney 600, a very small turbofan engine for business jets. The following year, I went to the UK and helped refine a similar line for the CFM56. It's one of the most common turbofans in the world—there are more than 20,000 installed.

At that time we were using batch production; five guys building a product from start to finish. It took up a lot of space and quality wasn't as good as it should have been. They knew there were problems. But when you have someone new come in and say we're going to change the way you do things and turn this around, you always get push back.

You don't have to be an expert in that field. You just have to listen to the people who are

Keeping promises, building trust

So humility and reliability are absolutely fundamental. You have to sit down with the production people and listen very carefully to their ideas.

After all, the only reason I have a job is because of the people who build product. That's where the value is. So when they make a good suggestion, you have to make it happen. Work with the manufacturing engineers, the quality engineers, procurement, whoever you need to, but get it done. Then, when it comes to implementing other people's ideas, they'll listen a lot more carefully.

That's how we did it on the CFM56. And we won Snecma's Best Supplier Award for operational performance as a result. You've got to tailor what you're saying so people understand and, crucially, trust you.

Bigger roles to play

Two years ago, I took over as Director of Site Operations here at the Meggitt Control Systems plant in Corona, California. My predecessor had been here for 20 years and knew every aspect of the business. Mention a part number and he'd know exactly where it was supposed to be in the factory and who should be doing what to it.

Coming in fresh to this site, I had no option but to rely entirely on what people told me. My biggest fear was that no one would talk about the issues coming up. Fortunately, the tools we have in the Meggitt Production System—Daily Layered Accountability and living Pareto boards particularly—encourage people on the shop floor to speak up. Thanks to the way we work, they know we're behind them 100%. Once I showed that issues raised got attention and got solved, we made good progress. On time delivery hit 100% four times in 2013 and we've kept to an average of 99% for 2014.

In the end, I guess I'm learning the same lesson again and again. To improve in a particular area, you don't have to be an expert in that field. You just have to listen to the people who are. ●

Train up and get on

Meggitt's specialist heat exchanger business, Heatric is expanding its technology from oil and gas where it has a high profile, into power generation, waste heat and air processing. David Clemmitt, Director of Engineering, is moulding a new generation of engineers for new Heatric applications.

What can engineers joining Heatric expect?

Great things! Our unique diffusion bonding technology is the future of heat exchange in challenging applications. We've got some very satisfied high profile customers—BP, Shell and Petrobras to name a few—and there's a great sense of enthusiasm and purpose here. That makes it a very rewarding place to work.

However, with disruptive technology, you get a situation where there are a few specialists with very deep knowledge. My task is to broaden that base while maintaining a culture of excellence. If you've got what it takes, you'll find more than enough opportunity for a career's worth of challenges here and across the group. And, crucially, you'll get the training and support to make the most of it all.

What do you think is the secret to good training?

It's a combination of demanding projects, great mentors, high standards and clear career paths. Bright, energetic trainees help too!

Seriously, though, training has to be built into the culture of an organisation, part of everyone's thinking. We're strengthening our structures to make sure it's embedded at all levels.

Our Graduate Programme is the focus at entry level and that ties into the programme we've developed with the Institute of Mechanical Engineers (IMechE) for more experienced engineers. Qualify as a Chartered Engineer (CEng) and your skill and experience will be recognised worldwide.

As we also have a large population of chemical engineers, we are forging similar links with the Institute of Chemical Engineers (IChemE), which has a chartered development programme. Chemical engineering is a core competence in our business for sizing and selecting the appropriate compact heat exchanger and delivering the very best solution to our customers.

What does it take to qualify?

The CEng is a demanding scheme and takes most people four years. Participants carry out regular reviews of their own work. Mentors—who are always Chartered Engineers themselves—work with them to check progress against all the skills and abilities required.

You've got to get up to speed on everything from budgeting and team management at one end to technical competencies at the other.

There's plenty of work to be done and you're expected to drive things along

Staying ahead of the competition

yourself but the scheme is well structured and clear.

What kind of projects do your engineers work on?

They learn on the job with a range of customer projects and cross-discipline initiatives. We've made a big effort to ensure that all managers think training. That way young engineers get the stretch projects they need to grasp how product evolves here, from design through to shipping and what their impact is at each stage.

Can you give an example?

One of our engineers, Ben Noble, is well into his CEng. One of his main projects was to streamline drawing standards across the engineering discipline and introduce a new software package to help the process. All our products are bespoke so we generate more new drawings than many firms. He's creating a library of components and a set of templates we can all share to make our drawings crystal clear to manufacturing.

Before joining Heatric, I sometimes would see poor designs where the manufacturing team hadn't been involved. As a result, a lot of money had to be spent on bespoke tooling. If the design engineer had involved the manufacturing team early on this could easily have been avoided. We always make sure sales and design engineers spend enough time on the shop floor.

The Meggitt Production System (MPS) also helps our engineers see exactly what their impact is in other parts of the business. MPS combines very strong communication tools—which highlight production issues—with problem-solving processes that put the power to change things in the hands of individuals. If problems don't get solved, they're escalated to the MD's desk in just two or three days. That really focuses attention.

> The secret to good training? Demanding projects, great mentors, high standards and clear career paths. Bright trainees help too!

What are the long-term career prospects like?

We cover oil and gas but we move in exciting and evolving power generation, waste heat and air processing markets. And because our customers are all over the world, there's plenty of international exposure too.

We encourage our young engineers to think carefully about where they want to specialise and many move out of design into other areas such as quality, bid or sales engineering. As everyone's using the CEng to train up, the same high standards will be familiar across the full engineering discipline.

In addition, we're now introducing a technical career path for more experienced engineers so if you don't want to move into management, you can focus on building your technical expertise and championing innovation.

Being part of a global leader like Meggitt brings other opportunities too. Some of our engineers are involved with initiatives like Meggitt20, a group-wide forum for exploring the capabilities we'll need in 20 years' time. Others will find openings elsewhere in the group full time. At the moment, for example, we're seeing strong growth at Meggitt Aircraft Braking Systems and at Meggitt Polymers & Composites.

The proof of the pudding is in the eating though, isn't it? So the fact that lots of good engineers are applying to work at Meggitt speaks volumes.

The Meggitt group continues to grow and the only way to make that sustainable is to make sure our people are too. Excellent learning and development is the only option. ●

Roy Deakin worked his way up from apprentice to managing four facilities for Meggitt Aircraft Braking Systems (MABS) in three different countries. "If you've got the talent, Meggitt has the technology, the variety and the training to help you open some of the biggest doors in aerospace."

Look at my CV and you can see that every four or five years, I've been lucky enough to get a huge new challenge.

After starting as a mechanical fitter, I became a manager at 23. I then moved into maintenance, repair and overhaul (MRO) and on into sales. That gave me a chance to get in close to the airlines and that's a wonderful thing. Seeing one of our wheel and brake assemblies on an aircraft makes me very proud—I know what it takes to get a safe landing, time after time.

Leaders in technology

Engineers ask me about operations opportunities here and there are four things I say. First, we're in aerospace, the most advanced area of engineering, and our technology is up there with the best. If you're ambitious, second best is not an option.

Next, the variety of what we do is exceptional. When I started, we produced the brake, the wheel and a handful of control components. Now we have about 30 line replacement units, ranging from sensors and steering systems to tyre pressure monitoring systems. And of course, if you look beyond brakes, Meggitt's range of expertise in extreme environment engineering is vast. If you have an interest in, say, thermal systems or fire protection

Take the Oxford Leadership Programme, for example. The calibre of the speakers here in the UK was astounding and our second week gave us the latest insights into Indian engineering, with a trip to Infosys in Mysore—it's the world's largest corporate university and it's like a slice of California in India. It was an extraordinary opportunity to learn about next generation engineering leadership.

But at Meggitt, it's not just people at the top who get great training. Our people need it throughout and we're investing to make sure they get it. MPS has a number of tools focused on learning and organisational development, from problem-solving and mistake-proofing to continuous improvement techniques.

And we're using technology too. Take the smart workbench I mentioned earlier. It's taking 'standard work', a key Lean tool in MPS, to a higher level, enabling us to consolidate and standardise the very best techniques from our top trainers. Younger operators using it can reinforce what they've learned using the laser guides—all of which will free up time to train more people and design and calibrate more intelligent workbench processes for brand-new lines.

or composites, we lead the field in those areas too. You won't run short of new avenues to explore.

State-of-the-art manufacturing

We want to lead in manufacturing technology too. Historically, our focus has been on optimising machines but in this business we can't automate cost effectively because of low-volume demand. We can definitely work smarter, though.

Working with the UK's Advanced Manufacturing Research Centre in Sheffield, we're developing an intelligent workbench which uses a laser light to guide operators on which parts to pick, place and fit for assembly and, potentially, for disassembly in the case of repair or overhaul.

Trials here at MABS are already showing higher build accuracy, better quality and faster build times. And to make sure as much feedback can be channelled into better product designs, the workbench also has a built-in camera so assembly can be recorded and analysed later. (See Benchmark of the Future, page 12).

Staying ahead, continuously

The third reason for joining Meggitt is the radical change we're making in continuous improvement. It's one thing to have the best technology but you also have to be competitive.

Once a business achieves over 90% on-time delivery, for example, getting to 100% involves attention at a microscopic level. The Meggitt Production System (MPS) makes sure we're always taking small steps towards better. It's a comprehensive set of tools and processes that keeps us focused on how we, personally, can get a better product out of the door, no matter what our role is or how junior we might be.

Our starting point is that if you give skilled, intelligent people the opportunity, they'll take the initiative and work out how they can do things better. And they'll enjoy their job more, too. So it's about empowering people to make the changes themselves. It's not about managers telling you what to do.

That may sound like common sense but it's not easy to put into practice. You need a structure that is rigorous and consistent but also flexible. MPS comes closer to it than anything else I've seen.

Train up and train on

The fourth reason Meggitt stands out from the competition is the training. I started as an apprentice at 16 and now I'm responsible for four facilities around the world—that's about 1,300 people. I've needed a huge variety of training along the way —technical, managerial, leadership and personal development.

Of course I've felt overstretched at times and out of my depth. That's often when you least want to take time out for training. But every time I do, I learn what I need to get on.

> Seeing one of our wheel and brake assemblies on an aircraft makes me very proud—I know what it takes to get a safe landing, time after time

More opportunities than ever

So, those are my four reasons why ambitious operations engineers should join Meggitt. Two of them—state-of-the-art technology and training—were part of the package when I started. But today, the pace of change is faster, Meggitt's range of expertise is broader and critically, we have MPS. So if you join now, you'll have even more opportunities than me.

If you're lucky enough to come and work here, all I can say is fasten your seat belt. It's going to be quite a journey. ●

Meggitt Avionics taught in school

Meggitt's intelligent reading for pilots. As every pilot knows, the effects of sensory overload in extreme conditions can be significant. That's why the design of Meggitt Avionics' compact flight deck instruments—for navigation, engine, fuel and flight data—focuses on human factors and the assimilation of critical information under stress. *Pictured:* AVIC Aircraft Xi'an Branch has chosen Meggitt's latest standby display, the iSFD, for its new regional MA700 aircraft.

Meggitt's Chief Executive Stephen Young and members of his management team hosted senior executive top talent from subsidiaries of China's premier aviation organisation, AVIC, in Q4, 2014. The day-long event organised by the Henley Business School (HBS) was part of a global executive programme on doing business in international aviation.

Classroom learning is balanced with facility visits and events that provide cultural insight. Delegates produce post-programme action plans to help improve AVIC's future performance. These embrace what David Rees, HBS Visiting Executive Fellow and Programme Director describes as "business transformation strategies expressed through change management and leadership", a theme on which Meggitt's own group management team extemporised during presentations for AVIC led by Group Organisation Development Director, Robin Young, who spearheaded the group's 'Transformation' programme in 2009.

Delegates were exposed to management systems in action at Meggitt Avionics during a tour of the Fareham, UK-based facility led by General Manager, Mark Crompton and Continuous Improvement Leader, Jon Bradley. Rees commented: "AVIC delegates were impressed with how the theory of management and operational work systems were demonstrated in real time and particularly noted Meggitt Avionics' attention to health and safety."

Peter Huber, Group Sales & Marketing Director, who also attended said: "We can be proud of having such a distinguished group of top Chinese aerospace industry leaders choose to visit us. They were eager to learn how a strong British aerospace company is run and how our factories work. However, in my 10 years of dealing with our Chinese partners, I have understood that we can learn as much from China as it can learn from us."

> In my 10 years of dealing with our Chinese partners, I have understood that we can learn as much from China as it can learn from us

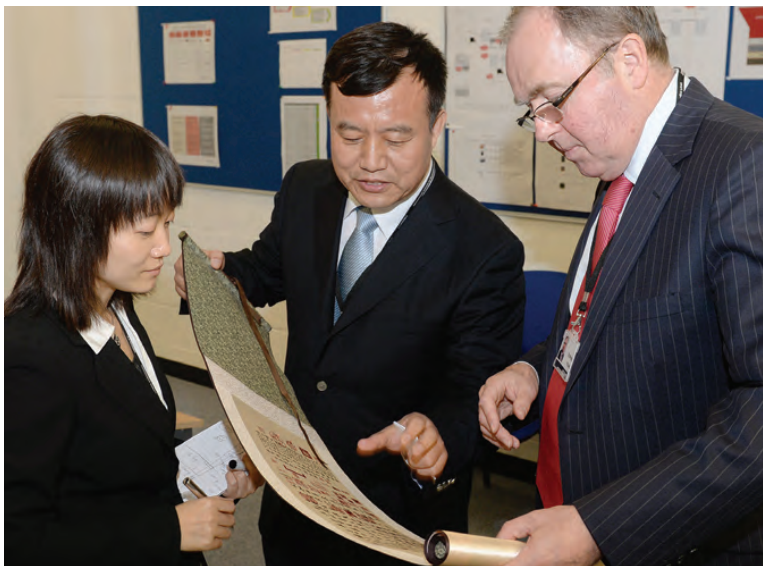
Huber draws our attention to the progress of the aerospace industry in China and the opportunities it presents. "They have covered in the past ten years what took Europe and the US a half-century through intense learning, improving, persistence and hard work. Today AVIC are important new partners in a new and growing market for Meggitt's smart engineering technologies."

That partnership has already begun. In the past, Meggitt has won wheels and brakes, control units and engine sensors on the ARJ21 regional aircraft and engine sensors and valves on the European LEAP engine for the C919 commercial airliner. The group has won the same equipment on the Chinese domestic engine programme for this aircraft from the Shenyang Engine Development and Research Institute (SEDRI) and is bidding on the alternative AVIC Commercial Aircraft Engines (ACAE) programme.

A new chapter

In Q1 of this year, AVIC Aircraft Xi'an Branch invited Meggitt Control Systems to embark on a multi-million dollar programme involving three packages of work for its MA700 70-seat regional aircraft. Meggitt and AVIC entered the joint development phase involving two fire protection systems, one for the engine and auxiliary power unit and the other for the cargo and cabin; and a bleed air leak detection system. The first delivery is planned for 2019 with production expected to last at least 25 years. Meggitt Avionics won the standby flight display. It will deliver hardware for integration testing in April 2016 and flight test units in December 2016 (see above).

Chief Executive, Stephen Young, who led the AVIC delegation at Meggitt Avionics, said: "These awards confirm Meggitt's continuing status as a world-leader in high spec, safety-critical sub-systems and equipment." ●



Above: With senior AVIC executives and translators: Front to back: Richard Morris, Meggitt Avionics Strategy & Marketing Director demonstrates an air data computer, observed by Peter Huber, Group Sales & Marketing Director, Clive Nash, a software engineer who had just demonstrated a flight simulator, Stewart Watson, Meggitt Equipment Group President and David Rees of the Henley Business School.

Left: Zhongyuan Wang, Vice President, Aviation Industry Corporation of China (AVIC) presents Meggitt Chief Executive Stephen Young with a reproduction of a calligraphic masterpiece by Tang Dynasty artist, Wang Xizhi – a silk brocade scroll containing a poem about 42 literati gathering at an Orchid Pavilion near Shaoxing, Zhejiang, at which they to composed poems, played music, and enjoyed wine ...

INTEGRATED RESPONSE

CHAPTER 26 ATA FIRE PROTECTION

Meggitt and AVIC Aircraft Xi'an Branch have entered a joint development phase involving full Chapter 26 fire protection for the MA700 70-seat aircraft.

The X-Factor

Piher Sensors & Controls, Meggitt's high tech sensing business in Spain, has used the group's Chinese facility in Xiamen to win its place in the 100% Chinese supply chain of German global mechatronics player, Kostal. Piher has not only established a model of global team working for its global customer but the Meggitt group itself.

When Kostal decided to source 70% of its worldwide requirements from a new procurement centre in Shanghai, Piher, already a key supplier, saw a 'game-changing' opportunity to grow its high-tech printed circuit resistor (PCR) business. Piher's PCR process prints position control sensors onto the automotive printed circuit boards controlling most of what you can see on the dashboards of almost every car marque from the Ford Fiesta to the Porsche Panamera.

After investment from the Meggitt group and almost a year's planning, Piher had enabled Kostal to certify operators from Meggitt's Chinese facility in Xiamen on a brand-new PCR installation based at Piher's home turf in Tudela, Navarra in late 2013.

In early 2014, a mixed team of Spanish and Chinese operators was flown to China with the installation—a snaking continuum of elements from different machine suppliers covering printing, surface treatments, curing and laser trimming amongst other state-of-the-art processes—where it was recertified two months earlier than planned. Equipment and people passed with flying colours.

Now running to capacity, Meggitt has provided a second tranche of investment to commission an additional PCR line in Xiamen in Q4 this year.

If Piher employees thought that a product line transfer—more properly called a product line 'replication'—was a threat to jobs, this was dispelled when spare capex from the elegantly executed Xiamen project was reinvested in new kit (a high tech oven) for the Tudela facility. All three lines—two in Tudela and one in Xiamen—are running to maximum capacity. There is plenty of work to go round as Piher services the Kostal and other automotive supply chains in Brazil, China, the Czech Republic, France, Germany , India, Ireland, the UK, the United States and on its home turf, Spain.

"We could not have made this quantum leap in our PCR business without Meggitt Xiamen. None of our European competitors had easy access to plant in China—and none of our Asian competitors can produce for Kostal in Europe," says Jesús Martinez, Commercial Director. "We remain the only certified full-process supplier to Kostal operating in two continents."

Piher's printed PCR journey started with simple light controls such as car headlamp levelling. Today, these are increasingly integrated with higher value engineering such as complex miniaturised switch functions and the new generation of steering column modules. According to Martinez, as a significant proportion of

Kostal's design and engineering capability will reside in China, there will be more opportunities for Piher to exercise its considerable engineering capability on the ground there. As over 70 Chinese companies are striving to produce new car models using advanced engineering, Piher's engineering capability is bound to attract a variety of indigenous customers—

Piher's professionalism stems from experience in the automotive school of hard knocks

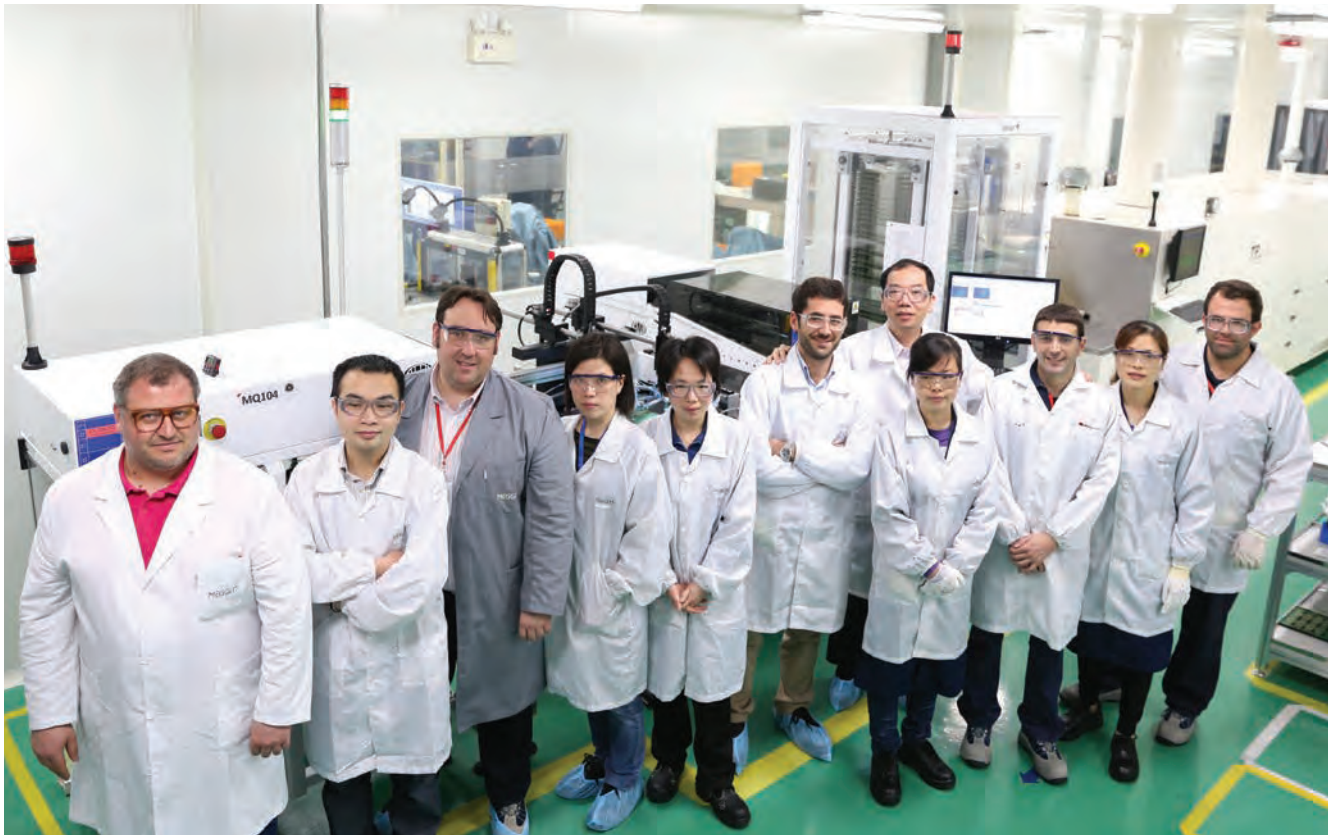
not just in automotive. Piher's markets include medical, marine, home automation and industrials. "As these products become more successful, global sourcing will begin for global platforms, bringing manufacturing back to Europe. It's a model already forged in home appliances," he says.

Since 2009, China has become the biggest automotive market worldwide. In 2014, nearly 19 million cars (almost 10% of the world market) were sold. A 7% increase is expected this year and by 2020, while growth will slow, sales will easily top 20-plus million units.

Meeting Kostal's capacity requirement appears not to have ruffled the composure of the Piher management team—at least on the surface. Such was the great method with which the team approached the task, Kostal staff were, at one point, oblivious to the transfer from Tudela. Piher's professionalism stems from experience in the school of hard knocks, its agility honed after decades working in the demanding automotive market. "Failure to deliver is just not an option in this business, "asserts Martinez. "If you don't deliver, you go out of business. You rarely get a second chance." Representatives from Meggitt's aerospace businesses tend to cast a hungry eye over Piher's parts-per-million (PPM) defect level of less than 100, even if Piher's manufacturing processes are highly automated.

Plan B, C and D

The Piher management team set to work using tried-and-tested 'plan, set, do, check' tools plus advanced quality planning practice such as FMEA (failure mode and effects analysis). And if there was a Plan B, there had to be plans C and D. They never underestimated the impact of combining a product line transfer involving complex import and export processes: Daniel Vega, the Xiamen-based project manager, had significant experience here. Then there were the logistics of transporting sophisticated machines: a dedicated aircraft was hired. The transfer of knowledge between individuals of different generations, mother tongues and business and operations cultures was eased by the surprisingly effective lingua franca of 'OK', 'Yes', 'No' 'Watch', 'Repeat' and interchange underpinned by universal themes of family and football.

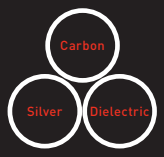


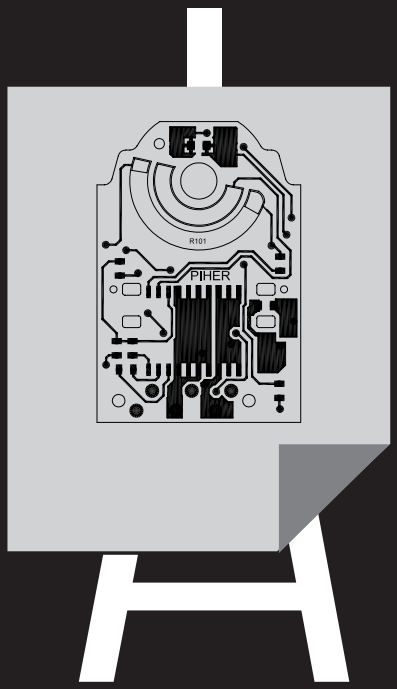
East meets West in one Meggitt team: *L-R:* Marcos Gonzalez (QA Engineer, Piher) Cody Yu (Product Engineer, Meggitt Xiamen), Daniel Vega (Project Manager, Piher), Rachel Huang (Project Manager, Meggitt Xiamen), Nancy Dai (QA Engineer, Meggitt Xiamen), Gonzalo Muñoz (Operations Director, Piher), Sherman Guo (General Manager, Meggitt Xiamen), Jiang Li (Operator, Meggitt Xiamen), Pablo Litago (Operator, Piher), Li Xiaomei (Operator Meggitt Xiamen) and Rafael Jimenez (Operator, Piher).

Down to a *fine* art

High volume, low tolerance printed PCB resistors

Carbon printing at the cutting edge of laser-trimming technology



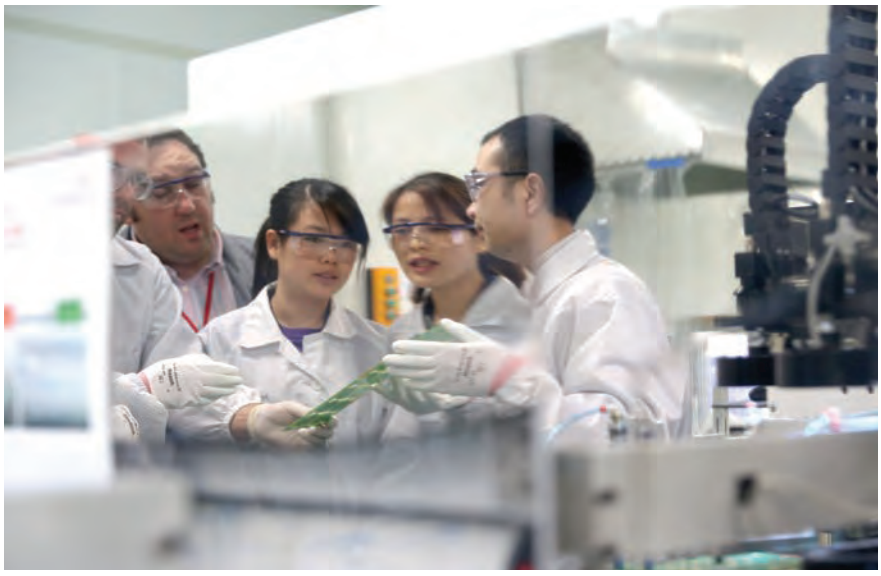


Gonzalo Muñoz, Operations Director, convened an initial transfer team of more than 20 individuals. Volunteers from Piher's 300-strong workforce were not hard to find for this intriguing project, a third of whom remain working on the project—a mix of Spanish and Chinese engineers, with a tri-lingual (Spanish, English, Chinese) customer support manager, Ms Meng Yaoh Loh based at Meggitt's Asia aftermarket centre in Singapore. "The critical success factor for this project was and remains self-sufficiency," says Muñoz. "The PCR process could never be directed from the other side of the world. It had to be sustained by operators and engineers on the ground.

"There was a significant capital investment in machinery. We also had to invest in our people. We designed close collaboration into the product transfer process. From the start of the project, two teams from two countries, very much with their own cultures, worked at our Spanish headquarters. They not only learned the process—they learned to work together."

Today, the Xiamen/Tudela PCR team consists of twinned functions. A quality manager in Spain man-marks a quality manager in Xiamen. Similarly production management, engineering and mechanical and electronic maintenance are all mirrored by support in Tudela.

The PCR Xiamen team is unlike others at the Xiamen plant which are characterised by large teams, labour-intensively assembling products such as aircraft seals, aerospace, industrial and medical sensors, ground fuelling products and some Piher position sensors and controls for white goods and home and building automation. The PCR line is a high tech process, involving high tech machines



Top right: L-R: Quality experts Marcos González, Pablo De Vicente and Quality head Luis Arellano verify laser trimming parameters

Left: Rafael Jimenez, Daniel Vega, Jiang Li, Li Xiaomei and Cody Yu in a training session to identify printed circuit resistor defects. The Chinese line is a mirror image of Spanish production.

creating high value products. "It was not difficult to attract good people to train for these technically demanding roles and the opportunity to work with highly experienced Western staff," says Muñoz. Retention figures in a country where turnover can be rapid, speak for themselves. Only one loss for non-work related reasons has been sustained since production started 12 months ago.

When the Meggitt Review interviewed Nancy Dai, Quality Engineer, and Cody Yu, Focused Factory Manager, the laughter from members of what appears to be a very happy team rang out.

Cody, who started out on the project as a process engineer, is now leader of Piher's PCR 'Line 2'. He enjoys working for Western companies after a first experience working in a very procedurally driven, command-and-control environment earlier in his career. "We looked like a team but in reality you were assigned a task as an individual and you worked on it alone and reported back. There was no support." The notion of being able to change your reporting line or simply challenge a proposal was unthinkable until he joined an American business. It is even better at Piher, he says. "I like the work but what I like most about my job is the team. It's about the way we work together. You are never alone with a problem."

Professionally Piher remains thrilling for him. There was the excitement of the transfer, the capacity gain and a second line [Piher's PCR 'Line 3'] to commission at the end of this year. However, he is most proud of the Xiamen team's success and wants the rest of the Meggitt group to know what it is capable of.

Dai loves working with the Piher team in Tudela. "If we have a problem, we get support very quickly from them. I have great respect for their experience." Like Cody, she enjoys the freedom to take the initiative after a similar experience working for a prescriptive company. 'Everything was specified there. For example, I was only responsible for process quality. At Meggitt/Xiamen, I cover material, process and final product. I have learned that to optimise quality, you have to look at it systemically." Like Cody, she is excited professionally but what she most looks forward to when she comes to work is daily interaction with the

> We could not have made this quantum leap in our PCR business without Meggitt Xiamen

Pig's heads, lamb's trotters, snail and tripe

Tudela's Chinese colleagues, whose cities "change by the year", enjoyed visiting "old Spain" according to Daniel Vega, the Xiamen-based PCR line's project manager. In turn, Vega likes coastal Xiamen's gardens, which contribute to the city's reputation as China's 'Green Pearl of the Sea'.

The Chinese, he says, are good at catnapping during breaks. Vega can only manage siesta on holiday.

Traditional Spanish food that is not so common at home these days—pigs' heads, lambs' trotters, snail and tripe—were popular with the Chinese team but Piher hired a Chinese cook to look after them during their time in Tudela. Nothing however could beat the Chinese restaurant sought out by Piher Managing Director Rafael Fernandez-Ladreda in Madrid for one evening celebration, revealing how much they missed the taste of home. Vega likes Chinese candy.

Vega notes that the Xiamen team chose dormitory living when they were in Spain—quite different to Europeans who place a premium on personal privacy.

L-R: **Las Machinistas:** Operations engineers Ana Navascués and Arancha Sánchez monitor production, project managers Virginia Clemos and Marta Lacaba evaluate the manufacturing of prototypes and PCR Operations Manager Anabel Sarriés selects software for a new batch of production.

team." Project manager, Daniel Vega has clearly set the right structure and the right tone.

Quality street

WHAT IS THE SECRET OF LUÍS RELLANO, Piher's Quality Director when it comes to that PPM of less than 100?

Long experience across automotive and related industries and economies from Turin to Tangier comes into play. With his team, he uses advanced quality management tools and always addresses the human factors, the biggest influence over the success of any project, says Arellano. "There were barriers and borders to cross. It was imperative that the whole company understood the criticality of the purpose: to fit into a major customer's procurement strategy and to expand in ways that would also benefit the Spanish operations."

The whole Tudela/Xiamen Quality team surely deserves a medal. Muñoz recalls: "In January last year, we were preparing for the Kostal audit in Xiamen in March. The team was going to take a break for Chinese New Year but received a request in late January with 24 hours' notice for a pre-audit from Kostal. We achieved 89% of what was needed for full certification. That put us two months ahead of schedule and hastened the mass production phase."

> The Xiamen and Tudela lines are "location neutral". All run to the same production values and capacity

Arellano is delighted with Piher's performance. "We were founded in 1960. Some of our employees have worked here for 40 years or more and yet, here they are, working with multi-disciplinary teams with colleagues on another continent and really stretching their skills. We have developed and tested new competencies and we can claim a truly international outlook."

Anabel Sarries, Resistor Tracks Factory Manager [automated potentiometer production plus the PCR lines), has reinforced the Quality team's effort to ensure the Xiamen and Tudela lines are "location neutral". All run to the same production values and capacity, supporting the embedding of skills needed to fine-tune the fine art of PCR processing. The former biochemist observes: "Lots of people in China know how to print carbon but the final adjustment to provide a top quality project is not easy.

"That is why it was really important to take operators and technicians from China to learn on our line here and immediately start working on the new line in China to avoid skill fade," says Sarries. "The hardest part of the project for me was setting up the line in Tudela while bridging Kostal's immediate capacity gap."

Machinistas

PCR Production Engineer, Ana Navascués, a chemical engineer whose second job after graduation was with Piher, has a nine-year relationship with the PCR machines. What

L-R: Virginia Clemos and Marta Lacaba review PCB cleaning and activation processes ready for a new product

Model engineers

Piher's carbon printed electronics technology has evolved significantly since it started printing resistors onto customers' pre-printed circuit boards (PCBs) in 1993.

Adapting screen printing processes to the finest tolerances required for miniaturisation using new inks and printable materials like silver or dielectrics and applying state-of-the-art laser trimming technology to a range of PCB substrate finishes including electroless nickel immersion gold (ENIG) has positioned Piher as a leading manufacturer worldwide.

In 2015, it produced more than 12 million position sensors and controls for safety-critical automotive applications, using PCR technology, possible only says Commercial Director, Jesús Martinez, thanks to the dedication of experienced chemical engineers like Marta Lacaba. She has worked at Piher since 1984, first specialising in inks, which Piher continues to produce in-house, and later carbon printing over ceramic substrates.

Lacaba worked closely on the Xiamen process replication in Xiamen, with Virginia Clemos, a chemical engineer who joined Piher in 2007. Representing the new generation of talented Piher engineers, Clemos is industrialising steering column modules for various luxury car marques.

she does not know about them is scarcely worth knowing. Her colleague, recent chemical engineering graduate Arantxa Sánchez (PCR Production Engineer), represented Piher knowledge on the ground in China, directly interfacing with the customer, 'qualifying' the line and making what Muñoz describes as an "outstanding" contribution to scrap reduction.

Navascués' role is about maximising the performance of the PCR machines which run 360 days a year. She and her team know to the nearest Euro how much revenue is lost when a machine loses efficiency. The process is a complex one and she takes a magnifying glass to its many variables in the endless quest for optimal operation.

Changing a product on the line used to take two hours. Now it takes 30 minutes. She and the maintenance team remain ambitious. For example, they think they can tease another 25% out of the time it takes to clean the machine. "It is like a Formula One operation," she says, "performing as many operations as we can while the machine is running, with only a few left for when the machine is turned off."

What Ana Navascués and team achieve in Tudela is imparted to the Xiamen team but the new line has provided an unexpected boost to best practice at home. The PCR machines in the Tudela plant are up to 16 years old. The machines in Xiamen are barely a year old and state-of-the-art. "The two lines double the data, double the experience and double the learning," she says. "My colleague Arantxa and her Xiamen colleagues have a lot of fresh ideas. We all learn from each other."

Sarries agrees: "Xiamen practices the 6S [Safety, Sort, Set in order, Shine, Standardise, and Sustain Lean Manufacturing] tool to a very high standard. That made us look at how we do that in Tudela with new eyes. Wherever it originates, best practice becomes our practice."

Warming to this theme, Arellano loves his Chinese colleagues' endless curiosity: "'Why? Why? Why?' It makes us think again about why we do things in certain ways." After the intensity of the transfer peaked, he has been able to stand back and review established processes. It's a classic approach to continuous improvement: never rest on your laurels. Productivity is very good in Xiamen but there is always more to learn. "It takes years to acquire high mastery of the PCR process," Arellano confirms. Root cause analysis and corrective action tools are practiced in Xiamen increasingly effectively, boosted by the Meggitt Production System, the first phase of which the entire Xiamen factory has completed successfully.

Daniel Vega, an industrial engineer with 10 years' international plant and project management behind him, is based at the Xiamen plant and is at the centre of the Xiamen/Tudela nexus. Like Sarries, he has focused on creating a team capable of solving problems. There is backup in Tudela but key decisions must be taken on the ground. He is delighted to see the confidence of Xiamen staff grow as they consult their opposite numbers in Tudela directly. "The young team wants to learn and they learn very fast," he says.

Vega was intrigued by the Tudela/Xiamen integration challenge. "You have cost, timing and project goals—that's standard." What wasn't standard was the integration of a young Chinese team and relatively mature Spanish workforce.

Top: Anabel Sarriés uses visual inspection tools

Bottom: **Through the magnifying glass**: A x2 ampliier is used to check the position of screen-printed resistors on a printed circuit board. A team inspects close to 2,000 PCBs per day—about 20,000 single circuits. No artificial vision cameras capable of addressing the multiple dimensions of many different circuits on these products are yet available.

Initial concerns about the transfer of jobs disappeared as capacity in Tudela increased. "The reality is that both factories continue to work 360 days a year," says Vega, "and the experience and warmth of the Tudela people really paid dividends when it came to reassuring the Xiamen operators that mistakes are a valuable part of the learning process."

Sarries explains: "In the early days, I think the automotive quality standard must have been quite a surprise and so they would have found our management system very demanding."

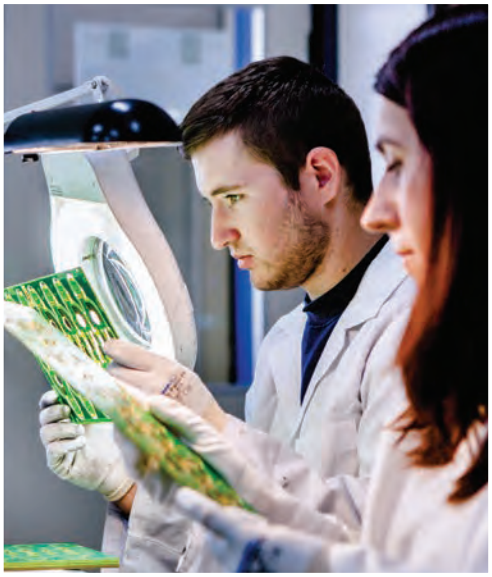
East meets West

Cultural differences between East and West are overstated in Vega's view. "We all face the same issues. We talk about our managers, buying houses, cars, our families—and even more important, football."

Vega rolls up his sleeves, working alongside the operating teams, just like Sarries, Navascués and Sánchez, wherever and whenever needed. That example is much appreciated by the Xiamen team. It is an expression of commitment that generates the personal trust so valued in Chinese society.

The big lesson he would like to pass on to any manager starting out in China is: "In every project, you have to stand back and exert the right pressure at the right moment. However, the Chinese put a very high premium on relationships. If you lead by example—which you should in any country and culture—and you are fully engaged in the activities of your team, you will succeed. If you try to manage at a distance, you will fail. That requirement for mutual respect is very pronounced here."

Jesús Martinez thinks he can triple the PCR business within a ten-year plan that will see persistent high double-digit sales. "The demand in China is there for all the world to see," he says, "and we have proved



that we have the management capability and engineering expertise to meet it."

Rafael Fernandez-Ladreda, Piher's managing director, concludes: "Today, Meggitt can respond at speed and with greater insight to the needs of Chinese business. We are doing it in the same time zone, in the same language and, most significantly, with a superior level of indigenous expertise. There's wider access to bids and new projects for which we are growing a design and engineering capability as well as production at our Xiamen plant."

What excites him most, however, is that this is not a low-cost labour project. "It is about the establishment of a truly integrated international team, where our printed PCB resistor lines are distinguished simply by numeric reference, not location."

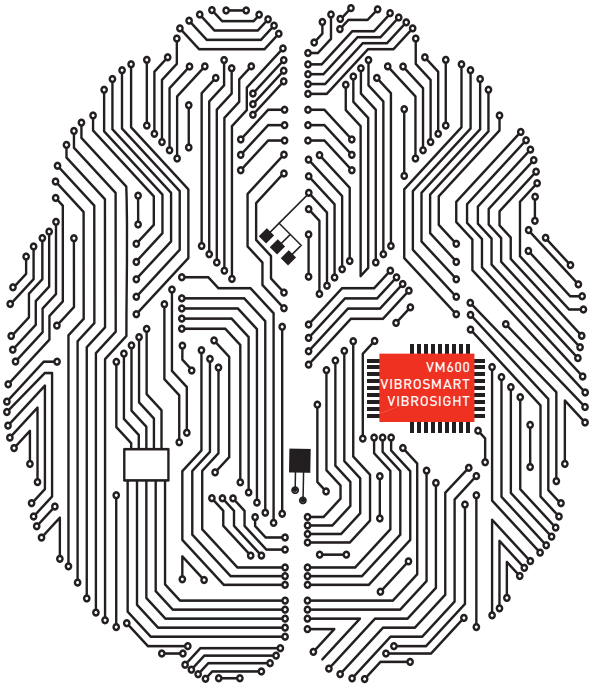
He is proud of the way his management team has created a new Meggitt model for Xiamen, the very model of high tech, high value capability in China, for China. ●

Top middle: Machinist, Sergio Baigorri, screen printing.

Top right: Operators Ezequiel Aguado and Natalia Garijo inspect a printed circuit resistor

Middle: L-R: Ana Navascués and Arancha Sánchez monitor screen printing parameters

Bottom: L-R: Jesus Martínez, Commercial Director and Gonzalo Muñoz, Operations & Procurement Director, in a weekly operating review.



Industrialising genius

An Integrated Product Team (IPT) within the Meggitt matrix has accelerated VibroSight's entry to market and enabled Meggitt Sensing Systems to deliver smart features that will excite the competition, says IPT Director, Andrew Hubbard (below).

An applications specialist in vibration, with a background in test environments, Andrew Hubbard knows what the inside of a power plant looks like – hundreds of them actually, in over 50 countries. He's lost count of taking first flights from one side of the world to another at short notice, armed only with a briefcase to "mend" a turbine that has failed, or is about to fail, his appearance somewhat akin to the Second Coming as he delivers a plant from the consequences of failing to provide critical power supplies to local populations—and businesses from taking catastrophic economic hits.

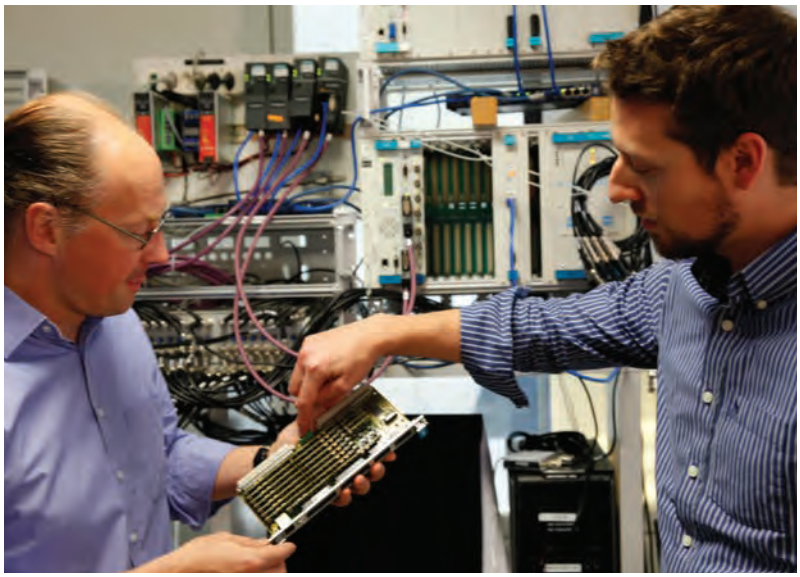
Now he is applying his talents to industrialising genius—sharing his hard-earned knowledge of what operators want, with the engineers and programmers who created the core of VibroSight, Meggitt's next generation condition-based maintenance tool for rotating machinery.

Lost generation

When introducing any condition-monitoring product to the energy market, there is much at stake, Hubbard reminds us. If Meggitt equipment were to provide incorrect data, the implications could be disastrous from a financial and safety perspective. "For example, the cost of lost power generation is about $0.75 million per day for a 660MW turbine. At its worst—on the combustion side, say—a turbine could explode if the air/fuel mix is wrong. That is why there is no room for functional silos diffusing the sense of responsibility that must be top of mind when developing products for this market. In a matrix organisation like Meggitt, an Integrated Product Team sharpens this focus—and it is where the buck stops."

Second breath

"What's more, when a product nears completion, an application-led IPT can really rejuvenate a programme," he enthuses. "It enables you to lift your gaze from the bench to the plant and gives you the agility you need to fine-tune the product for end-users." One of the division's major customers has been delighted with Meggitt's response to its requirement for direct data technology. Hubbard explains: "VibroSight provides the operator with a snapshot of turbine behaviour at regular intervals. However, if anomalies are detected, our system will now continuously store data—like turning on a tape recorder." It's a fine example of customer collaboration within the IPT structure and the ability of the multidisciplinary team to respond quickly to a last-minute specification from the customer. It has also resulted in a specification that is separating the Meggitt product from the common herd.



Left: Cyril Pellaton, Software Team Leader, Energy products evaluating and testing firmware for VibroSmart distributed monitoring software modules in Fribourg's test laboratory using real data.

Below left: L-R: Hans Claudius Reiss, Applications engineering manager and Stefano Trono, Project Manager (Energy), Strategy, Sales & Marketing preparing tests on the centralized VM600 monitoring system before installation on a large gas turbine. Meggitt is one of the few companies providing combined vibration and combustion monitoring solutions for powerplants.

Below right: Sylvain Queloz, Energy Systems Engineering Manager, working on the rotor kit on which a range of Meggitt sensors are installed to provide realistic signals for machinery monitoring systems evaluation.

The IPT has also enabled the team to think quickly about the ways VibroSight can help customers use the vast amounts of data that are being gathered as a result of exponential growth in computing power. Hubbard and team are also looking at how they can expand the limits of their core expertise. "Meggitt Sensing Systems does combustion monitoring very successfully, so now it's a question of asking what other parameters we need to understand that would help an end-user understand even more about their engines. We might correlate other parameters with events such as changes in temperature, vibration and pressure. Then maybe we could predict the flow characteristics and be part of a control loop that could lead to a change in the air/fuel mix based on those parameters."

On the combustion side, say—a turbine could explode if the air/fuel mix is wrong

Speed to market will always be important in the world of high technology, whatever the application. The energy market, however, has additional complications. Turbine stress as a result of thermal cycles is becoming more common as renewable energy sources are integrated with traditional power generators. Hubbard explains: "When a wind turbine stops turning, a gas turbine has to kick in. Our systems now have to address periodical changes between reliability and availability." Furthermore, responding effectively to the customer assumes additional importance with engine manufacturers pushing for ever-higher levels of servicing and maintenance. "Again, as a result of the IPT, we have the tools that will enable us to carry out prognostics to cater for the effects of this step-change in 'mix' that was not so evident in the early R & D stages." [see Box page 82]

Common sensing

Despite management training, Hubbard retains the sense he was born with, perhaps because his formative years were spent as an apprentice with GEC gas turbines

(now Alstom). "There's nothing better than having someone on the opposite side of a desk to you to sort things out. The IPT is

You can promise the world if you're not the one that's got to produce it

all together on one floor and everybody shares. For example, when the software developers have a product or a feature to show, they demonstrate it to the whole team in a test area."

He explains: "We can say, 'That's not exactly what we envisioned' or 'Now we've seen that, we'd like this.' It's a sanity check through which we can review the specification in the light of a visualisation and it gives software developers in particular an invaluable opportunity to really tune into the application."

A common theme of the effectiveness of the IPT is about responding convincingly to customers' requirements. "You can promise the world if you're not the one that's got to produce it. But we can provide customers with plans from the IPT's dedicated product manager and engineering team so they know that promise will be kept."

Good collaborative practices always find their way, like a river finding its course, into the mainstream

Following the success of the VibroSight IPT, the majority of Meggitt Sensing Systems' energy-oriented R&D projects are taking this approach, ensuring there are no silos and everyone works to a common end.

BUT THE END IS NOT THE END. Hubbard knows that when an IPT disbands after a product is successfully taken to market or has completed its evolution, good collaborative practices always find their way, like a river finding its course, into the mainstream.

STOP PRESS

Andrew Hubbard is now directing customer support and product management for the division's entire energy portfolio, using IPT best practice to eliminate silos and assert the primacy of customer need when directing the efforts of applied engineering integrated with product management. Hubbard will continue to apply Meggitt's global programme lifecycle management tool to provide cradle-to-grave responsibility for the energy product portfolio.

Knowledge really is power

When the margin of profit within a power supply contract can range between less than a single dollar and thousands of dollars per megawatt hour, plant managers need superior data on which to make decisions about the criticality of maintenance downtime. That's where VibroSight comes in, extending the return on investment beyond the basic machinery protection mechanisms required by regulators to the advanced condition-monitoring capabilities that attract the attention of accountants as well as engineers. *Andrew Hubbard writes:*

The role of plant managers varies across countries and regions but essentially they all are paid to provide energy—*on demand*.

Place your bets

Power plants bid for slots on the grid and agree a fixed price. If there is demand above and beyond what is agreed, serious money can be made—the rate charged can be very much higher. Taking advantage of the peak requires round-the-clock availability, which requires a dexterous maintenance regime.

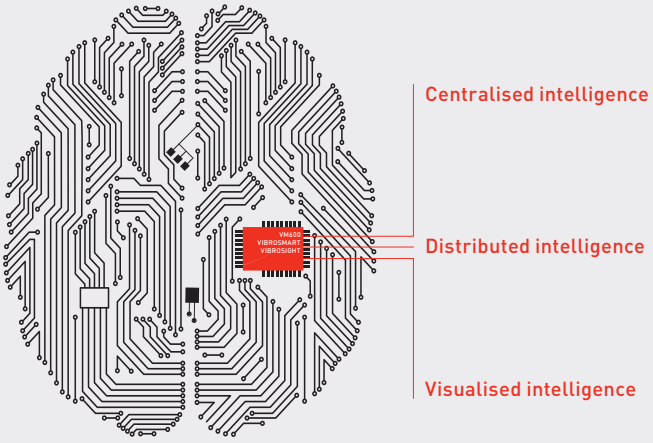
Maintenance planning is important for all electrical and mechanical plant. However, there are differences depending on type and operating regime.

Nuclear power plants are designed to run steadily and efficiently for years. Shutdowns are planned for years ahead, largely due to safety constraints and the nature of the technology, which requires slow and deliberate maintenance and replacement processes. The critical success factor for such plants is *reliability*.

Fossil-fuelled power plants, which supply the major share of grid requirements, are the subject of multiple turbine start-ups based on responding to demand variations. This exposes the components to more thermal cycles, which increases the risk of failure and consequently the requirement for ongoing component maintenance. The critical success factor for these plants is *availability*. For the plant to be viable, power must be readily available, especially during peaks—cold snaps, heat waves, kettles boiling at half-time during major sporting events all spike demand—despite the impact of thermal cycling on equipment condition.

Break your plant or break your business?

This is the backdrop against which a power plant manager will be making decisions about committing to fuel supply contracts where he might have to drive his plant hard to avoid significant financial penalties. The power plant manager has to make a careful risk management assessment, reconciling the commercial requirements of the owners with legal and civic requirements, safety factors and the long-term health of the plant.



Data to decision

If the plant manager does not have all the appropriate inputs—availability of spares and personnel, emissions limitations, financial data and, of course, very precise and wide-ranging information on plant condition, he cannot make an optimal decision. Plant managers work with engine-makers and other OEMs to establish a maintenance strategy. Meggitt's rack-based (VM600) and distributed (VibroSmart) condition-monitoring systems provide plant engineers with information on actual performance, not only to protect plant (shutting down key equipment to prevent catastrophic damage) but to establish various scenarios for its continued operation. The plant manager and his experts put the results of prognostic analysis into the decision tree.

If a condition-monitoring strategy is applied correctly, it will help a plant manager and his team assess the optimum equipment and method and estimate the period between outages. Given that protecting valuable rotating assets is of primary concern, prognostics help when making decisions about keeping plant or a piece of equipment running until downtime (or an outage) becomes convenient.

Running on empty

A nuclear power plant had been operating for almost two years and a vibration trend had become evident over the past two months. An outage had been planned for two months ahead and the simple question was: could they make it?

The trend in vibration indicated an increase in the first harmonic component of the signal. If the overall trend continued, vibration levels could damage the plant.

The power plant management considered its options.

1. Continue doing nothing until the machinery was in danger of damage

OR

2. Control the vibration by setting the reactive power at its optimal level to reduce the vibration (incurring cost as some flexibility is lost)

OR

3. Reduce load (incurring costs in lost power, risks to the reactor and loss of efficiency—preferable to a complete shut-down)

OR

4. Shut down and carry out a temporary fix (a rotor balancing exercise that would not wholly address the root cause. There would be one to two days of lost power, risk that it wouldn't work well enough or be detrimental to the reactor or the rotor line)

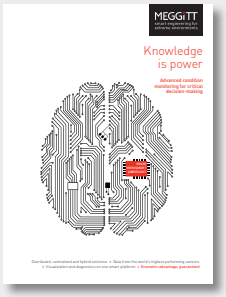
OR

5. Bring the outage forward (stopping power production, failing to meet the contract and incurring knock-on effects to other plant and even other stations).

The first two options were the preferred strategy and the plant reached the planned outage without incurring additional costs. However, plans were put in place to react quickly to an opportunity to carry out a rotor balancing exercise if necessary.

In this real example, none of this would been possible without prognostics derived from a sophisticated condition-monitoring system.

Download the Meggitt Sensing Systems' VibroSmart/VibroSight brochure www.meggitt.com/latestproductliterature



Stretching the boundaries of possibility.

Forget everything you thought you knew about stamping and etching: Precision Micro's photochemical etching process is cutting edge in every sense of the word. Ultra-precise and cost-effective, the technology enables the production of super-fine, stress and burr-free components capable of withstanding extreme temperatures and is rapidly becoming part of forward-thinking engineers' repertoires where previously they would have used traditional metal machining processes. We find out why the process is being used by everyone from satellite engineers to the military and how it could transform every aspect of component production.

F1 teams have come to depend on the innovative approach and speed of service that Precision Micro provides.

The management team at Precision Micro is fizzing with excitement. Mention the potential uses of the company's techniques and their eyes positively gleam. On a mission to tell the world about their techniques, the only thing that dampens their mood is the thought that other people don't know what they do.

What they do is photochemical etching. Also known as chemical machining, it enables the production of bespoke, high-precision metal components with ultra-fine etched apertures and surface features.

Originally a family business, it was acquired by Meggitt in 2012 to secure the side of its business that supplied etched heat exchanger plates to Heatric, Meggitt's heat transfer engineering business dedicated to energy markets, based in Poole, UK.

IT'S NO SURPRISE THAT IT HAS SETTLED IN WELL with its new family: its process is very much in the Meggitt spirit. It involves precision and accuracy and produces components that can withstand extreme environments—and at startling volumes: Precision Micro produces more than 50 million components per year. Mick Taylor, Commercial Director, describes it as "precision on a grand scale."

In keeping with the Meggitt tradition, Precision Micro is involved in ground-breaking techniques. It was the first company in the industry to use laser direct imaging in photo etching and it is always looking for ways to innovate and develop. Research and development is an essential part of its business model.

Precision Micro has worked hard to establish itself as Europe's leading photo etching company.

The challenge in taking the business forward is that, as Taylor says, photo etching is "not part of most engineers' repertoire"—many design engineers are simply not aware of it. This is surprising for a process that has so many advantages over traditional manufacturing methods.

Despite the high quality of the components it produces, the process is

deceptively inexpensive, especially when low to mid volumes are involved. Whereas stamping can make economic sense when producing large numbers of components, the cost of tooling can make it unviable for a short run. Precision Micro is ideal for low volume components as it might charge as little as £100 to create the template for a new design.

If the component is a complex one, photo etching really comes into its own, particularly where feature density is high. As features are produced simultaneously, it is no more expensive to create a complicated design than a simple one.

It is also quick. It can take many months to build and debug a stamping tool, whereas a CAD-designed photo tool can be created in under an hour. When one client, Highland Biosciences, needed parts for testing at a sub-contractor, for example, the process was started on a Monday morning, the parts were manufactured, with a full dimensional inspection report, and hand-delivered on the afternoon flight from Birmingham to Barcelona for delivery to the sub-contractor that evening.

Photo etching is incredibly flexible. Almost any metal—even high performance and proprietary alloys—can be photo etched. The components can be formed, plated or electro-polished in-house and photo etching can be combined with other techniques such as LEEF and wire EDM.

Perhaps the greatest advantage, however, is the nature of the process itself. The temperature to which the metal sheets are exposed has no effect on the properties of that metal. What's more, it produces components that are stress-free and burr-free—a huge improvement on other, more traditional, processes. As Taylor says, "It has all the strengths and none of the weaknesses of other processes."

Word is starting to get around and Precision Micro has secured a number of major long-term contracts with original equipment manufacturers, notably in the automotive industry. A five-year contract with Continental has seen Precision Micro making millions of springs for ABS systems, whose life cycle is increased by the fact that no stresses are added by stamping or laser cutting.

Anyone driving a small car is likely to benefit from Precision Micro's technology, too: it etches a flexure to control the flow of fuel and a sound-dampening spring in a revolutionary fuel pump found in most small car engines, including Fiat, Audi, Ford, GM, Peugeot-Citroën, Renault, Seat, Toyota, VW and Volvo.

Precision Micro has produced plates for fuel cells used to power zero emission vehicles. These plates required complex channels and shapes—traditional tooling for this would have run into many hundreds of thousands of pounds.

Precision Micro has even ventured into the high performance world of Formula 1. In the 2009 season when the KERS (kinetic energy recovery system—a forerunner of hybrid power) was used for the first time, Precision Micro worked with an F1 engine manufacturer to provide components for its high performance engines. Before Precision Micro got involved, KERS had been dogged with problems: stories abounded of cars catching fire and people getting electric shocks from the cars. Reliability was more important than ever. "We were part of a very select group of key suppliers," says Taylor.

Gratifyingly, with Precision Micro on board, not only were there no further problems, but it was so successful that Precision Micro continues to provide components for that engine.

"The F1 engineer is working to the very extreme of engineering and technology," says Taylor. "He knows when he selects a particular grade of material in a particular condition that after we've processed it those mechanical characteristics will still apply. We don't adjust them, we don't introduce any stress, we don't take it through any sort of significant thermal cycle, so he can design with confidence."

> The type of work we do is unlimited. If you are using conventional machining methods, you need to consider our technologies

All these factors make it especially suitable for extreme conditions, and they don't come more extreme than space—a field that Marcus Heather, Director of Operations and Engineering, describes as "even more risk-averse than aerospace".

So it was that Precision Micro became involved in a partnership with a cryogenics manufacturer to produce a diaphragm spring for a satellite's cryogenic cooler. The metal was, according to Taylor, "a very high performance material that's very difficult to process in conventional ways."

"Because the flexure vibrates at a high speed and in extreme environments, any profile imperfections such as recast layer or heat affected zones could lead to fatigue failure," adds Heather. "It needed a process that didn't change the material's properties. It was going into a satellite so it needed to last. We had to guarantee complete perfection."

Indeed, the manufacturer had tried other, more traditional, processing such as wire EDM and laser cutting—and even photo etching with one of Precision Micro's competitors—before Precision Micro came up with a robust solution. They collaborated

SPEED READ

Precision on a grand scale
Acquired by Meggitt in 2012, Precision Micro uses photochemical etching to produce bespoke, high-precision metal components. It also combines photo etching with other processes such as wire EDM and Laser Evolved Electroforming.

Trends with benefits
The advantages of chemical etching over more traditional methods such as stamping and laser cutting are its low cost, high speed, flexibility, suitability for complex designs and, most important, burr-free components whose mechanical properties have not been changed by heat or stress.

Extremely good
The nature of the etching process makes Precision Micro's components particularly suited for use in extreme environments and have been used in space, aerospace, defence, automotive (including Formula 1) and medical devices.

Research pioneers
Precision Micro's processes often involve pioneering research and its engineers are frequently involved at the design stage, collaborating with customers and exploring new ideas and technology.

Etch-a-sketch
Prototypes are quick and inexpensive to create so you can experiment with designs. Precision Micro is eager to hear from Meggitt design engineers to find solutions to their technological challenges. It can arrange WebEx seminars and provide sample packs.

Photo opportunities
Precision Micro aims to double in size in five years and has plans to expand nationally, overseas, within the Meggitt group and at the cutting edge of technology.

UAV helicopter

The pocket size UAV, features miniature motor laminations which uses the photo-resist protecting the material surface during photochemical etching as the bonding agent. This novel approach offers improved performance versus conventional punched, riveted or welded laminations.

Flexure springs for cryogenic cooler

Flexures made using photochemical etching retain their properties even after many years of continuous operation, essential to the reliability and system life-time of high-sensitivity sensor systems used in space.

with the engineers until they had produced components that were sufficiently precise and reliable to be used in space.

Space engineering is not alone in making exceptionally high demands. The battlefield—another extreme environment—is an additional frontier where Precision Micro has been making its mark, producing components for a UAV micro-helicopter that can be sent around corners and into buildings on reconnaissance, reducing the danger to soldiers. An aircraft weighing little more than an AA battery presents an aerodynamic challenge. Any inconsistency will affect the balance so precision is essential.

"We etch the metal component shape from a design," explains Heather. "That component goes for screen printing and is then assembled in a plastic capsule that has to be sealed and separated from the environment so that it is medically clean."

The component could not be produced without photo etching, Heather explains. "This product cannot be stamped—we cannot use competing technology. It has to be chemically etched to protect the properties of the metal—any other processes potentially change the structure of the metal. If you stamped the product, stamping might introduce mechanical stresses and burrs. Laser cutting will also thermally affect the material properties. If the structure of the metal changes, the device can't be consistent and it won't work in the market place."

Equally revolutionary is Precision Micro's work with a global medical device manufacturer, for which it has developed a process for a bone-cutting saw blade for hip and knee replacement surgery.

The manufacturer had been getting the first stage etched by a competitor in the US before sending the components away to get the bone-cutting element laser cut and then bringing them back to be ground and polished. This was expensive and involved a number of different companies.

Precision Micro was able to offer a one-stop shop, halving the number of processes. With some development it was able to etch the first and second profiles before using a wire EDM machine to cut the teeth and then polishing the component ready for use.

HEATHER IS PROUD OF THIS PROJECT. It is, he says, a classic example of the Precision Micro ethos. "We're a lot more than just etching a sheet of metal. We're offering an intelligent, entrepreneurial, alternative solution to whatever customer works with us. They get the part quicker. They get better quality and it's more cost-effective."

As for the future, the firm has invested in a titanium etching capability. A dedicated facility was commissioned in early 2015, a development driven by a partnership with the world's leading provider of lithography systems for the semiconductor industry, for which Precision Micro makes cooling plates. Precision Micro is now the first plant in Europe to etch titanium on a production scale.

It is just this kind of project that leads the Precision Micro team to believe that there are many other potential applications for photo etching. It is already making heating elements for Meggitt Polymers & Composites' ice protection systems and the team is keen to take the business further

If the component is a complex one, photo etching really comes into its own, particularly where feature density is high. As features are produced simultaneously, it is no more expensive to create a complicated design than a simple one

The company's willingness to work alongside other partners and to participate in cutting edge research has led it into medical applications, too. It has been involved in the government's Technology Strategy Board consortium group, developing a completely new product for the medical market, designed by a start-up company, Highland Biosciences. This product will measure endotoxins (potentially fatal toxins produced when bacteria are killed) in blood or other liquids, which hitherto have only measured by a complicated and long-winded procedure.

within the group.

Meggitt's Chief Technology Officer, Keith Jackson, talks enthusiastically about the company's potential within Meggitt and believes that the business's use of additive technology could take it into new internal markets. This technology, which involves taking plates, etching them with channels and surface features and stacking and bonding them, enables the creation of channels and unique, lightweight structures that are especially suited for cooling by passing air or liquid through them.

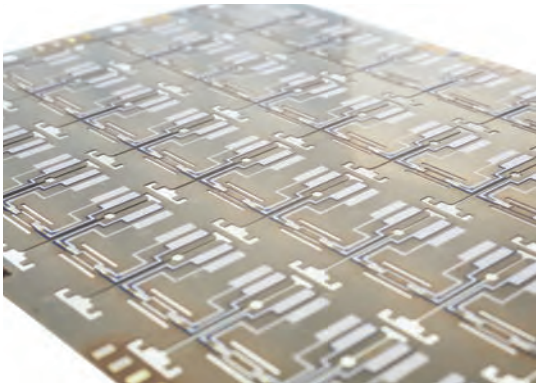
"They can build hollow structures such as coolers that are curved to fit the environment. They can produce very complicated heating, minimising joins and interconnects in composite structures. In time, conductors can be embedded for power, data, sensing and actuation allowing the construction of truly smart structures like a composite aircraft surfaces with heating and structural health monitoring features.

Jackson is excited by the potential for making sensors in Precision Micro's creation of spring devices measuring movement. "I have wondered whether using the etching process would be a way of opening up more variety in developing the levers in vibration sensors or energy harvesting devices," he says. "An energy harvesting device tends to only work around the same frequency. If you have more complex levers, you could have something that resonates at different frequencies."

The message to the rest of the Meggitt group is clear. "The type of work we do is unlimited," says Taylor. "If you are using conventional machining methods, you need to consider our technologies."

This 82mm squared mesh, manufactured in nickel using the LEEF process, is used in mass spectrometry. Featuring a 90% open area, each 18µ strand would reach 37 metres in length if placed end to end.

By diffusion bonding chemically etched plates, Precision Micro's engineers can create complex pipes and channels in a wide range of metals, including high temperature alloys.



Precision Micro and fellow Meggitt Equipment Group business, Piher Sensors & Controls, are collaborating in the production of a revolutionary new biosensor for medical device start-up Highland Biosciences.

The bigger picture

Precision Micro is thinking big. With a sales programme that will include seminars, trade shows, branding exercises and social media campaigns, Rafael Fernandez-Ladreda, who also runs Piher Sensors & Controls, Meggitt's positions and controls designer and manufacturer headquartered in northern Spain, aims to double the business in the next five years. "The market is waiting to explode," he says.

His expansion plans include consolidating other, smaller businesses in a market dominated by fragmented, family-owned SMEs and growing Precision Micro's share of international markets.

The association with Piher has advantages for both parties. Piher will, says Fernandez-Ladreda, benefit from Precision Micro's chemical expertise (he would love, for example, to find a way to clean and activate copper so that it could replace gold in Piher's printed circuit resistors) as well as its IT know-how. In turn, Precision Micro can learn from Piher's knowledge of electronics.

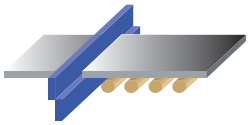
The two companies have much to offer each other in terms of economies of scale in the form of shared resources such as licences, data collection, and warehouse and exhibition space, as well as sales networks.

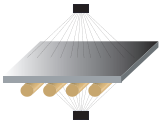
Continuous improvement will come to both enterprises with the deployment of the Meggitt Production System and, hand in hand with this, greater automation of Precision Micro's process.

More widely, Fernandez-Ladreda is quick to acknowledge the benefit of being under the Meggitt umbrella. "Big corporations don't want to do business with small independents. Belonging to Meggitt gives Precision Micro an advantage over its competitors," he says. "We are respectable—you can introduce us to your mother."

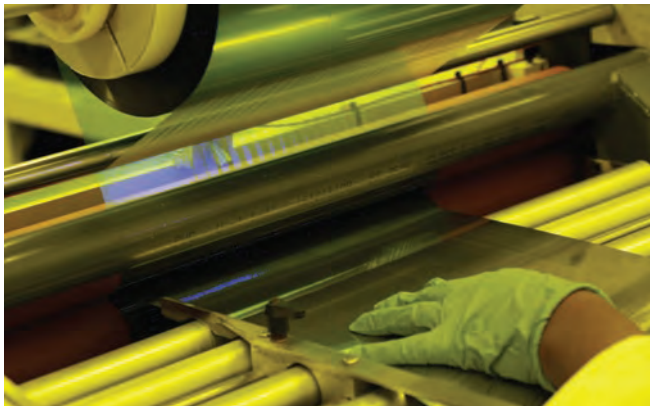
The etching process

1 Technical Manager, Albert Tsang, and CMM Programmer, Russell Davidson, review customer-supplied CAD data before photo tooling production.

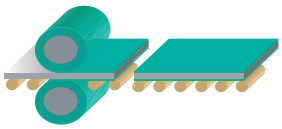


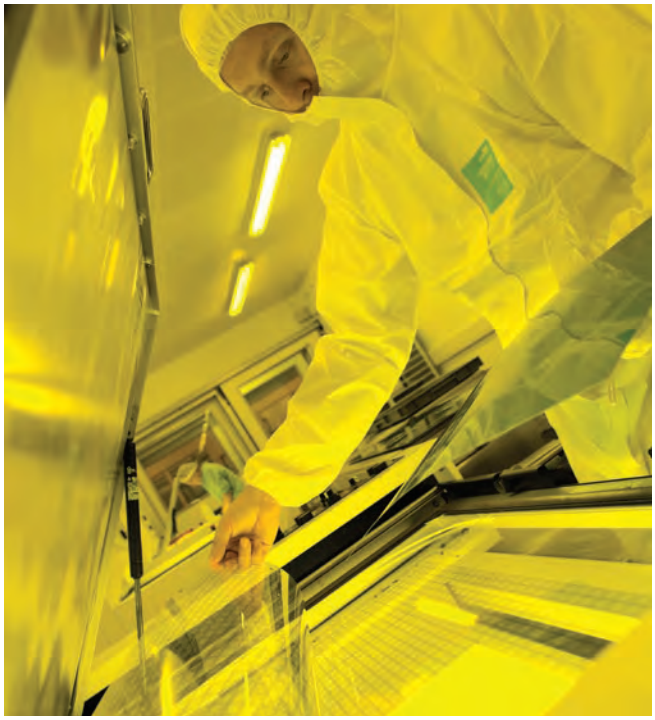


2 Team leader, Randy Russell, loads pre-cut raw metal sheets into the ferrous cleaning line, where contaminants are removed.

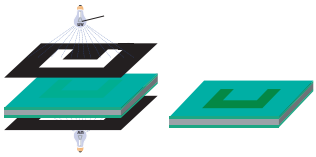


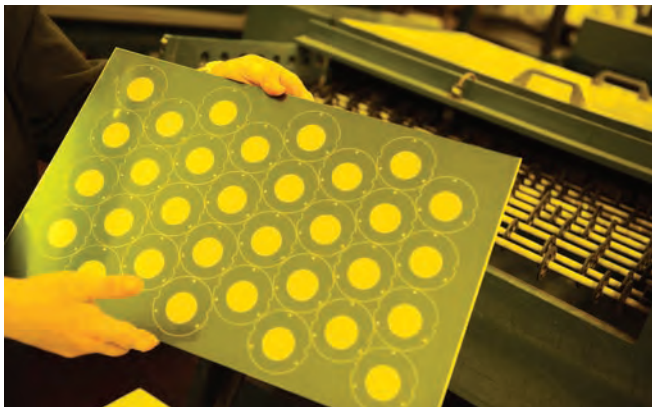
3 The material is transferred to Precision Micro's class 10,000 clean room where it is laminated between two layers of photo-sensitive polymer.



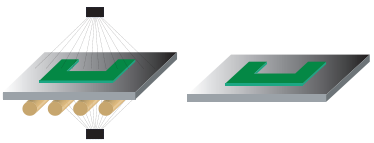


▲ **4** Using the photo tool as a mask, the material is exposed to UV light which leaves the design pattern hardened into the acid-resistant surface.

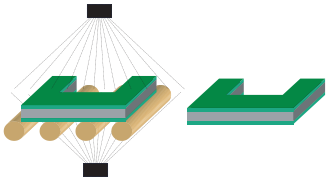


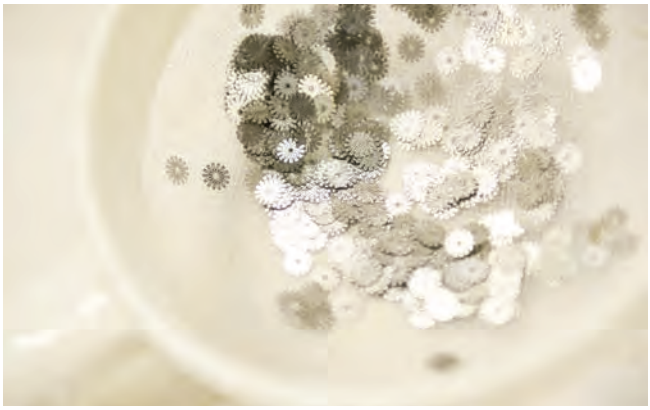


▲ **5** The developing process washes any unexposed laminate from the sheet to expose the raw metal ready for etching.

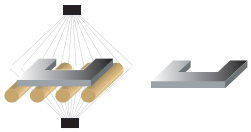


▲ **6** Etch room manager, Neil Jennings, removes etched sheets from one of 10 conveyorised etching lines.





▲ **7** The remaining protective laminate is removed to expose the finished components. The products shown are supplied to F1 teams and are used for high performance sealing applications.



▲ **8** Components are automatically visually and dimensionally inspected before despatch. The flat springs shown in the image form an integral part of a fuel pump and make more than one billion cycles over the course of their lives.

▲ **9** Precision Micro offers in-house forming, wire EDM, plating, machining, electro-polishing and bonding, which facilitates additive layer products such as compact and shaped heat exchangers.

Group aftermarket services prepares for take-off

Mirroring Meggitt's *Transformation* approach to original equipment manufacturers in 2009 when the industry was moving into a big product and platform development cycle, now Meggitt's aftermarket customers will come to enjoy a streamlined interface. A new aftermarket-dedicated organisation was launched in May with one aim: "to create fantastic service throughout the service life of our products so our airline customers can do what they are good at—fly aeroplanes," says Chief Operating Officer, Dave Johnson.

In line with Group strategic business priorities as set out by Chief Executive Stephen Young in January, May saw the launch of an integrated Meggitt aftermarket organisation—Meggitt Customer Services & Support (CSS)—led by executive operating board director, Lorraine Rienecker.

Dedicated aftermarket centres acquired as part of the Pacific Aerospace acquisition—Miami, Simi Valley and Louisville, USA, Kassel, Germany and Maidenhead, UK—became CSS businesses. Meggitt Aerospace Asia Pacific, which represents virtually every Meggitt capability in terms of maintenance repair and overhaul or spares distribution became a CSS regional hub.

The new global operating model is needed to respond to the increasingly dynamic market for spares and repairs. Airlines are outsourcing aftermarket services and new players are entering.

> We can leverage our intellectual property in new ways—applying our intimate knowledge of product performance to maximise time on wing

Brokerage has come to the fore. Original equipment manufacturers continue to invest in their own service programmes and independent service providers alike are investing to capture their share.

"This means plenty of opportunity for a smart team to make its mark," says Rienecker. "And the way to do that is to run our aftermarket businesses as one organisation with dedicated management in *One Meggitt* mode."

The aim of the new organisation is to simplify the interface between Meggitt and its aftermarket customers, coordinating the efforts of sales and marketing personnel more effectively. Metrics will be established for all Meggitt aftermarket operations to ensure every Meggitt team rises to the standard set by the best and to facilitate a closer feedback loop between customer and provider. To continually improve product and service to the airlines, product performance will be looked at in the context of maintainability as well as length of life, based on rich feedback to business unit and divisional engineering teams.

Taxi-ing

The first phase of CSS implementation will focus on centralising aerospace aftermarket sales and customer support activities "to simplify the group's interface with customers," says Rienecker, who wants to improve day-to-day service as well as establish an 'innovation loop'. "Our sales teams should become so close to customers that invaluable data on performance can be fed back to engineering design teams and fixes built into design iterations for upgrades, retrofits and even brand new developments," she explains.

"As the OEM, we have built-in competitive advantage. For example, customers want to keep their parts on wing for as long as possible and with our teams of outstanding product designers, we are extremely well-placed to redesign for longer-life retrofit. That's why our new aftermarket organisation will be focusing more than ever on data capture and trend

analysis, applying our intimate knowledge of product performance to maximise time on wing."

She is keen to highlight the opportunities for growth that are inherent to Meggitt's extensive product portfolio. "If individual divisional relationships are shared across the group and we leverage our intellectual property in new ways, we can become easier to do business with and help our customers bring the cost of fleet management down."

Standing by

The second phase of implementation will focus on delivering greater value from spares distribution and, with divisional presidents and operations directors, optimising existing maintenance, repair and overhaul facilities ready for the growth in business that will arise following more focused marketing.

This will be underpinned by the Meggitt Production System which will make fast and efficient service as much a competitive advantage in aftermarket centres as it is for those facilities concerned with the industrialisation of product for original equipment manufacturers. "There are many outstanding aftermarket teams at Meggitt but the competition is becoming stronger and airlines are having a greater influence over their supply chain. Meggitt's original equipment customers—the airframers and engine-makers—want to partner with suppliers who can deliver. MPS will ensure we standardise at the highest level across the group so there are no weak links," Rienecker explains.

The crew

Adrian Plevin is responsible for strengthening Meggitt's global aftermarket sales team across the group's key centres in the Americas, EMEA and Asia. After successfully building group aftermarket operations in Asia (Meggitt Aerospace Asia Pacific) over the past six years, growing revenues to over SGD$40 million, he spearheaded the Meggitt Production System deployment with Director of Operations & CI, James Mariadass to polish the strong service and performance ethos established there. Before that, Plevin accumulated over 10 years' experience in customer development at Meggitt Aircraft Braking Systems and Dunlop Aerospace.

Amy Merkley is responsible for the cost, quality and speed of delivery of Meggitt spares and the performance of repair operations. Merkley has a strong track record driving aftermarket performance improvements with more than 20 years' experience in senior operations roles at Honeywell, Eaton and Allied Signal before joining Meggitt where she grew the group's Miami-based aftermarket business by 20% in five years. Merkley takes a hands-on approach to driving continuous improvement in distribution and repair operations and is highly attuned to what is needed for turnaround and other services in this competitive market.

Nigel Woodall is appointed Senior Vice President, Customer Support. Woodall is responsible for managing Meggitt's AOG help centre and developing and implementing the processes, tools, skills and KPIs needed to deploy world-class regional service. In addition, he will ensure close cooperation between divisional engineering teams to improve in-service product performance.

A former aircraft engineering apprentice, Woodall's early training in line and heavy maintenance activities on airline fleets equipped him with an in-depth understanding of aerospace engineering and civil aircraft operations. This led to technical field service and roles of increasing seniority at Honeywell, encompassing commercial, contracts, sales and product support and, ultimately, regional management of OE and aftermarket sales and support across all Honeywell's aero product lines. He joined Lufthansa Technik (LHT) in Hamburg—the world's largest MRO—in 2009 as General Manager for the UK and Ireland where he represented and grew all support divisions. Nigel has just completed three years as Meggitt Control Systems' VP Aftermarket.

Gloria Jackson, the new CSS Human Resources Director, led the HR function at Meggitt Aftermarket Services in Louisville, Miami, Maidenhead and Kassel after over 28 years at Honeywell, resourcing aftermarket and OE teams in space and defence, including special operations groups.

AFTER SPENDING CLOSE TO A DECADE as Meggitt's EVP of Strategy, Sales & Marketing, Rienecker is enjoying the opportunity to specialise and focus on one market, albeit multi-faceted, with a dedicated team. "In the OE market, programmes can be very long. AM [aftermarket] is much more cyclical and much more event-driven. You can see the results of service improvements and market tactics much more quickly." ●

A shared service with dedicated management in *One Meggitt* mode

Our most extreme environment yet?

Back in 2005, an order of cabling shipped from Meggitt Safety Systems California. Three billion miles later, the first images of Pluto captured by the New Horizons space probe were beaming back to Earth through its wires.

Born out of the need for more robust components following the Three Mile Island nuclear disaster in the 1970s, Meggitt's silicon-dioxide insulated communication cabling can be found on almost every extreme environment platform.

Lightweight and proven in the harshest temperatures, the cables have a Mean Time Between Failure of one million hours—the ideal choice for a three-billion-mile mission to complete man's initial reconnaissance of the Solar System.

Data about Pluto's geology, surface and atmosphere, passing through our cables on its way back to Earth, has so far revealed mountain ranges, glaciers of nitrogen and methane and an atmosphere five times wider than previously thought.

But as only 6% of the data captured has so far been transmitted, scientists are hoping for more discoveries, particularly if the probe succeeds in the second part of its mission: to explore the small icy bodies of the Kuiper Belt, remnants from the Solar System's formation, 4.5 billion years ago.

Beyond that, the fate of the spacecraft is unknown.

Continuing the 'message-in-a-bottle' tradition started by Pioneer 10 and Voyager, New Horizons carries a number of cultural objects to introduce extra-terrestrials to life on Earth. Extraordinary to reflect that 'they' might also learn a little about life at Meggitt.

Formula Student gets us in front of some of the world's smartest young engineers.

A new formula for talent

Competition for the talent Meggitt needs in the 21st century is intense as ever.

Formula Student is the perfect vehicle for getting in front of students at the world's top engineering universities. "You really get to see what the engineers are made of," says Chief Technology Officer Keith Jackson. "Especially when things go wrong ..."

You're 21 and you're back at university. You've got £25k and a team of 35 fellow students, part time. Could you design and manufacture a single-seat racing car that would make it at Silverstone?

That's the challenge Formula Student (Formula SAE in the US) gives to thousands of young engineers from more than 100 universities all over the world.

Cars are judged on speed, acceleration, handling and endurance in a series of time-trial races while teams are tested on design, costing and business knowledge.

"We started sponsoring the University of Sheffield team in 2014," says Jackson, a keen racer himself. "It gets our name as a top graduate choice out into the fast lane. And it helps us get a good look at talent from all over the world."

One ex-'Formula Student' joined the graduate programme last year, another joins this year while others have done internships at MABS, MCS, MPC and Heatric.

Optimise for victory

Big changes to the car in 2014—including a new engine, a redesign of the rear of the vehicle and smaller wheels—took the team up nearly 20 places in the ranking. They would have finished even higher but a missing retaining clip brought them to a standstill in lap four of the endurance race.

"This year," says 2015 Team Principal Thomas Bloomfield, "We focused on optimisation. Additive layer manufacturing played a big part. You can redesign and reprint easily and that means you can adapt fast. When a backfire blew apart the plenum chamber, for example, it only took 48 hours to redesign and reprint."

Overall, the team printed 17 components in titanium and polymers, bringing the weight down by 4kg. And they looked to two other Meggitt specialisms for further optimisation: composites and fire protection.

"Our new composite seat integrates the driver's support and the firewall around it including a state-of-the-art fabric called Nomex," says Bloomfield. "It's used in Formula 1 helmets and can withstand temperatures of 600-800°C."

Cutting-edge technology on trial working with the Advanced Manufacturing Research Centre (AMRC) opened the door to cutting-edge manufacturing techniques such as robotic machining for the car's body panel moulds and sacrificial geometry.

"To help the driver time gear changes more accurately, we wanted to embed an LED engine speed gauge in the steering wheel. So we printed a chain into a wire routing tube which could be pulled out during post processing. That allowed us to remove any loose material and thread the wiring through without difficulty. Using any other technique would have been pretty much impossible."

"Sacrificial geometry is perfect for fitting components required for better engine monitoring," says Rémy Trang, an engineer on the Meggitt graduate programme who studied at Sheffield and has just completed a nine-month placement at the AMRC.

Graduate engineers Thomas Black and Matt Scovell have worked with Trang throughout the year to manage the relationship with the Formula Student team.

"Working with the team is a bit like a multi-player internship," says Keith

Jackson. "It's highly competitive to get on the team and anyone who does comes out much more well-rounded, especially when things go wrong."

Epic adventures on the track

There was no shortage of trouble when the team got to Silverstone for the four-day competition.

"The scrutineering judges were tougher than ever," says Bloomfield. "On day one, the first thing they flagged up was the driver's safety harness. Luckily, we found a local supplier who could turn a tighter one round in 90 minutes. But then things really started to slide."

In spite of passing a paper test weeks before the event, some of the chassis tubes were deemed too thin—by a margin of 0.4mm. The team worked overnight to cut them out and refit. On day two, the steering rack was found to be too high and further problems emerged during the tilt test. Worse was to come.

"After a superhuman effort from the team, we finally got through scrutineering by the end of day two. But early on day three came the noise test. We'd been well under in our own tests but changes to the ratings used in the competition meant the car was six times over the limit!" grimaces Bloomfield.

> With no baffle plates, we filled the exhaust with scouring pads and bolted a mesh over the pipe to stop them flying out

After some furious head scratching, the team came up with an ingenious fix.

"There were no baffle plates available so we filled the exhaust with scouring pads and bolted a mesh over the end of the pipe to stop them flying out. There was a huge cheer from the crowd of friends and family when we got through that one."

With all the fixes, however, time was running out for the remaining tests, let alone the racing events.

"We went down to the wire on the brake test but finally got through on the last run by pumping up the tires to the max, tweaking the suspension and getting our lightest driver behind the wheel."

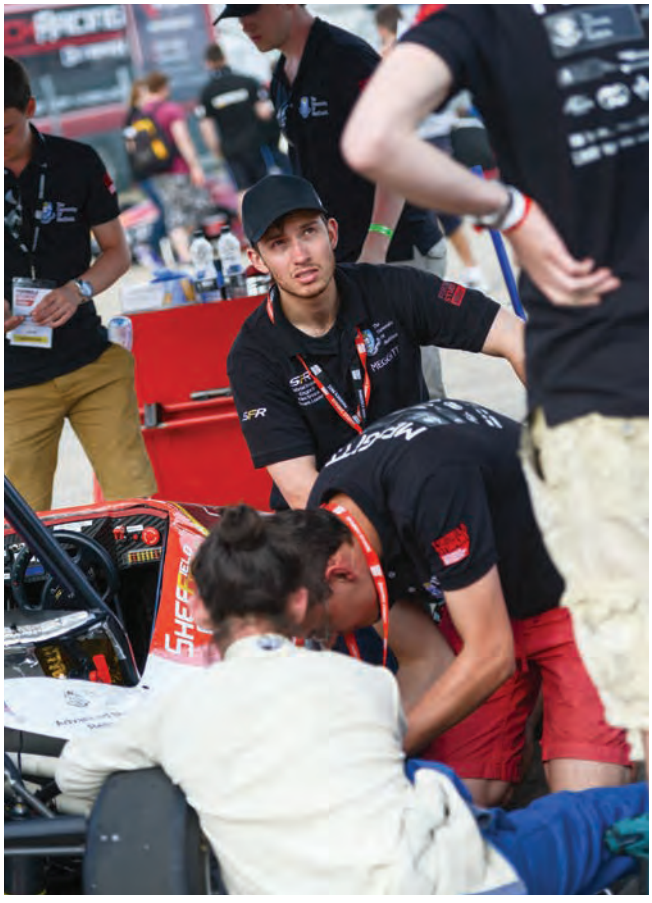
There was no time for the speed event which meant the team had to make up whatever points they could on the 22-lap endurance event.

"I was driving at first," says Bloomfield, "And the car was running beautifully. With each lap completed, we were getting more points, pushing us up the table. I remember thinking if we finish, we could still make it to 30th."

But once again, disaster struck. "After lap 11, I pulled into the pits for the driver changeover. He was all set to go when one of the judges noticed a tiny shimmer of oil on the wet tarmac under the engine. 'Sorry guys,' he said, 'The rules are very strict on leaking fluids. You've got to come off."

The team was devastated. Only half the 100 cars had made it through scrutineering. So to be out on the track and running well in spite of everything, only to be called in for the smallest of leaks was a huge blow. "Our moment of triumph turned into the lowest moment of the weekend," says Bloomfield.

"And yet, when I look back, I feel enormously proud. The team tackled problem after problem, day and night, with ingenuity, guts and good humour. I can't wait to see what they pull off next year."



Exhausted. Noise test showed the car was six times over the limit.

Tired. (Top) Down to the wire on the brake test, getting the lightest driver behind the wheel.

Leaking. (Bottom) Out for a tiny shimmer of oil on the wet tarmac under the engine.

Fast track to a chartered future

Becoming a chartered engineer marks you out as an experienced professional and opens the door to mentoring, networking and further professional development. Thanks to a new partnership with one of the world's leading engineering institutions, Meggitt engineers with the right experience can now qualify fast.

IF YOU WALK INTO A MEETING WITH A GROUP OF ENGINEERS AND THE BUSINESS CARDS GO ROUND, THE ONES WITH A CENG GET MORE AIRTIME, says **Jane Flower**, Principal Project Engineer at Meggitt Aircraft Braking Systems. "Getting chartered really does make a difference."

"I couldn't agree more," says **Steve Pilling**, General Manager at Meggitt Control Systems in Coventry. "I started off as an apprentice and looking back, it feels like I've come up the rock face. It's been tough. With the mentoring I do now as a Fellow of the IMechE, I can see there are easier routes. To qualify as a CEng, you need a sponsor and that means you get the advice and support of a more experienced engineer. A mentor can help you plan the most effective route ahead."

Shortly after qualifying in 2013, Pilling was on a business trip when a colleague said to him, "Now you're a CEng, have you thought about applying to be Director of Engineering?"

"I had to smile. Nothing about me or my experience had changed. But with this external stamp of approval, people saw me in a new light. That's what the CEng does and that's why it's more or less a prerequisite for any senior engineering position at Meggitt."

Yet in spite of this prestige, there are relatively few chartered engineers across the group.

"Up until now, the application process has been time consuming. And that means it often gets left in the in-tray." says Sushma Hayes, Meggitt Group Learning & Development Manager.

Get it done in a day

One-day fast-track application workshops were started in autumn 2014 to help Meggitt's mechanical engineers get chartered more quickly.

"A team from IMechE comes and talks you through the application in a small group so you can get it right first time," says **Hassan Aziz**, Director of Engineering at Meggitt Control Systems. "I originally planned to apply in 1996 but work and family life kept getting in the way. I'm delighted to be fully qualified now."

The first two workshops in Fareham and Coventry have got 11 engineers well on their way to qualifying.

"We ran two more workshops in the UK over the summer and one online for our mechanical engineers in North America, Europe and Asia," says Hayes.

Senior figures are becoming chartered to fly the flag for engineering within Meggitt and in society more widely

"The IMechE qualification is more and more recognised globally. So it's worth qualifying wherever you are."

"A few years ago I completed the application form online," says **Barry Robinson**, Engineering Manager at Meggitt Sensing Systems. "I got the written feedback but never got round to rewriting my application. I went to the workshop and got most of it done in just one day. You get some good advice about the interview too."

Get chartered, get mentoring

Senior figures across the group are becoming chartered to fly the flag for engineering within Meggitt and in society more widely.

"The engineering sector will continue to play a key role economically," says Meggitt's Director of Engineering, **Steve Parker**. "Membership of a professional body raises our profile and gives us a louder voice."

The qualification is also essential for mentors who want to pass on their knowledge and shape the future of engineering at Meggitt by coaching tomorrow's talent.

"I mentor two graduates," says Parker. "Their energy and enthusiasm is infectious and it's a real pleasure to pass on some of what I've learned over the past 35 years. But to mentor the graduates through their qualification as chartered engineers, you need to be one yourself."

> CEng—it's more or less a prerequisite for any senior engineering position at Meggitt

> I've ended up mentoring one of my old mentors through their CEng. It creates a very strong bond

That's the main reason **Simon Mulholland** applied. Having started his career as an apprentice 20 years ago, he worked largely as a contractor until joining MABS in 2013 to manage and grow the systems engineering team. He applied for the CEng so he could take on more mentoring. "I believe that what you learn as an engineer is not yours to keep. Qualifying as a CEng allows you to hand it on to the next generation, with interest."

Mentors on the IMechE scheme get together informally, creating a high value network of senior engineers across the group. "I've mentored graduates and more senior engineers like Hassan and Simon." says Stephen Pilling. "Funnily enough, Simon was on the panel who interviewed me for my first job here nearly 20 years ago. So I've ended up mentoring one of my old mentors through their CEng. It creates a very strong bond."

After reviewing Mulholland's initial application, IMechE suggested he apply to be a Fellow, the highest class of membership they offer.

"I've only been a Fellow for a week but already I'm getting some very interesting invitations to attend and speak at conferences. It really helps to raise your profile." ●

Book your fast-track ticket today

If you've got the right experience and qualifications, book in to a fast-track application workshop wherever you are and get your CEng fast.

The next workshops are:

	When	Apply by
Meggitt Aircraft Braking Systems, Coventry	Sept 22	Aug 31
IET, Coventry	Oct 1	Sept 17

Remember—don't apply to IMechE directly. Come to a fast-track workshop. Register via the Learning Management System within HRISon. For further details contact: sushma.hayes@meggitt.com

What's on offer?

Membership of the internationally recognised Institution of Mechanical Engineers (www.imeche.org) offers:

- a badge of quality: international recognition of your skills and experience
- a global network of talented engineers: local and national events in the UK and beyond
- continuous professional development with access to the latest in research and technology: 10,000 market reports, 3,000 journals
- Open to all engineers. Meggitt pays for membership

Do I qualify?

To become a chartered mechanical engineer (CEng), you need:

- six years' professional experience
- Masters in engineering (graduates from 1998 onwards)
- Bachelors in engineering (pre-1998 graduates)
- if you have trained as an engineer at work, you could still be eligible although you may need some additional learning.

Electrical, mechanical, chemical? Get qualified whatever your discipline

If you're not a mechanical engineer but you still want to get chartered, don't worry. We are working with the other engineering bodies to make sure you can. These include:

- Institution of Engineering and Technology (IET)
- Royal Aeronautical Society (RAeS)
- Institution of Chemical Engineers (IChemE)

To find out more, e-mail sushma.hayes@meggitt.com

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Tomorrow's factories will be intelligent, highly responsive units—smart components will find their own way to becoming products using the 'Internet of Things' to talk to machines and people.

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... and news of the present

We've been test-driving Meggitt on social media for the last 12 months. The pros and cons of access at work are still under review—email your thoughts to fiona.greig@meggitt.com to join the debate. In the meantime, follow us outside the office to keep up with the latest from around Meggitt and the wonderful worlds we inhabit.

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