The Manufacturing Technology Centre

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Q4.2014

INTERVIEW:
Hamid Mughal, director of manufacturing, Rolls-Royce Group

CLOSING THE SKILLS GAP
Providing tomorrow's manufacturing workforce

RAISING THE GAME
MTC founders' roundtable

VALUE RECLAIMED

Hybrid technology that combines laser cladding with machining – unleashing the potential of high value remanufacturing

qm 04.2014

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mtc Manufacturing Technology Centre

Head office:
MTC Limited
Ansty Park Coventry
CV7 9JU
T: +44 (0)2476 701600

MTC contacts and locations:
www.the-mtc.org/contact-us
MTC subscriptions:
www.the-mtc.org/qM
Sales enquiries:
businessdevelopment@the-mtc.org

Conceived and produced for MTC Ltd by:
TwoTone Media Ltd
Editor: Tony Lewin
Contributors: Anthony Smith
TwoTone Media Ltd contacts:
Anthony Smith:
AVSmith@2tmedia.com
Tony Lewin:
tonylewin@2tmedia.com

Client confidentiality is of the utmost importance to MTC, which means that we can only report on a small fraction of the work carried out by the company. So we are especially grateful to those MTC customers who have kindly agreed to co-operate with qM and allow their programmes to be highlighted in print: without such help from customers it would not be possible to present such a fascinating insight into the development of new products, technologies and innovations.

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REGULARS

qM OPINION

Creating a new future for High Value Manufacturing

Clive Hickman,
CEO, The Manufacturing Technology Centre

When the Manufacturing Technology Centre (MTC) was originally conceived in 2009 it was with a bold and vital vision in mind: to inspire UK high value manufacturing by bridging the gap between academia and industry. While this might have been considered ambitious, the organisation is already proving its ability to deliver tangible benefits to the local, regional and national manufacturing economy.

Just three years since our brand new and purpose-designed building opened its doors in 2011, the MTC already boasts in excess of 70 industrial members, ranging from SMEs to some of the world's leading advanced manufacturers, including Rolls-Royce, Airbus, Siemens and HP.

Together with our members and academic partners, the MTC is engaging in some of the most exciting research into advanced manufacturing methods and processes being carried out anywhere in the world. In doing so, we are providing a unique facility and resource for UK industry; a catalyst for innovation between academia and leading industrial companies; a centre of excellence in research, and a focus for new approaches to training and career development.

High value manufacturing is already an important element of the UK economy but to facilitate long-term industrial growth, the country needs to excel in the new technologies, such as net shape manufacture – new technologies that have the potential to deliver a new industrial revolution. Facilitating the rapid development of UK industrial capability in this arena, and consequentially long-term global competitiveness, is central to the vision and role of the MTC.

A key element in securing sustainable success for the MTC's vision lies in spreading the word about the latest research work and innovative successes, so that new members, customers and research partners become aware of our mission and of the benefits of collaborating with us. To this end I am proud to be able to introduce the first issue of qM, our new quarterly magazine. Each issue of qM will offer a regular review of the latest thinking across the entire advanced manufacturing sector, but with a particular focus on the projects and research programmes of the MTC and its members. The magazine will combine news and views with in-depth, incisively-written feature articles, all written and presented in an accessible and interesting format. We hope that it will be read right across the advanced manufacturing sector, and reach decision-makers and opinion formers beyond it.

I hope you enjoy this and future issues of qM, as we seek to share our passion and vision for advanced manufacturing in the UK.

> "Together with our members and academic partners, the MTC is engaging in some of the most exciting research into advanced manufacturing methods and processes being carried out anywhere in the world"

World's first truly collaborative robot introduced by ABB

ABB has unveiled the world's first truly collaborative robot: YuMi. This human-friendly dual-arm robot is designed for a new era of automation, for example in small parts assembly, where people and robots work together on the same tasks. The name of the robot is derived from 'you and me,' – reinforcing the notion of working together.

ABB says YuMi has been developed "to meet the flexible and agile production needs of the consumer electronics industry in the first instance." The company is promising to roll it out to cover other market sectors.

Displaying the ability to feel and see, YuMi boasts soft, padded dual arms, combined with innovative force-sensing technology to ensure the safety of its human co-workers. Safety is built into the functionality of the robot itself so that it can work cage-free. Capable of handling everything from the delicate and precise parts of a mechanical wristwatch to the components used in mobile phones, tablets and desktop PCs, YuMi performs with accuracy so great it can thread a needle.

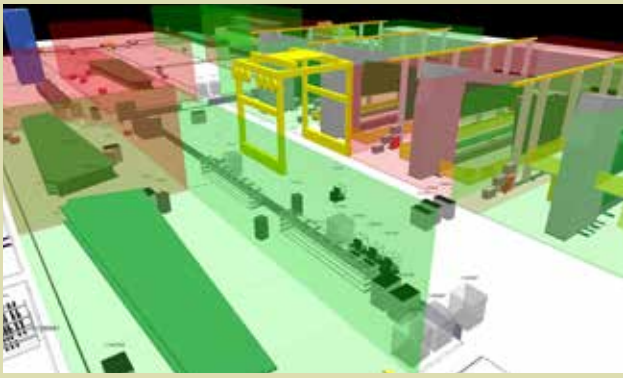
"YuMi is going to change many of mankind's assumptions about manufacturing and industrial processes," says Pekka Tiitinen, head of ABB's discrete automation and motion division. "YuMi will open endless possibilities. We are at the start of a very exciting new era for industrial automation."

YuMi will be commercially launched on April 13, 2015, at the Hannover Messe in Germany, the world's largest industrial technology fair.

Future factory

Work is progressing on Airbus' plans for "Factory of the future" concept. The company has incorporated innovative digital tracking and monitoring RFID (radio-frequency identification) technology to help streamline and increase the efficiency of its industrial operations.

By using RFID tags – attached to objects such as aircraft components and tools which are read automatically from distances of up to approximately 100m – Airbus can track and visualise its production processes in real-time. These capabilities have been deployed on the A330 and A350 final assembly lines in Toulouse, France, as well as for A400M wing assembly operations in the UK.



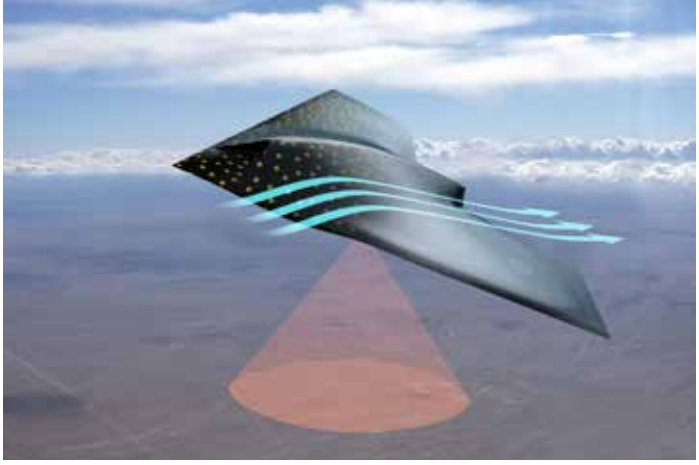
Collaboration on additive manufacturing announced by GKN

A 3.5-year, £13.4m research and development programme called Horizon (AM) is to be undertaken by a consortium led by GKN Aerospace. Together with other UK companies, the goal is to investigate the future of additive manufacturing, and the project has the backing of the UK's Aerospace Technology Institute (ATI).

As well as GKN Aerospace, the Horizon (AM) team includes: Renishaw, Delcam, and the Universities of Sheffield and Warwick. It will take a number of promising additive manufacturing (AM) techniques from research and development through to viable production processes, able to create components that could be as much as 50 percent lighter than their conventional counterparts, with complex geometries that cannot be cost-effectively manufactured today. These new processes will unlock innovations in low drag, high-performance wing designs and lighter, even more efficient engine systems – and lead to dramatic reductions in aircraft fuel consumption and emissions.

The programme will focus initially on using AM techniques to create near net shape parts which require very little machining. This will dramatically improve the 'buy to fly' ratio of the part by reducing the considerable cost in time and material wastage associated with the conventional machining of metal forgings.

BAE Systems to make aircraft more 'human'



Work has started at BAE Systems on a programme that will give aircraft human-like 'skin', enabling the detection of injury or damage and the ability to 'feel' the world around them.

Engineers within the company's Advanced Technology Centre are investigating a 'smart skin' concept which could be embedded with tens of thousands of micro-sensors. When applied to an aircraft, this will enable it to sense wind speed, temperature, physical strain and movement, far more accurately than current sensor technology allows.

BAE says its 'smart skin' concept will enable aircraft to monitor their health, reporting back on potential problems before they become significant. This communication would, says the company "reduce the need for regular check-ups on the ground and parts could be replaced in a timely manner, increasing the efficiency of aircraft maintenance, the availability of the plane and improving safety."

The microsensors can be as small as grains of rice and even as small as dust particles at less than 1 mm^2. Collectively, the sensors would have their own power source and when paired with the appropriate software, be able to communicate in much the same way that human skin sends signals to the brain. The sensors are so small that the possibility is being explored of retrofitting them to existing aircraft and even spraying them on like paint.

Senior research scientist Lydia Hyde – who is leading the R&D project – reveals that her eureka moment came when she was doing her washing and saw that her tumble dryer uses a sensor to prevent it from overheating. "Observing how a simple sensor can be used to stop a domestic appliance overheating got me thinking about how this could be applied to my work and how we could replace bulky, expensive sensors with cheap, miniature, multi-functional ones," she says. "This, in turn, led to the idea that aircraft, or indeed cars and ships, could be covered by thousands of these motes creating a 'smart skin' that can sense the world around them and monitor their condition by detecting stress, heat or damage. The idea is to make platforms 'feel' using a skin of sensors in the same way humans or animals do."

CMM for harsh environments

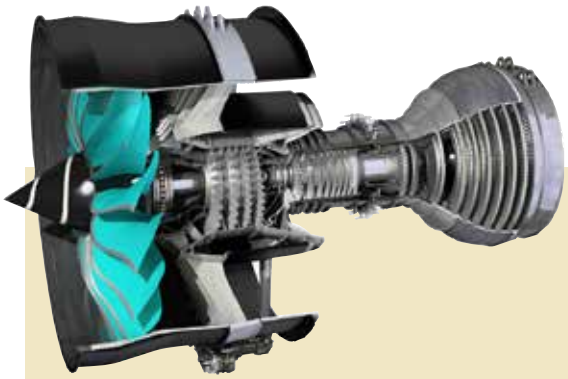
A new coordinate measuring machine (CMM) has been launched by Hexagon Metrology – the 7.10.7 SF – that is specially designed to excel in harsh industrial environments. According to the manufacturer, the 7.10.7 SF offers distinctive usability enhancements aimed at making the CMM more convenient and productive for manufacturing operations.

The 7.10.7 SF's computer, controller and interface boxes are housed in one self-contained unit for easy transport on the shop floor. The CMM has a measuring stroke of 710mm x 1010mm x 680mm, and uses standard 110/220 volt single phase outlets with no need for shop air.

Another new feature is the integrated and flexible part fixture system enabling customers to locate up to four 300mm x 300mm fixture plates or one 500mm fixture plate on the table. Using a unique kinematic locating system, the fixture plates can be quickly loaded and unloaded, allowing users to swap individual parts or part types in a matter of seconds.

Other user experience improvements include fully-integrated workspace lighting and message lighting. The workspace lighting feature fully illuminates the measurement volume, addressing the concern that a poorly lit measurement volume is a major impediment to productivity.

Message lighting on the CMM's Z-axis cover displays the status of inspection operations on the shop floor, and eliminates the need to 'babysit' the CMM. Status lights visually indicate when the inspection process is complete, whether a part passed or failed, or if an unexpected problem occurred during the operation.



Composite fan systems tested by Rolls-Royce

The Rolls-Royce composite carbon/titanium (CTi) fan system for the Advance and UltraFan engine designs has completed its most recent phase of testing at the company's outdoor jet engine test facility in Mississippi.

The fan system undertook crosswind testing on a Trent 1000 ALPS (Advanced Low Pressure System technology) engine, ahead of flight testing on the Rolls-Royce 747 flying test bed based in Tucson, Arizona.

The CTi fan system includes carbon/titanium fan blades and a composite casing that reduce weight by up to 1,500lb per aircraft, the equivalent of carrying seven more passengers at no cost.

The Advance engine design will offer at least 20 per cent less fuel burn and CO_2 emissions than the first generation of Trent engine and could be ready for entry into service from 2020.

New machines on show

With a major presence at the AMB trade show in Stuttgart, DMG MORI gave debuts to a number of products in its line-up. Particular highlights were three world premieres: The DMC 1450 V vertical machining centre; the 4th generation of the 5-axis universal machine DMU 125 P duoBLOCK; and the LASERTEC 45 Shape for high-precision 3D laser material removal and texturing.

Together with its smaller siblings, the new DMC 1450 V aims to take the performance of the vertical machining centres of DMG MORI to new dimensions. The machine concept offers travelling column design with top-mounted carriage unit, and linear guides that are 28 percent bigger, plus 25 percent bigger ball-screw spindles. DMG MORI says this combination of factors creates "the perfect framework conditions for maximum stability in the process."

Meanwhile, the DMU 125 P duoBLOCK sets a new standard in 5-axis machining with precision, performance and efficiency that is 30 percent better. The 5-axis magazine provides maximum cutting performance and precision with high dynamics because of the high-stability duoBLOCK design. Like all 4th generation duoBLOCK machines, this latest unit also provides the best prerequisites for universal precision cutting, from aerospace to tool and mould construction.

Finally, as the successor to the LASTERTEC 40 Shape, the new 45 model has been noted for its variability, productivity, precision and ease of operation. As well as the extended travel distances, the bigger worktable and the heavier workpiece weights, the significant process improvements are particularly impressive. The highlight in this respect is the unique interaction between the precision optics and the machine axes, of which there can be up to five.

Ground breaking ceremony for manufacturing and technology site takes place

A ground breaking ceremony has taken place in Solihill, West Midlands to signal the start of construction of Aero Engine Controls (AEC)'s Advanced Manufacturing and Technology Facility.

The new £60 million facility will replace two existing AEC sites in Hall Green, Birmingham. The 28,000 m^2 building will incorporate technology, design, development, manufacturing and testing capabilities, with associated expansion space. When operational, the facility will produce engine control systems for a range of applications, including the Rolls-Royce Trent family of aircraft engines.

"Today's ground breaking ceremony marks a significant milestone in this project, and is an opportunity to celebrate the support and effort of all of our employees, the project design team and Solihull Council," commented Simon Burr, CEO, Aero Engine Controls. "This investment is a key element of our business growth strategy enabling us to be more efficient and to help us continue to attract talented employees."

Councillor Ken Meeson, Solihull Metropolitan Borough Council, added: "We are delighted to welcome AEC to the borough and this major investment which underlines their commitment to continue providing highly-skilled job opportunities in the region. The development also illustrates Solihull's growing reputation for attracting high quality manufacturing."

High temperature talk at MTC

On 18 November 2014, NPL is hosting a one-day conference at MTC entitled 'The Future of High Temperature Electronics Manufacturing'.

For electronics, high temperature typically refers to operation in the range 150 to 200°C range; however, there are many applications operating at even higher temperatures, up to 300°C.

This workshop will combine coverage of high temperature applications, materials choice and assembly processes, with practical demonstrations on the MTC's full set of electronics manufacturing and characterisation equipment. Presentations will be made by well-respected industry experts Chris Hunt of NPL and Bob Willis.

For more information, contact bob@bobwillis.co.uk

Record-breakers in the manufacturing industry

Tooling specialist Sandvik Coromant has helped set a new Guinness World Record for the 'World's Largest Coin Mosaic' during the International Manufacturing Technology Show (IMTS). In an effort to raise awareness of the vital role the manufacturing industry plays and the opportunities it presents for the next generation of workers, the mosaic incorporated more than $65,000 worth of coins – the value manufacturing contributes to the U.S. economy each second.

"While achieving this Guinness World Record is an enormous accomplishment for the industry itself, it is truly gratifying to know that the sum of the coins used, as well as additional donations from event sponsors, will benefit the growth of our industry and the future generations that strive to keep it alive," said Klas Forsström, president, Sandvik Coromant.

INTERVIEW

"A beehive for advanced manufacturing"

One of the pivotal figures in the creation of the MTC has been **Hamid Mughal**, manufacturing director of the Rolls-Royce Group. **Tony Lewin** asks him about the original thinking behind the centre, how the idea became reality, and how its inspiration promises to revolutionise the supply chain and galvanise the integrated high-value manufacturing networks of the future

What has gone wrong with UK industry in recent decades, and how did this inspire the concept of the MTC?

If we look back, the UK had aerospace, defence, bio-pharmaceuticals, micro-electronics and mechanical [engineering]. We did once enjoy a strong technology advantage, but over a period of time that advantage became eroded. There were lots of reasons for this: the social aspects of engineering in the country, impatient capital and, in many organisations, the lack of leadership who truly understood the emerging value streams and how the world was changing. One of the main reasons was that we didn't have full scale 'pre-production' facilities, the equivalent of Catapult centres, to accelerate the transfer of innovation from early university research to industrial exploitation. This was a major area of weakness for decades and needed to be addressed. That's why I became so committed to contributing to its solution and started in earnest to present the case for advanced manufacturing centres to UK government, industrial leaders and academia from mid-2006.

We have fantastic universities [in this country] that create very good innovation; we're talking about some absolutely brilliant innovation. The problem is that a lot of this innovation doesn't reach the higher levels of manufacturing readiness and, as such, doesn't create economic or social value. Manufacturing is a physical entity and you cannot do it in the university laboratories. You may be able to conduct design concepts, computer systems and simulation packages, but when it comes to manufacturing with its components, products, assemblies and structures, you need machine tools, people, systems, CNC programs, CMM routines – all the equipment, people and variables that need to come together to produce highest quality at the lowest cost to the business. Laboratories aren't large enough for these things to come together – you have to find an industrial sand-pit where you can innovate and optimise these physical variables and then implement them on the shop floor.

This is a prime reason why the UK had been starved of good technological breakthroughs in high value manufacturing for decades as good ideas could not be progressed through to production-ready levels of technology. We produced very good concepts but others commercialised them and generated economic value.

So what does the UK need right now?

A large company like Rolls-Royce could easily invest in a pre-production infrastructure

> "MTC is a big enabler in turning the pipeline of ideas into commercially successful solutions"

with machine tools and everything else to take early concepts and develop them into solutions. Large companies have the resources to do that. But that would be very ineffective, with relatively low utilisation, restricted to our own knowledge base, and of no tangible benefit to anyone else, such as our suppliers. It would be a waste of capital equipment worth millions; the solutions coming out would also be very restricted.

The right thing to do is to sustain and grow the seven cross-sector High Value Manufacturing Catapult Centres to deliver manufacturing solutions at pace and, in the process, to develop the indigenous supply chain by technology uplift and training. These centres are public-private partnerships designed to operate in the traditionally difficult space of manufacturing innovation where application research is developed, matured and applied using full scale capital equipment. The government has a big role in it, so do the universities: there are direct and indirect benefits in bringing all these partners together. You get a common purpose and joint strategies. The HVM Catapult Centres have a wonderful way of binding together previously disparate organisations into something that is of common good for the UK.

Was Rolls-Royce the prime mover in getting the MTC set up?

MTC wouldn't be MTC if it hadn't been for Rolls-Royce and the effort it put into it. I personally went out of my way for three years fighting the case for it. And I'm very proud of the MTC and what its organisation has achieved, but it's the relationships they are developing with over 70 industrial members that are the most important factor in its success. A lot of people at the MTC took the initial model and made it a big success: my own view is that the presence of a centre of this magnitude and the relationships, skills and capabilities it is creating will in time have a major impact not just on the region but also nationally.

On a broader macroeconomic level is there a much higher multiplier at work when it comes to high-value manufacturing?

High value manufacturing doesn't just produce wealth at a national level, it is also very effective at extending that kind of wealth to regions. An example is Rolls-Royce at Derby. We employ around 11,000 people directly and source goods and services from up to 900 suppliers in the region, therefore sustaining lots of jobs. The other important fact is the proportion of skilled employees in the city of Derby is 2.5 times the national average: that tells you that high value manufacturing has unique characteristics. Derby also has the highest percentage of the workforce in high technology of any UK city as well as the highest export value per head of population anywhere in the UK.

Going forward, why is high-value manufacturing so important to the UK?

Because it builds upon our deep scientific knowledge and values. The DNA of the UK has always been deep scientific knowledge, so why not build something on that rather than on low labour costs, which have been the hallmark of some of the other economies? Going forward, my own view is that technology will be a primary source of global competitiveness and value creation. I'm 100 percent convinced of it. There are lots and lots of primary technologies and secondary technologies that will come together quite seamlessly – not just at the product level but also at the process level. They will enhance product performance as well as the cost-effectiveness of manufacturing processes and value chains.

You have often cited sensor technology as key to the next phase of industry. Why is it such an important factor?

Integration of sensors into networks of technology will absolutely revolutionise manufacturing. You will have adaptively self-correcting manufacturing processes to give complete process autonomy. My name for that is embedded manufacturing intelligence – foolproof systems-oriented and knowledge-embedded manufacturing. With this we can be very successful because suddenly the competitive advantage is not just reliant on labour cost. [These systems] will always be able to produce just what the design intent was: the future of industry is very exciting and high value manufacturing will play a huge role in it.

Do you see this as a revolution that will sweep through manufacturing just like lean production did?

Absolutely, and I call it Lean 2. While Lean 1 is a people-oriented system that uses standardisation as a basis for continuous improvement, Lean 2 would be systems-oriented manufacturing value streams, which use standardisation embedded in the systems to create manufacturing excellence. People will create the intelligence that feeds the systems: those standards will be deployed by the systems directly and self-corrected, and the role of people will be to keep innovating new knowledge and feeding it into the system. The same standardisation applies, but this time the systems govern the standardisation and the people provide the intelligence to create the standards. This is a very profound [change] and words that underpin many of today's norms such as quality assurance and inspection will become outdated and redundant.

What else is involved in this new way of thinking?

The value chain will become increasingly extended and fragmented for many manufactured goods. Resource scarcity and higher costs for energy and waste disposal will also shift manufacturing value creation to new models. Companies will start to extract very high values through new streams: from extensive packaging of services with products; from new sources of information on how products are used, drawing upon embedded sensors and information technology; from becoming 'factory-less goods producers', capturing value by selling technological knowledge, and from becoming a re-manufacturer returning end of life products to original specification or better. In addition, technologies such as additive manufacturing (3D printing), new materials, computer-controlled tools, biotechnology, and green chemistry will enable new forms of personalisation.

Direct customer input to design will increasingly enable companies to produce customised products with the shorter cycle times and lower costs associated with the more standardised mass production.

Is MTC's new additive manufacturing technology one of the first examples of this?

Yes it is but there is a lot more coming our way. One such development is the complete system integration – sensors embedded into self-correcting manufacturing plants across the enterprise, and then these plants linked together by integrated information systems continuously feeding in supply chain system information. This means the supply chain is continuously adapting to changing

conditions; switching on and off, depending on customer flow and demand. The whole value chain is self correcting, always having optimum buffers and inventories, knowing what needs to be produced tonight, and knowing exactly what needs to be produced tomorrow, and how. There's a complete integration of the value chain, right from digging [things] from the ground all the way to remanufacturing [at the end].

With this level of automation, would there not be consequences for employment?

Yes, but employment in a different way. The factories of the future will be very varied, more distributed than those of today. The landscape of the future will include the capital-intensive super factory producing very complex and reconfigurable units, then there will be lots of smaller modular units closer to the customer, because factories will be so environmentally friendly that you will want to have them in your backyard or your street. Some of them could be mobile or domestic production facilities. So instead of one large factory employing, say, 20,000, you may have 15 of these [smaller plants] spread across. So employment will be different: fewer people inside the factory, more people outside it creating innovative solutions that feed systems that control the manufacturing processes. The kinds of factories will be different, but the multiplier effect does not mean that there will be less employment.

What is MTC's role in this profound change?

MTC is a big enabler in turning the pipeline of ideas into commercially successful solutions. It's about galvanising the industry, creating government-level relationships, trade relationships, getting intelligence from the market, helping companies gain an inroad into those economies. Its role is very broad: it's about product, knowledge of the market, knowledge of customers, university relationships, research centre relationships – it will greatly contribute to a long term, coherent and comprehensive approach to manufacturing competitiveness.

Where do you see the MTC going in the next 10 to 20 years?

I have always had huge ambitions for the MTC. My ambition for the MTC is for it to become influential in lots of different ways – in creating a high value manufacturing cluster around the West Midlands, in creating a huge, highly skilled workforce that has developed from the Training Centre and the programmes that the MTC runs. I want MTC to become a beehive for the growth and success of high value manufacturing. My hope is that in a few years Ansty park will be full of high-quality companies attracting advanced research and manufacturing developments which will spill over across the rest of the region.

> "I want MTC to become a beehive for the growth and success of high value manufacturing"
>
> **Hamid Mughal, Manufacturing Director, The Rolls-Royce Group**

Hamid Mughal and Rolls-Royce

As director of manufacturing for the Rolls-Royce Group, Hamid Mughal is the functional leader for the group's 18,000 production employees in the aero, marine, nuclear and other sectors.

Although his title is director of manufacturing, Hamid states that it is almost impossible for one person to take all decisions on matters like manufacturing techniques, outsourcing and insourcing across such a complex company. "Some things I do myself; other things are devolved and the [individual] businesses do them. Major new manufacturing technologies, for instance, would be my responsibility but the day-to-day delivery and reporting line is to the business lead."

With some 85 plants and 11,000 machine tools, Rolls-Royce Group is a leading provider of engines and power to the civil and defence aerospace industries, the marine sector and the international energy and power systems sectors.

"We are organised in customer value streams, vertical product streams," explains Hamid, who worked with BMW in the automotive sector until 2001. "The technology processes are horizontal – they work across all, they are the enablers like the leadership and the systems."

In his current role, Hamid Mughal is responsible for leading the manufacturing activities and strategies across the company's manufacturing bases. This includes the development and deployment of manufacturing methods, standards, technologies, systems and lean practices and behaviours to achieve Best in Class performance. He is also responsible for the professional development of the global manufacturing community in the company.

He has an honours degree in Mechanical Engineering, a BA in Mathematics and Technology, an MSc. in Production Engineering & Management and a Doctorate in Manufacturing Systems. Also Pro Chancellor at the University of Nottingham and External Professor at Cranfield and Sheffield Universities, Hamid Mughal is a Chartered Engineer, a Fellow of the Royal Academy of Engineering, the IMechE and the IET. He is a winner of the IET's International Manufacturing Gold Medal and a Board member of the High Value Manufacturing Catapult and the Advanced Manufacturing Institute.

He was awarded an OBE in the 2014 New Year's Honours for services to Innovation, Technology and Manufacturing.

... if there is a way in which a product can be repaired or remanufactured with full functionality at less cost and total energy use than that of original manufacture and disposal, why would an alternative ever be considered?

VALUE RECLAIMED

Remanufacturing contributes around £5 billion to the UK economy but, as **Anthony Smith** and **Will Stirling** explain, it holds significant additional potential based on new technologies developed by MTC and its partners on the RECLAIM project

The long established principles of the waste hierarchy – as set out in regulations such as the EU Waste Framework Directive – very clearly identify product re-use as the highest priority for end-of-life disposal, ahead of recycling, materials recovery and disposal of residual wastes. In many ways this is merely a statement of supreme common sense: if there is a way in which a product can be repaired or remanufactured with full functionality at less cost and total energy use than that of original manufacture and disposal, why would an alternative ever be considered?

In reality and in particular for lower value products, technical complexity and commercial economics militate against the path of re-use and instead favour conventional end of life materials recycling. However, in high value manufacturing sectors such as aerospace, there are many examples where the cost of producing new products is significant and a practical means of remanufacturing – subject to the same rigorous specifications of dimensional accuracy, mechanical properties and material inspection as in original equipment production – could be a highly attractive commercial proposition.

Laser cladding

Additive manufacturing methods, often referred to in the media as '3D printing' have been heralded as one of the most important technical developments in manufacturing in recent years, with some industrialists going so far as to compare its potential impact to that of the silicon chip in previous decades. In addition to the creation of new components, however, one branch of additive manufacture focuses on the deposition and integration of new material into existing parts.

In the process known as 'laser cladding', a precisely controlled stream of powdered material or wire is directed at the surface of the component in the presence of a scanning laser. Using this means, the bond created between the added material and base surface is extremely effective, with minimal dilution, superficial melting and only a small heat-affected zone. But, while this technology is in itself very promising as a part of many potential remanufacturing processes, it begs the question what could be achieved as part of a commercial scale hybrid manufacturing system that combined laser cladding with 5-axis machining and in-process inspection?

The potential of RECLAIM

This was the challenge set with the launch in 2008 of the collaborative project RECLAIM (REmanufacture of high value products using a Combined LAser cladding, Inspection and Machining system). Partly funded by Innovate UK, the project sought to test and prove the hypothesis that shifting from a series of discrete repair and remanufacture processes based on work piece flow, to one of 'tool flow' production in a single integrated cell, can enable repairs to high value parts that are not

> “The applications for hybrid manufacturing technology extend far beyond repair. The approach can be used for the manufacture of complex parts… or to add specific features to an existing part.”
>
> **Hybrid Manufacturing Technologies Ltd CEO Jason Jones**

The RECLAIM system at the MTC *(far right)* **– launched in the form of the award-winning Hybrid HSTM 1000 machine incorporates a laser cladding head** *(top)* **in addition to inspection and machining, and an integrated control system** *(right)*. **Turbine blades and precision impellers** *(above)* **are typical potential high value remanufacturing applications of the system.**

otherwise feasible.

The Reclaim project originally involved partners including: Delcam, which developed the computer-aided modelling (CAM) programme; Renishaw, which developed the new rapid scanning Sprint™ inspection head in the project; Precision Engineering Technologies (PeTEC), which handled the machine integration; laser processing company Electrox; The Welding Institute; De Montfort University for laser cladding process development, and automotive turbocharger manufacturer Cummins Turbo Technologies.

Following the promising early work of the consortium, MTC joined the collaboration towards the end of the project to assist with the crucial roles of helping to test, validate and refine the new process to facilitate its commercial implementation. At the end of the project a new spin-out company, Hybrid Manufacturing Technologies Ltd (HMT), was formed to commercialise the new process, for which MTC is the preferred collaborator for process and equipment development and testing.

Innovative solution

A critical aspect of the hybrid manufacturing system, pioneered with the RECLAIM project, is the development of a cladding head that sits inside of the tool changer of the machine tool. This very ‘neat’ idea enables the cladding to be selected in the same way as a cutting tool or inspection head. HMT has developed a novel docking system that enables the laser, inert gas supply and metal powder feed to be coupled to the head once it is in position in the machine tool spindle.

The initial aim of the RECLAIM project was to use precision laser cladding to deposit metal onto a component followed by machining and inspection to enable high value engineering parts to be repaired in a fully automated adaptive remanufacturing process. The machine developed in the project undertakes all of the repair operations in a seamless automated operation.

Hybrid manufacturing technology of this sort offers significant benefits over other forms of additive manufacture. For example, the process is scalable to produce large parts, the productivity can be 100 times higher and dimensional accuracy and surface finish are on a par with existing precision manufacturing methods. Another important factor is the low

capital investment costs compared to other metal additive manufacturing processes.

Award winning technology

International collaboration is critical for success on a global scale, and towards the end of the project MTC, Delcam, and HMT teamed up with specialist machine tool company Hamuel Maschinenbau, based in Meeder, Germany, to develop a machine specifically designed for the manufacture or repair of industrial gas turbine parts.

The tangible results of the RECLAIM project were displayed for the first time at the 2013 EMO Hannover event, the biennial world machine tool exhibition promoted by the European Association of the Machine Tool Industries (CECIMO).

An industry-first, five-axis machine, the Hybrid HSTM 1000, was launched at the show – the result of five years of highly innovative research by the RECLAIM project team. It took the machine tool world by storm, and was awarded the prestigious EMO prize for 'Best Multifunction machine'. The media response was extremely positive too, with TCT Magazine describing the HSTM 1000 as representing 'game changing' philosophy – one which enables the most effective combination of manufacturing techniques to be used to produce a part.

"The applications for hybrid manufacturing technology extend far beyond repair," explained HMT CEO Jason Jones. "The approach can be used for the manufacture of complex parts through the sequential addition of layers of material to form the entire component or to add specific features to an existing part."

Continued development

Following completion of the RECLAIM project, MTC has continued to work with Delcam and HMT on advanced testing of the HSTM 1000 machine, as Professor David Wimpenny, MTC chief technologist for net shape and additive manufacturing, explains: "We are currently developing process parameters for a specific application: the repair of industrial turbine blades for power generation. At the end of these trials the machine will be shipped to the company for final testing and production use."

HMT is also working with MTC and Delcam in the development of the next generation of 'docking' hybrid manufacturing systems.

This is being offered in its commercial form as the AMBIT™ multi-tasking system – a unique British invention for which the company is exploring new commercial applications. And in addition to offering turn-key solutions based on completely new machine tools, the company is also offering to retrofit systems on to existing machine tools, bringing high productivity metals additive manufacturing within the reach of smaller companies.

A new centre of excellence

MTC has recently installed the latest version of the hybrid manufacturing system, based around a Mikron 450U compact 5 axes, vertical milling machine with rotary tilting table. This machine is fitted with HMT's latest system coupled to a higher power 1.2kw fibre laser and advanced powder feeder system, capable of delivering 4 different materials to the cladding head and thereby simultaneously allowing a wide range of metals to be deposited in graded compositions. MTC will use this machine for parameter and applications development across a wide range of industrial sectors.

The new machine was funded as part of the new **National Net Shape and Additive Manufacture Centre**, which was announced by Chancellor George Osborne at the start of the year. The centre – located at MTC – has been established to provide a factory demonstration which is capable of taking raw material and component designs in and producing fully finished parts, where every stage of the process is carefully monitored and controlled. It will act as a test bed, enabling industry to review the manufacturing capability readiness level of new manufacturing processes and equipment, as they are developed, in a low-risk neutral environment. Moreover, MTC will work closely with academia to support the fundamental research, which is essential to drive manufacturing capability forwards.

A new wave of hybrid machine tools

The idea of hybrid manufacturing technology has rapidly gained ground in the machine tool sector with several other organisations now offering competing systems. Following completion of the RECLAIM project, no less than six machine tool builders now claim to be developing or offering a hybrid solution, including Hamuel, DMG MORI Seiki, Hermle, Cincinnati and Hurco, with widespread industry rumours of others intending to launch or announce systems this autumn. In essence, MTC and its partners on the Innovate UK RECLAIM project have enabled the launch of hybrid manufacturing on a global scale.

Future prospects

With the undeniable commercial potential for extending the remanufacture of high value components such as aero engine turbine blades, the future looks extremely bright for hybrid manufacturing methods. But as MTC's David Wimpenny explains, there is significant additional research and development work to be done in process refinement and in application engineering: "This is a competitive market – so although hybrid manufacturing systems are now a commercial reality, we have to work to improve and innovate to realise their full potential in a range of high value manufacturing contexts."

As the home of the new National Innovation Centre for Net Shape & Additive Manufacturing, and with its own factory scale demonstration system already installed, MTC is ideally placed to assist the world's machine tool manufacturers, including HMT, in the development, productionisation and testing of their latest hybrid remanufacturing systems. Moreover it is also at the disposal of the high-value manufacturing sector at large – in particular the aerospace industry – as a potential partner in the implementation of this state-of-the-art technology.

The original RECLAIM research unit *(below)* **and a HTSM 1000 machine undergoing advanced testing at MTC** *(right)*.

> "This is a competitive market – so although hybrid manufacturing systems are now a commercial reality, we have to work to improve and innovate to realise their full potential"
>
> **Professor David Wimpenny, MTC chief technologist for net shape and additive manufacturing**

CLOSING THE **SKILLS GAP**

With UK manufacturing enjoying resurgence on a scale that many claim constitutes a new industrial revolution, a key determinant of future success will be to provide the highly skilled and internationally competitive workforce of the future. **Anthony Smith** reports

As we enter the autumn of 2014, UK economic indicators have undeniably begun to signpost at least the beginnings of a comparatively broad-based and stable recovery. But in what might be surprising to many who have grown used to the myth and legend surrounding political debate and media coverage since the 1980s, the manufacturing industries are fast being seen as something of a poster child of the country's bright new post-recession economy. Nowhere does this apply more clearly than to those sectors focused on technology, intensive innovation and high-value operations.

It's easy to see why this might be the case, and national and international statistics prove the point. In its 2012-2015 manufacturing strategy report, Innovate UK cites the UK (based on UN and ONS figures) as featuring in the global top ten for manufacturing gross value added (GVA), generating ten percent of the country's own GVA, accounting for half of UK exports, and employing 2.5 million people. There are some sectors that are notable stellar performers too: while the pharmaceutical industry might be widely lauded as a UK success story, perhaps rather fewer of the general public are likely to be aware that in aerospace the UK ranks second only to the United States. Moreover, the UK-based automotive industry is resurgent, according to SMMT figures – exporting in the region of 80 percent of its production and accounting for 10 percent of the UK's trade in goods.

Mind the gap

The positive picture is also reflected by the CBI Industrial Trends surveys over recent months, which show strong performance and positive expectations for continued growth.

> "...we believe that they will be extremely impressed with the apprentice trainees coming through the schemes"
>
> **Steve Gasser, MTC career development manager**

MTC's apprentice training is structured around a series of technological and business themes focusing on high value manufacturing technologies, including the latest virtual reality methods *(right)*.

But while the outlook appears positive on the surface, there remains an underlying issue surrounding skills availability, especially within the advanced manufacturing sectors that are clearly so crucial to future success.

"This is a challenge that has been emerging over a number of years," says MTC career development manager Steve Gasser, who was previously for many years senior business development manager of the IMechE responsible for training and education. "There was a significant drop in university applications to read engineering through the latter part of the 1990s and early 2000s. This coincided with the boom in the financial services sector, so it was perhaps unsurprising that with rising student debt levels and highly attractive 'golden hello' offers being made by banks and other financial sector employers, we were losing around half of the UK's annual engineering graduate output to finance."

As Gasser also points out, though, this situation has been resolved to a large degree following the recession, with Higher Education Statistics Agency data showing that just 2.7 percent of UK engineers graduating in summer 2013 moved into finance-related employment; this is still a significant figure, but surely not large enough to be the root cause of an industrial skills gap.

Even before the current period of recovery began to take hold, however, there were widespread reports of manufacturing skills shortages acting as a potential brake on future growth. A 2013 review of manufacturing competitiveness carried out by a research team from the University of Birmingham and Georgia Institute of Technology on behalf of the UK Government, observed that "many manufacturing firms are experiencing great difficulty in recruiting skilled employees and that this is holding back economic growth."

While at first sight it might appear something of a paradox that graduate unemployment remains a widely reported issue, it may perhaps be something of yesterday's news as the latest national data indicates that UK graduate unemployment six months after graduation is just 7.8 percent, against a 6.6 percent average for the broader economically active population.

So what needs to be done in order to close this potentially damaging skills gap – a gap that might otherwise impede the development of high value manufacturing?

Beyond the Richard Review

To answer this question it's useful to turn the clock back to the end of the last decade, when it was becoming clear to both industry and government that the then prevailing apprenticeship model of technical education and training had been devalued in comparison with other competing industrialised nations. In his independent 2012 report, The Richard Review of Apprenticeships, entrepreneur and educator Doug Richard set out what became something of a touchstone for developing government policy in this important area.

Key amongst the review's recommendations – findings that have subsequently informed government policy – were to:

- increase the delivered quality of apprenticeships
- place employers firmly in the driving seat in terms of defining standards, technical content and required skills and knowledge of trained apprentices
- channel government funding for the external training of apprentices via their respective employers.

This more strategic approach is aimed at empowering business and driving up the quality and relevance of apprentice training. "This policy initiative is in my view extremely timely," argues Gasser. "Guidance in schools has not been as objective as it should have been in the past, with perhaps too much focus on the 'A' levels/university route as the only viable pathway to a career in engineering. The reality is that apprenticeship offers a highly attractive alternative for many young people. It's one where they can feel that they are making a contribution in the workplace much earlier, they can earn money while they train and, crucially, it offers a potential future pathway on to a degree course should they opt for this in the future. The fact is that potential students are now very much aware of the costs of degree-level education in terms of the tuition fee debt that they will incur. This is leading increasing numbers to give serious consideration to apprenticeship training."

Blazing the apprenticeship trail

The cornerstone of the new approach to apprentice training in England is the creation of the so-called 'Trailblazers' – groups of employers working together to design new Apprenticeship standards for occupations in their sectors. The nucleus of a new High Value Manufacturing trailblazer will be the new Lloyds Advanced Manufacturing Training Centre, a £36 million facility currently under construction at the MTC campus and due to open in the summer of 2015. This Trailblazer aims to emulate the very best aspects of the once highly respected in-house apprentice schools maintained by large industrial companies and conglomerates in previous decades. It will do so, however, in a more modern context to reflect the needs of both rapidly emergent and potentially disruptive new manufacturing technologies. It will also be structured in a manner reflecting the more broadly based supply chain typical of the UK's high value manufacturing industries, a chain with a significant representation of mid-cap and SME companies for whom in-house provision is more challenging.

"SMEs in particular find it challenging to provide effective apprentice training entirely from within the organisation," explains MTC apprentice training manager Timothy Kyte. "It's also important to them to have people who are appropriately skilled for their operations, both technically and in more general terms as employees. On our programme we will aim to equip apprentices with exactly these types of crucially needed skills so that they can make a real contribution from day one with their employer. By the time that the apprentices go to their sponsoring organisation for placements in their third year, they will be used to the disciplines required of the workplace and will also be skilled at a much higher level than would otherwise be the case."

Thematic focus

MTC's apprentice training is structured around a series of technological and business themes focusing on high value manufacturing technologies. These include net shape and additive manufacture, high integrity fabrication encompassing friction welding and laser cladding, metrology and NDT, metallurgy, CNC machining, robotics and automation.

By structuring training in this way, MTC aims to be able – for its own sponsored apprentices and those that it trains as well as for its partner and member companies – to adapt training based on both the needs and the aspirations of the employer and trainee. "In developing our apprentice programme it's crucial that we do so in a consultative manner," continues Kyte, "taking on board the views and requirements of the sponsoring companies while also allowing the flexibility of learning that individual trainees require. For MTC it also meets one of our strategic aims in seeding the future workforce."

The typical experience of the apprentices trained by MTC will be to spend their first year at college covering basic academic and workshop skills development. In the second year they will return to the new Advanced Manufacturing Training Centre, where they will spend at least nine months working across some of the advanced manufacturing technologies available at MTC. The remaining time during the year will be spent shadowing applications engineers at MTC or in supply-chain companies. In the following years, the apprentices will spend one day per week at the training centre and the balance at their employing organisations. When fully established, MTC expects to be sponsoring just 20 percent of the apprentices, with the balance being employed by external supply-chain companies, including MTC members.

"We will be talking to member companies about what they require in designing this programme," adds Gasser, "and we believe that they will be extremely impressed with the apprentice trainees coming through the scheme; in the end, it's they who will be the best salespeople we could possibly have for future generations of apprentice trainees at the Advanced Manufacturing Training Centre."

Multiple streams and graduate development

While the 40 new apprentices recruited by MTC in the summer of 2014 represent the first cohort of trainees to benefit from the new

Prime Minister David Cameron meets some of the MTC's apprentice trainees.

> "This extraordinary centre is developing skills for the future, which is a crucial part of our long-term economic plan to secure Britain's future"
>
> **UK Prime Minister David Cameron**

> "In my opinion it is absolutely vital that skills acquisition and training is inextricably linked to the development of the latest world-class manufacturing technologies" **Clive Hickman, MTC CEO**

centre when it opens next year, apprentice training is just one aspect of its intended roles. A second and extremely important function will be to act as the focus of MTC's graduate development function.

Like the apprentice programme, graduate development is intended to be highly collaborative between MTC and its member companies. "Whereas the model of apprentice training we envisage for the new centre is deliberately skewed towards external supply-chain needs – as this is where most value needs to be added to secure the future growth of high value manufacturing in the UK – the graduate programme is primarily targeted at meeting our own requirements," explains Gasser. "However, we will be encouraging member companies who do not have training programmes of their own to place graduates into our programme so that its benefits can extend to, say, SMEs who might otherwise struggle to recruit the most talented graduates."

The graduate trainee engineers will be employed on a two-year fixed term contract and will rotate between themes in a similar manner to apprentices. They will however be individually mentored by experienced senior research engineers and technology managers within the business, or in some cases by external mentors. In addition to equipping the trainees for the career direction and technology focus they wish to pursue, the training programme will meet the requirements of the IMechE for future accreditation as Chartered Engineers.

Career conversion

In a further highly innovative approach to professional training, the third stream of training planned to be delivered from the Advanced Manufacturing Training Centre is aimed at engineers and scientists who wish to change track and re-skill as more specialist manufacturing engineers.

"We have a strong suspicion that many otherwise very promising and talented engineering and scientific professionals are lost to UK industry because they can't find employment in the fields that they intended or have become disillusioned with their early career choices," contends Gasser. "In a situation of skills shortage it's important that we address this potentially valuable talent pool in addition to those who come straight into high value manufacturing from school or university."

Training of these recruits is likely to focus in particular on some of the rapidly developing and potentially disruptive technologies that the MTC specialises in, such as net shape and additive manufacture and advanced automation, as well as the latest concepts in welding and metrology. Trainees will spend the majority of the first six months of the programme in classroom and workshop sessions, with the subsequent two years spent on research projects as an integral part of the MTC engineering team.

Industrial design incubation

The final stream of training currently planned for delivery through the new Advanced Manufacturing Training Centre is the brainchild of MTC CEO Clive Hickman: "The idea came to me when I visited an industrial design graduation show at one the UK's leading universities. The standard of creativity and innovation shown by the students in the product concepts they'd developed was extremely impressive but the key question for me was; what happens next? Sadly it seems that the answer is 'not much'. There are no obvious avenues for these would-be design entrepreneurs to take their design to market in the form of a product that can be sold. The loss of human potential is no less of a concern as I understand that only around 30 percent of students graduating in industrial design are able to secure employment in this sector."

Discussing with venture capitalists the design concepts he had seen confirmed Hickman's view that something needed to be done: "The consensus view was that one in ten of the concepts had potential to be developed into a successful and profitable product, while one in a hundred had the potential to grow into a world-class innovation-led business such as Dyson."

The MTC concept of industrial design incubation that Hickman has developed is in itself, highly innovative. Through a new ventures subsidiary, which will act as an investment vehicle for the companies being incubated at MTC, funding will be made available to successful applicants in exchange for a 30 percent equity stake in the new business.

The cross fertilization of ideas, technologies and innovation that this concept in business incubation intends to create is truly unique to MTC. Each cohort of industrial design entrepreneurs accepted onto the programme will be in an environment in which they will learn about the potential of the latest manufacturing technologies.

While many of them may previously have produced prototypes, MTC will help them to understand the processes required to bring their concepts to a much higher technology readiness level, addressing manufacturing, quality, durability issues and most of all, the need to create a product that will attract market demand while also delivering profit. The highly focused environment will be one in which space and learning will be shared with colleagues pursuing the development of new products and businesses in other sectors, potentially giving rise to further synergies and cross-learning.

"Our aim is to raise a fund of £10 million to pump prime this concept," continues Hickman, "but we believe that the fund will become self-sustaining over 12 years based on the equity stakes in successful companies. If successful, however, the benefit to high value manufacturing in the UK will far exceed this, through the creation of successful and profitable world-class businesses that make the link between product innovation, manufacturing and market exploitation."

National college designation

The significance of the Advanced Manufacturing Training Centre project was highlighted by UK Prime Minister David Cameron during a visit to MTC in March 2014: "This extraordinary centre is developing skills for the future, which is a crucial part of our long-term economic plan to secure Britain's future. It is also contributing to the re-industrialisation of our country, and I think it's great that this renaissance is taking place right here in the West Midlands which was of course the manufacturing centre of the world."

Further recognition for the project came in June with the designation of the centre as the first of a new concept in so-called 'National Colleges', aimed at delivering the higher level technical skills that businesses need.

Enabling future growth

In summarizing the potential of the new Advanced Manufacturing Training Centre, Clive Hickman is keen stress the strategic link between manufacturing technology and skills that has guided its creation: "In my opinion it is absolutely vital that skills acquisition and training is inextricably linked to the development of the latest world-class manufacturing technologies that we are leading as part of the Government's High Value Manufacturing Catapult. If we carried on with the old model of training and technology development being in separate silos, we would still have a skills gap five years from now. With the approach that we are championing through the new Manufacturing Training Centre we will not only make significant progress in closing that gap, but in doing so we will also help UK high value manufacturing to realize its potential for significant future growth."

The Lloyds Advanced Manufacturing Training Centre

- **Constructed as part of a major expansion of the MTC campus, due to open in mid-2015**
- **Funding of £18 million from the Department of Business, Innovation and Skills (BIS) matched by a further £18 million of industry support to the programme**
- **Aim to redress the manufacturing high-level skills gaps inhibiting the high value manufacturing (HVM) sector and develop the skills that are needed for delivering the technologies of the future**
- **Named as the first 'National College' in June 2014**
- **Four strands to training and development at the centre:**
  - **New model of HVM apprentice training focusing on the needs of new manufacturing processes and technologies**
  - **Graduate training specifically for the HVM sector**
  - **Career conversion – helping engineers and scientists retrain as HVM engineers**
  - **Industrial design incubation – closing the gap between design innovation and commercial product success based on HVM**

RAISING UK INDUSTRY'S GAME

It was early in 2009 that key players from leading UK companies, universities and national investment authorities first gathered to discuss an ambitious new project that would inspire British industry to raise its game to compete on an international scale. The mission: to bridge the gap between innovative university-based research and globally successful engineering solutions and industrial products. The outcome: the creation of the Manufacturing Technology Centre. Here **Tony Lewin** speaks with key members of the four founding organisations, the universities of Nottingham, Birmingham and Loughborough, and TWI (The Welding Institute)

Where – or who – did the original inspiration for the MTC project come from?

Rob Parkin The original inspiration for MTC actually came from Rolls-Royce. One thing that is very clear is that academics do very good research in this country in technology readiness levels (TRLs) one to three: the problem is that industry is not ready to use those technologies until they are more mature, at something like five, six or even further. So there has always been this so-called valley of death between levels four and six, and one of the things that convinced me to take part was that: over my life I have done 30-plus big EPSRC projects, and all of them were highly successful in academic terms, with top scores. Yet if I go and look at how many of them are out there in industry, it is a big fat zero. And to me that's just a waste of public funds – it keeps me amused, but it's hardly good bang for the buck. So the idea of somewhere that would help you take things from TRL three, say, to industrial reality would be a benefit to both academics and the industries that want to use the eventual output. Rolls-Royce were the champions of that, and helped persuade government to put the money into MTC.

How did the idea evolve along the way?

Richard Williams It has grown its talent base across all types of staff and has grown in confidence as achievements have been delivered. Knowledge of this success has spread and this has drawn in new companies as partners in different membership groups. The MTC has become a destination in its own right – quite an achievement in three years.

Rob Parkin The planning did change along the way. Although the building was always this size, the original concept was a more open environment. The Street – the long walkway through the centre of the building – was supposed to be glass all the way down so that visitors could see what was going on. That was fine at the start, but the companies all gradually backed off because there were secret processes going on in there: not only did they close off those windows, but they made it more secret still and built big white boxes around some of the projects.

But isn't that a sign of success? Companies deciding to put top projects into MTC?

Representatives of founding institutions *(clockwise from top left)* **Aamir Khalid of TWI, Richard Williams of the University of Birmingham, Andrew Long of the University of Nottingham, and Rob Parkin of Loughborough University.**

Andrew Long It is, provided you're not simply saying to a company that they can rent a space in this building that you're not going to tell us anything about, and then you can go away again: that's not what the MTC is for. There is some shared learning from these projects that will mean the MTC has learned something from this work, and some of that could be applied to other projects and to the benefit of all the members.

Aamir Khalid I feel very much the same. I've been a research fellow for many years and have also worked in industry, so I've seen both sides. We've set up a university centre inside our company. Previously, all of the research projects I did never hit the market, but since we've set this up we find that one in ten do. It's not a great ratio, but the reason [they do succeed] is that the researchers work with the industrial people. If you have a project and you want to make a prototype, the company makes the prototype for the researcher – that way the prototype is better, because it is industrially designed. The researcher then does experiments with the prototype, gets results with it, and then you tweak the prototype, going back and forth to improve it. It can take two or three years of dedicated research and then we can pick up the ball and go with it.

How closely does MTC parallel the model of the Fraunhofer Institutes in Germany?

Rob Parkin Bear in mind that this organisation existed before the Catapult. This place as such was not directly modelled on the Fraunhofer: that was the Catapults. The original funding was for buildings and equipment, and it was a membership model.

Aamir Khalid It's similar to Fraunhofer in that it works on the TRL levels, working with universities at one end and industry at the other. Those are the common things.

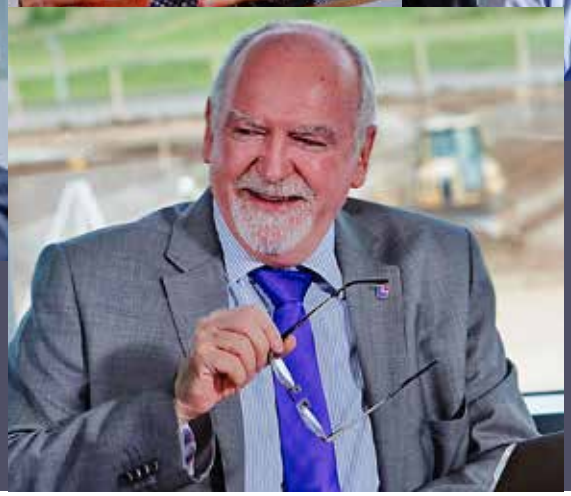
Rob Parkin The difference [in the future] will be how long the government has the appetite to provide the government side of the funding, because it took Fraunhofers many, many years. Without the government part, they wouldn't exist either. [MTC] is [already] a fantastic growth story, but you need the longevity because it takes people on the outside a long time to realise that this exists. Some SMEs have still not heard of MTC.

Representatives of the founders

Professor Richard Williams , Pro-Vice Chancellor and Head of the College of Engineering and Physical Sciences at the University of Birmingham, has a wide range of research interests including energy storage technology, nuclear waste management and particle science and engineering.

Andrew Long is Dean of Engineering and Professor of Mechanics of Materials at the Faculty of Engineering at the University of Nottingham. Among his listed research interests are polymer composites and technical textiles.

Aamir Khalid is technology director of TWI, The Welding Institute, in Cambridge, and is a specialist in automation and robotic inspection technologies.



Rob Parkin is Professor of Mechatronics at Loughborough University and lists as his research interests the design and monitoring of mechatronic systems, sensors and actuators, and intelligent processes and systems.

Does MTC have the capacity to become independent of government funding?

Rob Parkin If it does do that, it will never fulfil its purpose. It would eventually become just a consultancy.

Aamir Khalid TWI was based on this model in the 1990s. The funding was taken away, so we had to stand on our own feet; it made the organisation much more a consulting and testing organisation. Now we are getting more funding we are going back to doing more R&D. That funding should never be pulled away.

Andrew Long One of the things MTC has is a core research programme. That takes some of the membership fees and uses it for projects where the knowledge is shared across the sector. That's all part of the overall budget, so if you lose the government income you could perhaps no longer afford to be running such an activity. [For the members] it then wouldn't be a shared risk centre: [now] they share the risk of owning state-of-the-art equipment, they learn how to use it and decide whether it's for them. Ultimately, their company may decide whether to invest in that equipment. That's one of the major benefits.

The core research programme: is that the MTC's major strategic thrust?

Rob Parkin It's an industry pull: there are big industry players involved, like Rolls-Royce and Airbus, and they see the problems coming up and decide what areas they would like to go into. They will then decide how much of their subscription money they will put into each of the core research themes.

Andrew Long It's not enclosed in a box. The results are going to be shared with all of the members.

Could you give me one sentence which sums up the core mission of MTC?

Richard Williams Grow British engineering manufacturing business through developing capabilities in technology, talent and research translation.

Rob Parkin Move research into practice.

Andrew Long Taking innovation [and using it] to manufacture products.

Aamir Khalid I'll just add to that by saying industry-driven – so that industry chooses the research it wants to take forward; it's not up to the academics to decide.

Rob Parkin No, but frequently what they [MTC] get in the front end is the output of the academics and, like you say, they are only going to take it if it gets some traction with their core members.

What is the position on intellectual property (IP)? If there is a brilliant invention, is it shared by all?

Aamir Khalid I think that if it's part of the core research programme, the IP belongs to MTC, but for single-client industrial projects it would belong to the sponsor.

Rob Parkin Of course if it is something that came out of the universities to start with, the original IP may be with the university.

Andrew Long IP is a difficult issue in academia, I think. It's one where the interests of individual academics could be very different to the perceived interests of institutions. An individual academic largely sees considerations around IP as a barrier: they want to do their research and publish the results. But if someone says 'hang on, let's see if there is any IP to protect', that process will hold you up in achieving what's more valuable to you as an academic – publishing a high-quality paper – so you will see it as a barrier. Our university made a fortune from magnetic resonance imaging, but it can become a pressure and I've been in interminable meetings where people have asked 'what is the next magnetic resonance imaging?'

Aamir Khalid Overall, universities make a loss if you look at the amount of money you put

in to generate the IP, and the licence fees you get back. I'm quite closely involved with Brunel, and I know that they do [make a loss] but TWI actually makes a profit, though it's made from one invention – friction stir welding. The rest of them put together make a loss.

How does manufacturing in the UK currently compare with other countries? And why is the UK's robot density so much lower than, say, Korea?

Andrew Long Is robot density an area where we would wish to compete? I'd expect that we would wish to be implementing automated manufacturing technologies in industry or increasing the level of automation, but it won't be the same technologies that are occupying that many robots now in Korea.

Rob Parkin I think there are some interesting issues here. In other countries the tax breaks and incentives have been very different; other countries have therefore seen fit to invest in technology, whereas in the UK we've been investing in people – which is one of the reasons we've had more shake-out here. The stuff that's onshoring again is the stuff where they use technology rather than people – because one thing about technology is that when times get hard you don't have to pay it redundancy money, you just turn it off and put it back on again when you need it.

Richard Williams Robotics systems require significant investment and robots have long underdelivered in terms of true versatility. This is now beginning to change and MTC is at the forefront of these developments.

Aamir Khalid Now, R&D tax credits [in this country] are very good for SMEs and for large companies, so at least you are paid a bit of money to take some risk. The US has a scheme where companies fulfilling public contracts must put aside a percentage of that contract sum to R&D with a third party. This pumps huge amounts of money into the R&D sector in the US. Against low-cost countries such as China we've got no chance, so the best thing we can do is R&D – that's why this place is so good.

Rob Parkin We have a highly skilled workforce in the UK. Hybrid powerpacks for Japanese vehicles are made in the UK and sent back to Japan: they don't have the skills over there.

Andrew Long Another question is whether those high-skill jobs have to be in the same place they are doing the manufacturing. The Dyson example is a good one: he moved manufacturing out of the UK, but now he employs more people in the UK than he did when he manufactured here, and they're all highly skilled jobs.

Rob Parkin Ford doesn't make vehicles in the UK any more but all their production planning and robot programming is done in the UK in a virtual reality environment and the software is shipped to the line that it is going to be run on.

Aamir Khalid I think it's a great idea to ship these low-end jobs abroad, provided you keep the know-how and the IP in the UK.

Which project best encapsulates the mission of the MTC so far?

Andrew Long As an aside I should point out that the board does not always know about [all] the projects: we talk about them at the very top level and you may know about them if it's in an area you're interested in, so instead of naming an individual project I would say look at the equipment and the expertise that's in one place and you won't find anywhere else that has that.

Where do you see MTC going in the next 10 or 20 years?

Aamir Khalid This will be very much determined by the fee-paying members and what they want it to do. They will put the money into where they want it to go.

Andrew Long I agree. It's early days for the MTC: though it has expanded quickly, it's still really a start-up. The founding universities, and the other universities if they have things to offer, need to make the case better for what you might call technology push. Not just 'here's an idea, now give us some cash' but to say 'here are some disruptive ideas that are coming out of the universities: we think that they will have these particular benefits. We'll try and convince you of that, and if we do, how can the MTC help us develop them to a standard where industry can use them'. The gap, I believe, is between university research and the MTC. So if we develop a new manufacturing technology in our lab, there is no process at the moment by which that would be brought here to be taken through TRL four to six. At the moment the centre buys off-the-shelf state-of-the-art technologies, and the thing that's coming out of the university can't be bought by any supplier.

Richard Williams It will continue to work beyond aerospace and automobiles to encounter other sectors and deploy its design and optimisation tools to those sectors, whilst further advancing the original sectors of highest priority. It will have trained a new workforce and developed a talent pipeline in addition to a portfolio of wins for UK manufacturing.

> "It's early days for the MTC: though it has expanded quickly, it's still really a start-up" **Andrew Long**

> "It is a ripe time for industry to be looking at simulation, and technologies that are currently available to help us make more intelligent systems"

Joseph Darlington

Technology manager, virtual manufacturing, MTC

What did you want to as a career when you were a child?

I always wanted to be an engineer, and my dad wanted me to be an optician, because he thought it would be a [better] route to regular money. I applied to universities to study optometry, but I got my own way in the end and went with engineering.

What attracted you to the MTC?

My career background is in applied R&D, gained from working in numerous universities. My first degree was in mechanical engineering from Warwick University, and since then I have worked in various research roles, joining MTC in 2011.

I wouldn't claim to be an academic, but I'm passionate about research. I spent three and a half years at Bristol doing a PhD – working with JLR and Goodrich Aerospace – and two years at Loughborough, doing virtual manufacturing work. MTC is a really good fit for me, as it allows me to drive forward the simulation work we have, and getting it adopted in the industry is a big opportunity.

I see a long-term plan at MTC and I want to be a part of it. We have invested a lot in our group to make sure it grows, and there is still a lot of work to get to where we want to be.

What is a typical day like for you?

For me there isn't a typical day - it is really diverse, which is great. The area I work in covers a broad spectrum anyway, but as technology manager for virtual manufacturing I encompass everything from a 3D factory layout planning project, to ergonomics work. I also get involved in really detailed elements, such as programming, and designing robots offline, so that when you put the hardware in, they just work.

What aspect of your job interests you the most?

As an organisation we are in a really fascinating time, with big initiatives around, such as Industry 4.0, which effectively asks how we make manufacturing systems plug and play. Similar to how, when put into a computer, a USB gets recognised instantly.

So from a systems point of view you look at how you make that, and then put the IT over the top of the hardware to get all the intelligence out of it. Then related to that is all the simulation work. It is a question of doing more with the data we've got.

What would be your dream project to be involved in and why?

It is a ripe time for industry to be looking at simulation, and technologies that are currently available to help us make more intelligent systems. There is a huge amount of knowledge that exists in an engineer's mind, but the use of these technologies cannot be beaten.

Industry 4.0 is going to play a big part for us, and we need to be involved in it. So you could say I am already working on my dream project.

What is your biggest achievement/project been at MTC?

The biggest project I've led is Proving Factory, which is MTC working with Productiv and Tata Steel, who are trying to fill a gap for companies that develop advanced propulsion technologies, but are challenged by low-volume production. They want to build a KERS system, but for that to make it onto a road vehicle, car manufacturers will need five to ten thousand units to test, which is a huge challenge for relatively small suppliers.

We are currently working on designing an assembly system that delivers to those kind of volumes, and hopefully we will make a breakthrough soon.

Who has been the biggest influence on your career any why?

A lot of my drive comes from my Dad. He was very practical, and hands-on, so he has taught me to be fearless about what I do as much as possible. At MTC, the first six weeks are tough as there are so many projects to learn about. "Don't be frightened to have a go," was my Dad's motto, and I've tried to remember that.

Membership boost

Four new members have taken the already impressive membership of MTC to new levels. Joining at the strategic Tier 1 membership level is the air sector arm of global defence and aerospace leader BAE Systems – Military Air and Information.

"Becoming a Tier 1 member of the MTC was a natural choice for BAE Systems and one which complements our involvement with other centres within the High Value Manufacturing Catapult," said the company's head of manufacturing & materials engineering Andrew Schofield. "This helps us focus on specific areas of the development needed to support both our current and future products."

BAE Systems is joined by Alicona, a global supplier of optical 3D surface measurement for quality assurance in the laboratory and in production. Alicona's measurement capabilities will now be supporting the MTC's ground-breaking advanced manufacturing and engineering research. The third new member is Kennametal, a world-leading supplier of tooling, engineered components and advanced materials. Finally, as we go to press, the most recent addition to membership is global automaker General Motors.

Alicona celebrates its newly acquired MTC membership.

Siemens launches UK's first 'virtual factory'

Siemens has launched the UK's first digital factory demonstrator to showcase how a 'fourth industrial revolution' could shape the future of British manufacturing.

The launch – which was held in September at the MTC – showcased a virtual 3D factory alongside a physical production line capable of demonstrating mass customisation of consumer goods.

The virtual factory, also known as the Industry 4.0 demonstrator, is the first of its kind in the UK. Its immersive 3D environment allows users to interact with a 'living lab', which has been modelled from an existing machine that operates in the real world at a Siemens plant in Nuremburg.

The production line emulator operates continuously, assisting the creation of innovative production processes using new technologies – with the focus on increasing productivity, quality and energy reduction. Its launch was attended by a number of key figures from the UK government and the German embassy, including Martin Donnelly, the Permanent Secretary at the Department of Business, Innovation and Skills.

Siemens now wants to build a full living laboratory at the MTC, in which its immersive virtual reality 3D environment would be interactively linked to a UK living lab – similar to the one that already exists in Nuremburg. The company called for funding for this, and for tax-breaks to encourage further investment in automation technology.

Brian Holliday, MD of Siemens Industrial Activities in the UK and Ireland *(left)*, **Martin Donnelly, Permanent Secretary for BIS** *(centre)*, **and MTC CEO Clive Hickman** *(right)* **view some of the latest robotics research during the launch of Siemens' UK 'virtual factory'.**

MTC Achieves Quality Standard

The MTC has been awarded the respected and internationally recognised ISO9001 quality standard.

It achieved the prized benchmark after a detailed assessment process by the awarding body LRQA, which examined the MTC's core processes, its business management systems and its communications processes across the business.

MTC chief executive Clive Hickman said "It was a searching examination, but the rigour of our processes and our ability to adapt to the demands of a fast-growing business stood us in good stead. Because we have achieved so many of our business targets well ahead of schedule, and because we are growing so fast, it is important that we take a sure-footed approach to our processes and ensure the buy-in of everyone involved."

"In addition, the way we use technology to keep our people engaged with the business, and the way we focus on improvement rather than business-as-usual came in for special recognition."

Boris meets the Duke

Advanced robotics, surgical simulations and quantum technology were just some of the leading-edge innovations on show when HRH The Duke of Kent visited the Manufacturing Technology Centre for the Royal Academy of Engineering's summer soirée and exhibition in June. Amongst the displays was Boris – the most advanced upper torso humanoid robot in the UK. Equipped with two arms, a dextrous hand, and a stereo head with four cameras, Boris is able to grasp novel objects from cluttered scenes. Here Boris is viewed by the Duke (left) and Professor Jeremy Wyatt of the Centre for Computational Neuroscience and Cognitive Robotics at the University of Birmingham.

Virtual reality brings real competitive advantage

The MTC hosted an event in June for the Centre for Advanced Simulation & Modelling (CASiM2) project, demonstrating how the cutting edge simulation technology used to create video games and Hollywood blockbusters can be deployed by industry to model and simulate manufacturing challenges and processes.

"Virtual Reality is one of the most promising development areas in manufacturing," said MTC technology director Ken Young, "and the technology behind virtual reality has evolved to mean it's now user friendly and accessible for all businesses small or large. 3D technologies enable businesses to quickly explore, design, validate or communicate new products and operational initiatives, which provides businesses with valuable economic benefits."

Delegates at the event were shown how new simulation technologies can be deployed at each part of the value chain to add value to manufacturing processes. They were also informed how to access CASiM2 support and additional funding for simulation technologies and had an opportunity to tour the Manufacturing Technology Centre's cutting edge virtual reality suite.

New age Warrior

The MTC is providing its engineering expertise to Lockheed Martin in a project to extend the life of the British Army's Warrior battle tank. Lockheed Martin enlisted the services of engineers from the MTC to work on a design and development project for the armoured vehicle under the Ministry of Defence's Warrior Capability Sustainment Programme, which will extend the service life of the vehicle to beyond 2040.

Lockheed Martin has been working with the MTC to develop production processes for the enhancement of the turret on the tanks. The programme will involve each vehicle being taken out of active service, refurbished with improved armour and equipment, and fitted with more up-to-date armaments. It will ensure that the Warrior will continue to be at the heart of the Army's combat capability, with state-of-the-art firepower and electronics.

MTC member companies Sandvik, Brown and Holmes, DMG MORI-Seiki, CGTech and Roemheld also worked on the project. Each company contributed specific expertise with Sandvik providing advice on tooling strategy, Brown and Holmes supporting fixturing aspects which included Roemheld workholding solutions, DMG MORI-Seiki advising on machining and providing engineers' time to support the project. CGTech Vericut provided software support and verification of the CAD strategy.

"The working relationship between the MTC and Lockheed Martin project teams has been exemplary," commented Lockheed Martin programme manager Alan Jones. "This was a development project, and the flexibility shown by the whole MTC project team was a key factor in delivering a successful outcome. We were able to access expertise through the collaboration undertaken by the MTC's member companies."

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