INNOVATION MATTERS

ISSUE: 2024

Renishaw Central
Discover the connected machine shop

New and future business models
Exploiting new trends in manufacturing

Inside Renishaw's manufacturing
How to increase automation and productivity

Case study
Using additive manufacturing to mass produce medical parts

Innovation in action
How our products helped to make a probe that will explore Jupiter

Celebrating 50 years of innovation

50th anniversary mini-magazine free inside

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INNOVATION MATTERS

Contents

Turn to the inside back cover for your free 50th anniversary mini-magazine

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Applying innovation since 1973

Welcome to the Renishaw 50th anniversary edition of Innovation Matters. On page 47, you'll find a special mini-magazine, which charts our first 50 years of manufacturing innovations, following our formation as a company on 4 April 1973. We share the story of how it all began and trace our smart manufacturing journey from the 1990s to the present day and look to the future as we share our vision for transforming tomorrow together.

As Will Lee, our Chief Executive, says: ***"This is a year to reflect on the tremendous achievements of our co-founders and employees past and present, who have done so much to advance precision manufacturing globally, and to look forward with confidence to future decades of innovation and growth."***

This issue, on page 4, one of our industrial metrology experts shares technical and commercial insights from across the region in our new column. You can learn all about Renishaw Central, our new manufacturing connectivity and data platform, on page 5. In our 'New and future business models' feature, on page 15, we reveal the manufacturing trends shaping the factories of the future. Then, on page 28, we welcome you inside our manufacturing world to discover how we use Renishaw technologies in our own machine shops.

On page 26, our regular 'Innovation in action' feature demonstrates the power of additive manufacturing (AM) in the space sector. Discover the role that our AM technologies played in the lightweighting of components used in the European Space Agency's Jupiter Icy Moons Explorer probe, or Juice. With customers relying on our products and processes to help solve complex engineering and scientific challenges across a variety of industries and sectors, it's a well-known saying, here at Renishaw, that 'you're never too far away from something that's been produced using a Renishaw product'.

VIEW FROM...

The Americas

Dan Skulan
Role: General Manager, Industrial Metrology

Location: United States
Length of service: 27 years

Driving innovation from the start

Starting with the first touch-trigger probe enabling automated inspection, Renishaw has had a 50-year tradition of innovation that empowers industry.

At its heart, Renishaw always endeavored to bring solutions to industries around the world, and in 1981 its first subsidiary outside the UK was established in the United States. Initially providing repair services for co-ordinate measuring machine (CMM) probing systems, these operations expanded rapidly to drive the integration of machine tool probing directly at end users. This, in turn, motivated other equipment manufacturers (OEMs) to fit our product. This strategy is still in place today, where Renishaw sales and engineering staff drive demand through direct interaction with the world's leading manufacturing firms. As time progressed, our operations expanded to Brazil in 1995, Canada in 2003 and Mexico in 2012. Together, these subsidiaries form Renishaw Americas.

My association with Renishaw began in 1992 when the first ballbar was introduced to the US market through Federal Products where I was a sales engineer. I was honored to have serial number two of the "Quick Check" product and became obsessed with performing tests on customers' machines to teach others the value of establishing machine tool capability. This passion for Renishaw led me to join the team as Regional Sales Manager in 1996. Over the 27 years of my direct career with Renishaw, I've been blessed to help thousands of companies improve their manufacturing operations through our innovative products and exceptional people.

The Americas are diverse, from rugged seashores to gentle plains, mountain summits to grand canyons, and rainforests to deserts – there is an environment to please any taste. This diversity carries over to our manufacturing, where the Americas offer fertile ground for innovation in aerospace, automotive, medical, energy, defense and a vast array of other industries that provide a strong pipeline of opportunities for Renishaw to help our customers succeed. By sharing best practices, we continue to drive innovation through the greater global manufacturing community. I look forward to sharing more in future editions.

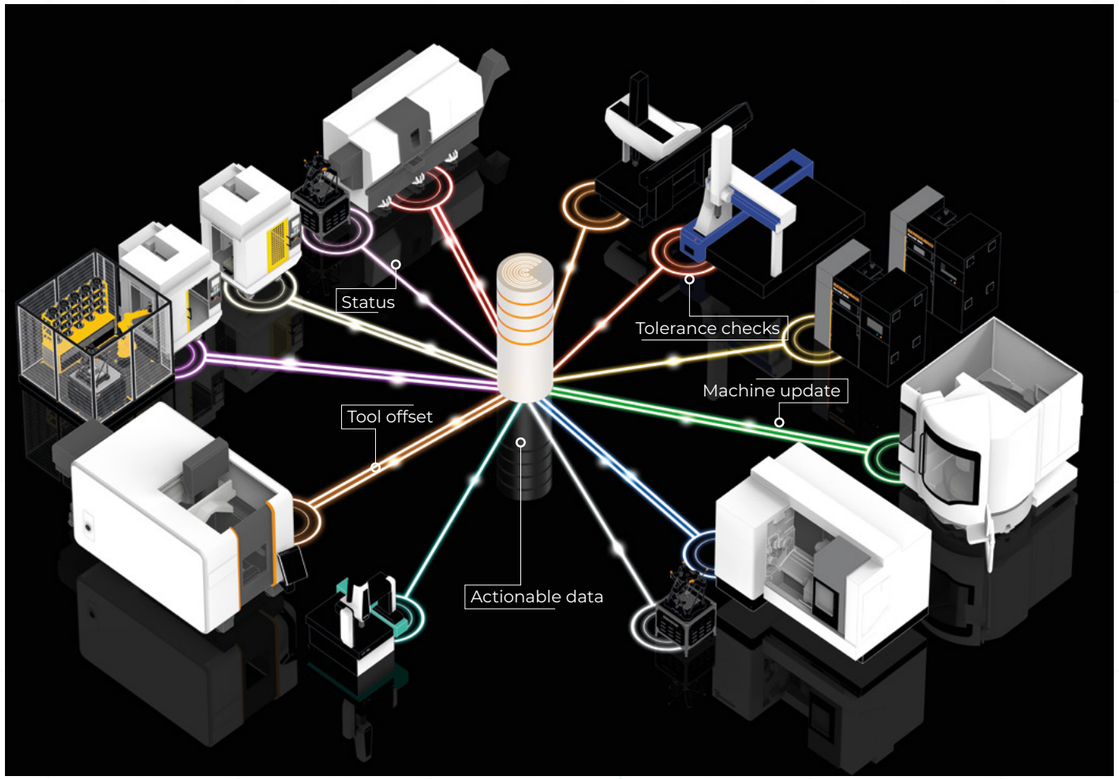
Dan

The connected machine shop: solving the shop floor connectivity challenge

Connect end-to-end manufacturing data from across the process chain with Renishaw Central

The journey towards data-driven production is both technically and operationally challenging. A key obstacle to overcome is implementing connectivity and networking the machines in your production areas. Data is the key to visualizing, understanding, and improving your manufacturing output, but connectivity is the key to creating an ecosystem in which that data flows seamlessly. Discover how our new smart manufacturing data platform uses connectivity to integrate manufacturing data.

The connected machine shop: solving the shop floor connectivity challenge



Global industrial digitalization has accelerated due to the COVID-19 pandemic, energy and inflationary pressures, supply chain instability and evolving sustainability targets. The digital transformation of industry will ensure that businesses are better equipped to operate with greater flexibility, agility and resilience. Digital technologies and platforms are essential to enhancing capability, efficiency and access to future technologies, and allowing businesses to improve processes, harness data, and embrace new and future business models.

The factory of the future is driven by data collected on the shop floor. We've seen rapid progress in technologies such as artificial intelligence (AI) and the Industrial Internet of Things (IIoT), which should help you run more efficient, increasingly automated factories. However, the use of shop floor connectivity to get these technologies working as interconnected systems within the manufacturing space isn't progressing at the same pace.

Introducing new technologies and processes is a major challenge for any business and its people. It requires a clear strategy and a willingness – throughout the organization – to embrace new initiatives. As manufacturers ourselves, we understand the complexities of integrating operational technology assets into a connected data ecosystem. It's one of many challenges delaying the mass adoption of advanced manufacturing technologies. However, the short-term pain of investing in digital transformation technologies will deliver longer-term competitive advantages.

Advanced technologies, including our own systems and sensors, have improved how quickly and accurately data can be captured. However, the ability to view, standardize, manage and analyze real-time information relies on connectivity. Connecting a machine shop is not easy, leaving many hesitant to implement the changes required to drive future manufacturing techniques.

The connectivity challenge: everything is 'different'

Every device on the shop floor is a valuable source of information about machines, processes and parts. Manufacturing data reveals what's happened in the past and what's happening now. With this information, you can predict what's likely to happen in the future and even use autonomous interventions to control processes.

Successful smart factory automation requires the consistent capture, transformation, and transmission of this data between the different machines in your factory.

The challenge is that most established manufacturers – ourselves included – continue to use existing legacy systems and only add new technologies when required. Most shop floor data originates from multiple sources, including sensors, controllers, and machines from different generations or made by different vendors. Different devices produce different types of data and communicate in different languages. But because most of these systems were never originally designed with connectivity in mind, it can be very difficult to establish seamless connectivity and data integration.

Connectivity is the digital thread that connects machines with other systems and each other, and allows them to communicate and exchange information. It's fundamental to creating production environments in which manufacturing data can flow efficiently. Collecting diverse data and being able to understand it, communicate with it and report on it in meaningful ways, clears the path to operating a fully automated, smart production facility.

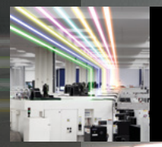
Now, thanks to Renishaw Central – our new smart manufacturing data platform for industrial process control – those looking to digitalize their end-to-end manufacturing operations can take their first steps towards getting their equipment speaking the same language.

Start capturing actionable process data

Anyone starting their digitalization journey needs data – and lots of it. Raw manufacturing data, from multiple sources, can be stored in a central repository. From there, diverse, unstructured data can be transformed into structured data for dashboards and other visualization tools for data analysis.

Renishaw Central is different because it provides contextual, process-related data. You can filter out the less important information and use what's left for activities such as predictive analytics, machine learning and process optimization. Collating information in this way allows you to discover correlations, patterns, and trends that could potentially be missed when analyzing data in isolation.

The connected machine shop: solving the shop floor connectivity challenge



What separates our data platform from the rest is that it can take the actionable process control data collected from the shop floor and use it to make real-time decisions and update processes automatically.

Renishaw Central: making connections

At the heart of Renishaw Central is the ability to connect measurement systems on machines across the shop floor, provide actionable data from connected machines in a central location, and use the data to automatically update CNC controllers.

The Renishaw Central smart manufacturing data platform connects new and legacy measurement devices from across the process chain, including on-machine measurement, shop floor gauging, co-ordinate measuring machines (CMMs), and sensor data from additive manufacturing systems.

The platform can collect and present process and metrology data, providing a clear view of shop floor operations. It standardizes the flow of information to and from the shop floor, making it easy for a variety of systems and processes to access Renishaw device data. This data can be used to analyze, identify, predict and correct process errors before they occur, for greater control over your manufacturing.

How is Renishaw Central different?

Our data platform provides powerful control over how information is passed between Renishaw devices, but it also has the unique ability to connect with a range of other machine and controller types. There are various standards for communicating between industrial devices, but they're not very 'standard' and are also subject to continual change.

Up-to-date machine and job information flowing from machines into Renishaw Central is made available in several ways, including standards-based output (such as MTConnect®), open application programming interfaces (APIs) and visualization in web browser views.

What separates our data platform from the rest is that it can take the actionable process control data collected from the shop floor and use it to make real-time decisions and update processes automatically. It also operates on-premises, giving you fast and robust process control feedback. This allows you to use local administrators, own your data, and ensure process control is not dependent on internet connections.

The connected machine shop: solving the shop floor connectivity challenge

Connectivity, consistency and control drive confidence

Connectivity

Connect multiple machines and devices to automatically detect which machines are running and determine why idle machines have stopped.

Consistency

Collect metrology data from connected devices in a central location and increase quality throughout the entire manufacturing process.

Control

Control process variables and gain operational knowledge over time. With intelligent process control software, automatically calculate adjustments and update tool offsets or variables.

Confidence

Understand, trace and build confidence in your processes and reap the benefits of true lights-out manufacturing.

Renishaw Central allows you to:

- Connect to a standalone machine or to multiple, networked machines
- Capture, transform and transmit data consistently
- Compare efficiency, accuracy and quality across jobs, machines and sites
- Access in-depth analytic features and consolidate real-time data as reports
- Analyze and health-check machine performance
- Examine device utilization and component quality
- Sign off and validate parts and processes

Connectivity for process automation

By design, Renishaw Central supports automated process control. This includes in-process probing measurement data, in-line (or near-line) gauging data, or end-of-line CMM inspection data. Results are collected by Renishaw Central, where intelligent process control (IPC) software supplies automatic closed-loop feedback.

The system's flexibility allows measurement data from any device to be used for the control of processes on any CNC machine. In an automation context, Renishaw Central provides confidence that part quality is being monitored, tracked and acted upon. This helps to overcome a well-known concern among automation users that, without supervision, automation systems can 'produce scrap at an impressive rate'.

Improving the interconnectivity between systems makes it easier to implement automation. Lights-out manufacturing depends on reliable connectivity and the seamless flow of data between machines, sensors and control systems for real-time monitoring, process control and co-ordination of automated processes.

Accurate actionable data from Renishaw Central allows you to implement smart factory process automation and continuously improve and modernize your processes. With effective *process* automation technologies in place, you can start to implement *physical* automation and draw more value from your equipment.

Automated process control allows you to:

- **Analyze, identify, predict and correct process errors before they occur**
- **Overcome skill shortages on the shop floor**
- **Increase machine uptime and output without adding more machines**
- **Minimize energy requirements**
- **Eliminate scrap components**

The connected machine shop: solving the shop floor connectivity challenge

Developed in our machine shops

Renishaw Central's functionality has been developed and tested within our Miskin and Stonehouse sites in the UK. For over 30 years, we've been using insights from the data captured in our machine shops to automate our production processes. By connecting our physical systems, sensors and processes with computational systems and software, we developed powerful rules for controlling processes.

The configuration of how processes are controlled and the rules and options available within the Renishaw Central software were all captured, learned and developed within our machine shops. Our experience in refining automated closed-loop process control has been built into Renishaw Central. The things we've learned in our factories enable us to support customers with user-friendly software and apps designed with them in mind.

We support our global customers with their smart manufacturing ambitions by helping them to operate their 'factories of the future' now. Supporting connected machine shops, Renishaw Central enables you to connect measurement sensors on machines across the shop floor, monitor data from connected machines from a central location, and use the collected data to update CNC controllers.

We recently implemented Renishaw Central connectivity at our well-established, low-volume, high-variety machine shops in the UK. Our Manufacturing Services team created a central store for collecting metrology, quality and utilization data to help increase proactive decision-making on our shop floors and to reduce assumptions when problem solving. However, Renishaw Central soon presented us with actionable data that would otherwise have remained hidden.

CASE STUDY

Our UK machine shops used Renishaw Central to boost weekly machine availability by 79 hours

Renishaw Central was born out of our own need to digitalize, visualize and control manufacturing and measurement processes within our production facilities. We wanted to reduce assumptions when problem solving and support the adoption of automated process control. We live and breathe many of the challenges our customers face, so we're confident that we've created a digital solution to drive actionable data across machine shop floors everywhere.

Challenge

As manufacturers ourselves, we face the same production challenges as our customers. Our top priorities are process improvement and reducing downtime and scrap. Ultimately, any process improvement can significantly affect the productivity and profitability of a manufacturing shop.

Solution

Confident in Renishaw Central's capabilities, we decided to implement it across our manufacturing sites in the UK. This powerful platform allows data collection from multiple machines across various sites. This empowered us to delve deeper into the data and identify trends and patterns that might otherwise have gone unnoticed. Renishaw Central enables us to monitor machine status, identify errors, assess machine health and gain valuable insights into quality from a metrology perspective.

Results

Across the 23 automation cells involved in the initial study, we achieved a weekly increase of 27.5 hours of machining availability. Renishaw Central and the productivity improvements were subsequently introduced across 66 automation cells, correspondingly increasing the gains.

Renishaw Central's connectivity with Microsoft® Power BI enabled analysis of the detailed process data, demonstrating clearly that 82% of automation stoppages were associated with the top two error types. Targeted remedial actions, focused specifically on these two errors, significantly reduced the number of unplanned stoppages. Fewer stoppages increased machine and operator availability for other tasks.

The set-up process for the manufacture of new parts on sliding-head (Swiss type) CNC lathes is traditionally an area in which automation is difficult to apply. Early trials applying Renishaw Central's IPC functionality to such machines indicate a possible reduction in set-up time in the order of 85% on the most complex parts.

Visit our website to read the full case study.
www.renishaw.com/central

New and future business models

Exploiting new trends in manufacturing

Are you ready to embrace new business models and transform how your business creates, delivers and captures value?

Historically, the biggest periods of significant economic growth have been fuelled by manufacturing revolutions. The first came during the mid-19th Century courtesy of the introduction of steam power and the mechanization of manual work. Second was Henry Ford's electrified mass production assembly line in the early-20th Century. Then, in the 1970s, came electronics and computer technology to automate manufacturing and production. Each industrial revolution created major economic growth by transforming the productivity of the time.

Today, industrial digitalization and the rapid fusion of physical and digital technologies – the fourth manufacturing revolution – will again drive growth and enable us to make better, smarter products.

Businesses today are concerned not only with productivity and getting products to market quickly and efficiently, but also with finding ways to leverage technology to their advantage. In our constantly changing economic and geopolitical landscape, productivity alone is no longer enough.

More manufacturing businesses are looking to design increasingly innovative, custom-made products in smaller, more agile, multi-product factories. They want to do this near to the end consumer, and all in the same time – and for the same unit cost – it would take to mass produce that product. To achieve this requires flexible production strategies.

The fourth industrial revolution will provide the key elements we need for growth – productivity and flexibility. This will make it possible to produce a batch of one product for the same cost and lead time per unit as for a batch of many.

New and future business models

What's driving business model innovation?

Industrial digitalization presents exciting opportunities for us to reimagine how we design, make and sell products. In the 50 years since our company was founded, the lifecycle of the average business model has shortened from around 15 years to less than five. New production technologies are helping manufacturers and supply chains to develop new business models that deliver longer-term advantages and more value for the consumer. Not necessarily discarding current business models, but rather introducing new ones that create fresh opportunities for revenue and growth. Drivers pushing businesses to explore new models include demand, disruption and digitalization.

Trends in consumer demand:

- **Hyper personalization**
- **eCommerce**
- **Fast-changing consumer demand**
- **Low carbon footprint products**
- **Reusable products**
- **Recyclable materials**
- **Frictionless purchases**
- **Transparent product information**
- **Rapid product innovation**

Buyer behaviors change all the time. Historically, the challenge for manufacturers has been to predict and respond to increasingly fast-changing demand environments. However, production planning is now less about predicting demand and more about manufacturing on-demand. So what do today's consumers really value and what will the experience of choosing, purchasing and receiving goods look like in the future?

Some expect nothing less than highly designed, flawlessly machined consumer electronics, ordered online, delivered the same day and with an upgrade to the latest model expected within 12 months. Others won't be impressed if their purchasing experience is not personalized, offering a wealth of options and unique specifications. Fast-growing numbers also want products with low carbon footprints and which can be either reused and/or recycled.

To meet such a wide range of new and differing product qualities and specifications, manufacturers and supply chains need greater levels of agility, flexibility and collaboration.

Let's get personal

Many consumers now pursue customized products that deliver a more personal purchasing experience and which offer additional value over standard products. Business models are now shifting to reflect this by giving customers what they want, not telling them what they can have.

Mass manufacturing focuses on continuously making a standard product in large quantities for the lowest cost. Production processes are rigid and design changes are expensive, requiring reinvestment in tooling and manufacturing processes.

Conversely, custom manufacturing focuses on the process of designing and making products based on a customer's individual specifications. Custom production is a manual process with much lower throughput. Further, it cannot easily be scaled, making the costs and delivery timescales unacceptably high to most customers.

As demand for personalization grows, neither traditional mass manufacturing nor traditional custom manufacturing are sustainable. The new approach is 'mass customization', which combines the flexibility and individuality of customization with the high volumes and low unit costs associated with mass production.

Advanced manufacturing and production technologies will play a key role in the growth of mass customization, enabling businesses to leverage data to run increasingly flexible production environments capable of making parts on demand.

New and future business models

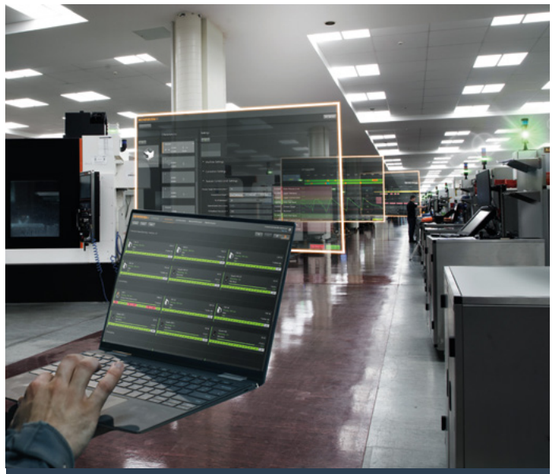
Using data to take control

End-to-end process data capture is invaluable for the insight, analysis and improvement of manufacturing processes. It allows manufacturers to predict, identify and correct process errors before they happen and pool that data for machine learning. Digitalization of end-to-end manufacturing processes increases operational efficiency, reduces reliance on skills, improves ease of use and enhances decision making for process improvements.

Our range of industrial metrology technologies support intelligent manufacturing. You can adjust and maintain control of CNC machining processes automatically, without skilled manual intervention. The results of machine tool probing and off-machine gauging, for example, can provide real-time process information and traceable individual feature inspection data which can be used to update tool offsets and adjust for process drift automatically.

Our IPC (intelligent process control) software can show variations between features produced on multiple parts, and identify process drift or tool wear. It then produces an instruction for the machine tool controller to update the tool offset and bring the process back under control.

Our new manufacturing connectivity and data platform, Renishaw Central, helps you to access the right manufacturing data at the right time, so that you can better understand production processes and improve your process control and part quality.



Smart manufacturing production strategies offer greater levels of customization, allowing manufacturers to cope with the high-variety and low- or even single-batch production of custom-made goods.

At the heart of Renishaw Central is the ability to connect measurement systems on machines across the shop floor, provide actionable data from connected machines in a central location, and use the data to automatically update CNC controllers.

The ability to control variables and obtain knowledge over an extended period can provide insight into your entire manufacturing process, today, tomorrow and at any point in the future.

The trend towards mass customization requires manufacturing processes that can accommodate wide product variety, often with short lead times. Flexible or programmable equipment is essential.

New and future business models

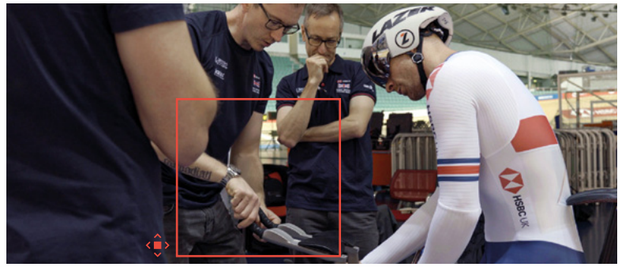
We design and manufacture additive manufacturing systems for making parts with a variety of metals, using a process called metal powder bed fusion.

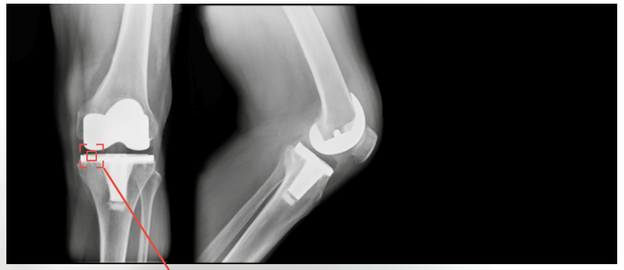
Increase your speed to market

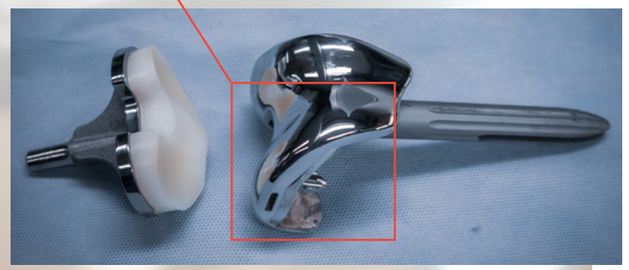
Other manufacturing technologies that support personalization and flexibility include additive manufacturing (AM), also called 3D printing. This involves creating a three-dimensional part from a digital file. Thin layers of material are used to create complex shapes, which cannot be produced using 'traditional' techniques such as casting, forging or machining. The new design possibilities provided by AM include opportunities to design and test previously impossible parts and tools, combine multiple components in production, minimize material use and reduce tooling costs.

Traditionally a high-cost phase of product development, prototyping is used to simulate, validate and launch innovative products. Today, however, use of AM can dramatically reduce prototype part development time and costs, as well as the production time and cost of manufacturing custom parts.

The design freedom offered by AM supports mass personalization and flexibility, and is capable of producing fully customized parts, allowing multiple custom designs to be produced in one build, or batch. Our AM systems have been used to validate designs and quickly transfer production from prototype manufacture to commercial production, helping manufacturing and design communities to bring new products and components to market faster than ever before.







By incorporating personalized products next to their core products, businesses can respond to the demand for personalized products where individualization adds value.

Rapid product development

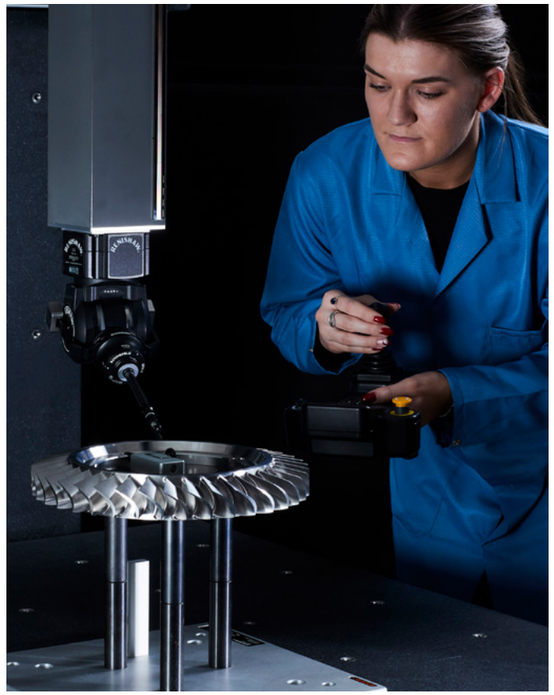
Product development times and product lifecycles are shorter. Few businesses can reinvest in tooling and equipment every time a product design changes or an innovative new product is developed. Instead, manufacturers need to be investing in versatile machining and measurement equipment, which can be reprogrammed or repurposed.

Renishaw's metrology systems and sensors are increasingly being applied to support flexible manufacturing. With our Equator™ gauging system, for example, you can save time and improve the efficiency of multi-device inspection processes. Programmable in-line gauging keeps processes centered and delivers quality assurance close to the point of manufacture. And it's starting to replace hard gauging in a variety of fast-changing sectors, including electric vehicle development.

Integrating Equator gauges into your production process can significantly reduce shop-floor gauging time. The Equator system can provide a fast method of measuring parts with the flexibility to adapt to different and fast-changing project requirements.

New product innovations often require increasingly complex parts, and we've incorporated multi-sensor functionality and the ability to measure a variety of feature types into many of our products. For example, our machine tool and co-ordinate measuring machine (CMM) probing systems offer surface finish and waviness measurement.

Visit our website to learn more about our solutions for electric vehicle manufacture.
www.renishaw.com/ev



Multi-sensor metrology equipment can transform manufacturing capability and versatility by enabling the measurement of a wide variety of different part features on a single platform. Renishaw's REVO® 5-axis CMM probing system with multiple probe sensor types, for example, can rapidly scan parts to inspect form and surface finish on a single integrated platform. Increasing the work that can be done on one CMM removes the need for other dedicated equipment and frees up valuable shop floor space. The addition of automatic surface finish measurement also minimizes the number of times a part is moved between platforms and the risk of damage to parts.

Design for manufacturability (DfM) involves optimizing a product's manufacturing process during its design. This means that you can ensure the product is easy and efficient to manufacture, assemble and test. Proven DfM methodologies in machining and inspection not only minimize manufacturing costs and ensure high quality and reliability, but also help to accelerate the new product pipeline. DfM is widely used in industries such as automotive, aerospace, electronics and consumer goods.

New and future business models

Local manufacturing hubs

To scale product innovations faster and achieve supply and demand goals, companies could be wise to increase collaboration with other partners. This could mean outsourcing manufacturing to specialist third parties or using local manufacturing hubs. New, environmentally conscious models include manufacturing products ‘made to order’ and close to the end consumer. Goods shouldn’t be travelling the world and then sitting in stockpiles before reaching the end customer.

Many have found, through the pandemic and times of geopolitical tensions, that sourcing locations need to be flexible. Distributed sourcing, with factories and suppliers in multiple locations, can help you to stay productive. The need for robust flexible manufacturing that is supported by digital information is critical.

Globalization is entering a new era, and the change will be significant. As developing economies become richer, the new manufacturing revolution will accelerate the transition of those emerging economies towards a growth model driven by domestic consumption.

For more mature economies, ‘bringing manufacturing home’ will create jobs, increase productivity and drive growth. However, it will also require a major shift in attitudes towards manufacturing, as well as the retraining of the domestic workforce.

The cost of manufacturing goods will soon be on par wherever you are in the world, and the fourth manufacturing revolution has the potential to promote sustainable growth in all economies.

Disruption provides manufacturers with opportunities to pursue new and innovative ways to approach production and find fresh ways to meet new and drastically different customer demands.

Disruption! Is there really an upside?

Disruption affects our ability to deliver products, manage the supply chain, and serve customers in the traditional way. It can take many forms, including geopolitical trade conflict, evolving climate change regulations and, of course, a global pandemic. Advanced manufacturing technologies can help to address disruption and even provide opportunities to gain competitive advantage.

The manufacturing supply chain is critical to the global economy. Few things have highlighted this more clearly than the widespread and unexpected disruption caused by COVID-19. The global pandemic forced many to fast-track plans to implement industrial digitalization to stay in business.

At the start of 2020, most manufacturers were still in the early stages of their digital transformation journeys, tending to focus on efficiency and producing more with less, rather than exploring longer-term opportunities and on-demand manufacturing. With the pandemic, however, came a new sense of urgency, requiring everyone to rethink their digital strategies and, in some cases, explore new opportunities.

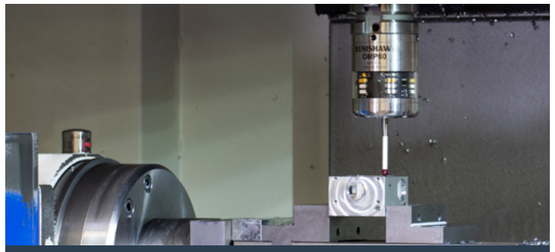
We’ve always worked to engineer solutions to real-world customer challenges, and our range of automation technologies had a role in helping our partners to flex and adapt rapidly to the many and varied demands of the pandemic. For example, where social distancing was needed within factory environments, manufacturers like us had to reduce the number of personnel moving around sites. The most effective way to do this, without reducing productivity, was to increase automation.

In our UK production facilities, we operate highly productive low-volume high-variety manufacturing.

Where product mix is unpredictable or likely to change, we use on-machine probing, which is proven to help maximize the efficiency, quality, capability and accuracy of machine tools. Automating traditionally manual activities, such as part set-up and process monitoring, simplifies operations and reduces manual intervention.

Our on-machine probing solutions for CNC machine tools include SPRINT™ technology with touch-trigger and scanning capabilities. SPRINT technology delivers high-speed, high-accuracy automated part set-up and measurement, feature form detection, and surface condition monitoring. Many businesses emerging from the disruption of the pandemic are now applying these sorts of new technologies to remodel their operations around themes of flexibility, resilience and sustainability.

Disruption can reveal opportunities to pursue new and innovative ways to approach production and find fresh ways to meet drastically different customer demands.



Our SPRINT on-machine scanning technology supports flexibility, resilience and sustainability.

COVID-19 was a catalyst for change, which saw many businesses transform their digitalization strategies just to stay in business.

New and future business models

Industrial digitalization

The digital transformation of industry has the power to improve and control many aspects of the manufacturing process, enabling all of us to develop game-changing new business models capable of fulfilling new customer demands. The availability of real-time manufacturing data and insights, for example, allows businesses to react and make decisions quicker, and supports predictive analytics for improving the design of future products and processes.

Improvements to the interconnectivity between systems and easy access to automation will also be vital to enabling the effective adoption of new processes and technologies. Those manufacturers who have embraced the fusion of physical and digital technologies will stay competitive by using these advanced manufacturing technologies to keep transforming and innovating their businesses.

As we see the latest industrial revolution transform the productivity of today, we're confident that our manufacturing customers will be equipped to embrace innovative new business models and become the smart factories of the future.

Many businesses are remodeling their manufacturing around themes of flexibility, resilience and sustainability with the help of Industry 4.0 technologies.

Visit our website to explore how Renishaw technologies are applied in your industry.
www.renishaw.com/casestudies

RENISHAW
apply innovation™

DESIGN | BUILD | MACHINE | INSPECT

The total AM process chain

Can your partner for additive manufacturing (AM) provide end-to-end expertise and support?

Only one company in the 3D printing industry offers the technologies and expertise that provide both highly productive metal 3D printing AND control of all finishing and downstream processes.

For end-to-end process control of AM parts, speak to Renishaw now.

www.renishaw.com/amprocesschain

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INNOVATION IN ACTION

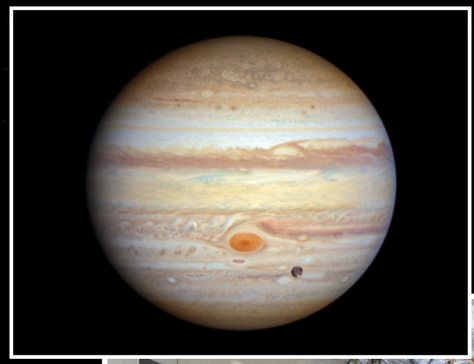
Renishaw produces 3D-printed brackets to help ESA study Jupiter and its satellites

The European Space Agency (ESA) is leading a mission to study Jupiter and its moons, and they're using 11 additively manufactured (AM) brackets to help them do it.

Produced using the highest strength aluminum alloy for 3D printing, Scalmalloy®, these brackets are 50% lighter than traditional ones, thanks to a collaboration between CATEC, Airbus, ESA, and CITD.

Our Spanish subsidiary, Renishaw Iberica, has been working closely with CATEC to engineer these brackets, and we're delighted to be a part of this exciting mission.

The JUICE space probe launched on 14 April 2023 and will reach Jupiter in 2030, where it will spend at least three years making detailed observations.



Main image: spacecraft: ©ESA/ATG medialab; Jupiter: ©NASA/ESA/J. Nichols (University of Leicester); Ganymede: ©NASA/JPL; Io: ©NASA/JPL/University of Arizona; Callisto and Europa: ©NASA/JPL/DLR. Inset image JUICE prepared for fuelling: ©2023 ESA-CNES-ARIANESPACE / Optique vidéo du CSG - P BAUDON

INSIDE RENISHAW'S MANUFACTURING

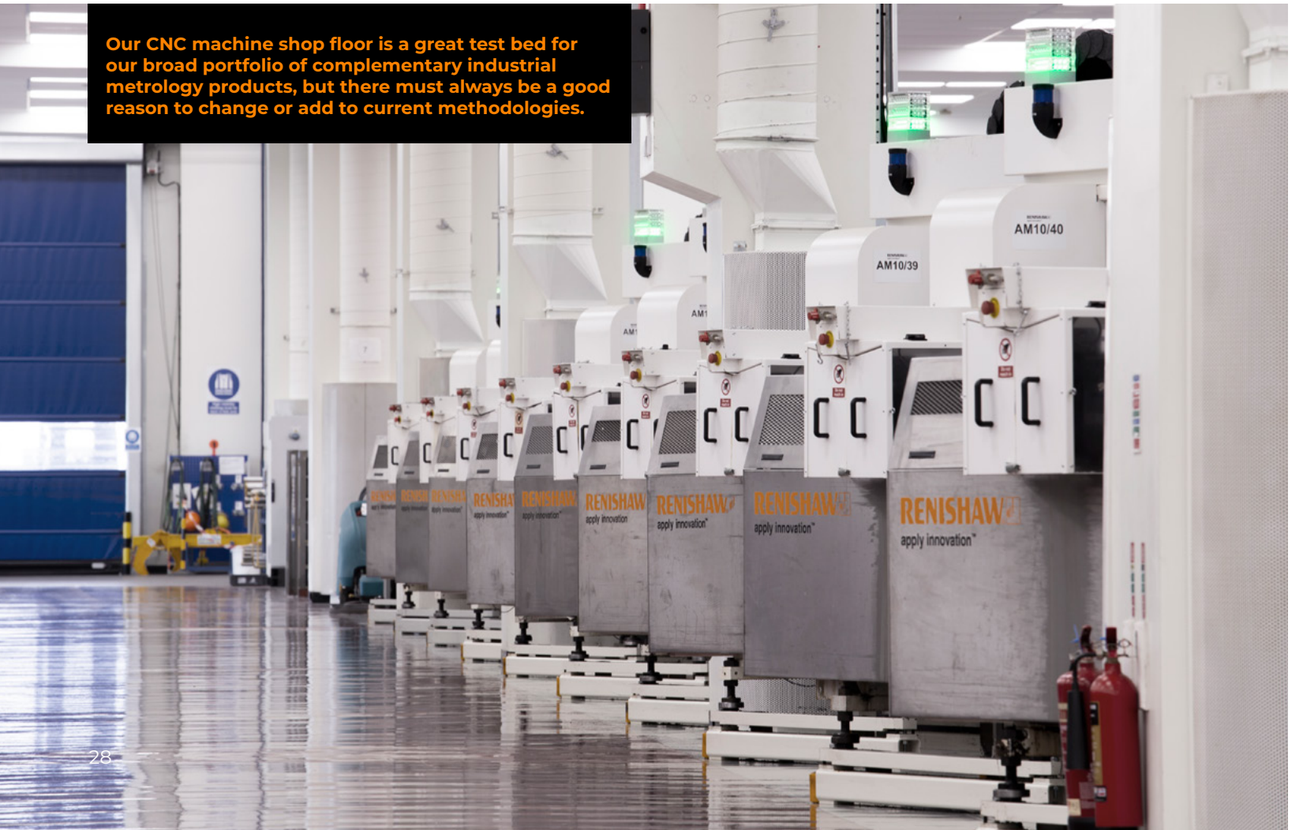
Find out how we use our own technologies to increase the levels of automation, productivity and capability in our machine shops

Renishaw is best known for the design, development and delivery of precision measurement and process control solutions for manufacturers.

Our products have been used in and around the manufacturing industry since the 1970s – particularly in CNC machining and quality control.

As a vertically integrated company, we have significant in-house manufacturing capabilities and use our own products in the precision manufacture of the technologies we sell. In fact, our own Manufacturing Services team are among our most demanding and discerning customers. These teams of experienced process design specialists, production engineers and quality technicians skilfully weave Renishaw technologies into their everyday CNC machining operations. They ask questions, provide feedback on current product performance, and won't hesitate to challenge new ideas. New technology is only introduced to our shop floor if it's proven to provide efficiency or manufacturing benefits that are at least equal to an established process.

Our manufacturing experiences are powerful, and we believe in our products. Using them every day in our factories has allowed us to achieve consistent capability, high levels of productivity, and lower costs. The intelligence that our business gains from our shop floors, by those applying our technologies in the real world, is vital to product development. If a product's right for us, it's likely to be right for our customers. Welcome inside our world of precision manufacturing...



Our CNC machine shop floor is a great test bed for our broad portfolio of complementary industrial metrology products, but there must always be a good reason to change or add to current methodologies.

How we apply our technologies: the Productive Process Pyramid™

Process variation is the primary barrier to consistent, efficient and productive machining. To combat uncontrolled variation in our machine shops, we built a framework of control around our machining processes. We call it our Productive Process Pyramid™. A structured approach allows us to identify sources of variation, including raw materials, environmental conditions in the factory, machine tool capabilities and, of course, human error.

Our Pyramid features four distinct layers of control which, when applied at the right times, build upon one another to systematically remove variation from the machining process. Anything that could affect machining variables is accounted for in the Pyramid.

We're proud to be among the most efficient manufacturers in the world. Visitors often remark on the cleanliness of our state-of-the-art manufacturing facilities.

Post-process monitoring

The Post-process monitoring layer features informative controls that are applied after machining is complete, to provide us with information that allows us to improve the process.

In-process control

The In-process control layer features active controls that are applied during metal cutting, to allow the process to adapt to known variation.

Process setting

The Process setting layer features predictive controls that are applied just before metal cutting starts, to remove large variations and prepare for the machining process.

Process foundation

The Process foundation layer features preventative controls that are applied before machining starts, to establish good conditions for machining.

INSIDE RENISHAW'S MANUFACTURING

1.

Process foundation
The foundation of advanced manufacturing facilities

Each layer of the Pyramid comprises a series of controls which, together, tackle sources of machining process variation. We use our Process foundation layer to create stable conditions for machining. Monitoring and optimizing machine performance gives us a stable platform upon which to carry out our machining operations. This is critical to the automation of our manufacturing processes.

The following necessary preventative controls are applied to reduce the number of sources of variation before machining starts:

- **Machine performance**
- **Environmental and input controls**
- **Process design**
- **Design for Manufacture**

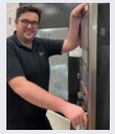
Calibration plays a key role in the Process foundation layer. Our systems have built-in alerts, which tell us when to calibrate our machines. This gives us confidence in what we produce. Even the best machines with the most qualified operators will produce defective parts if there are positioning errors within the machine tool. To monitor the condition of our CNC machines, we've established regular, repeatable processes and schedules for health-checking our machine tools.

A range of machine error sources can be identified and quantified using our high-accuracy QC20 ballbar. This quick test provides a powerful assessment of a machine's performance and allows us to identify where and when remedial action may be required. The QC20 ballbar can perform tests in all three orthogonal planes from one set-up, carrying out a 220° arc in two of the planes, and a full 360° in the third. The Ballbar 20 software generates diagnostic reports for fast machine tool performance diagnosis. Errors are ranked according to significance to the overall machine performance.

QC20 ballbar: industry-standard machine tool performance verification

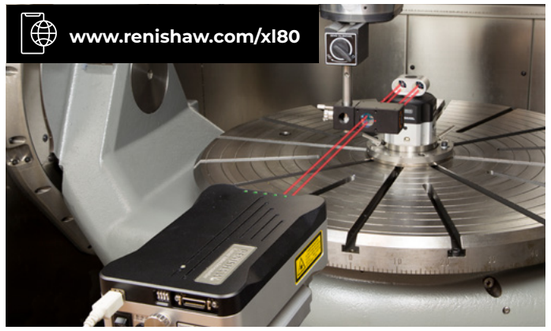
- **Ensure accurate CNC machined parts, first time.**
- **Reduce machine down time, scrap and inspection costs.**
- **Implement fact-based predictive maintenance.**

"We regularly use the QC20 ballbar in the machine shop to verify the geometric capability of CNC machine tools. In the event of failure, we use the ballbar to quickly diagnose problems that may require corrective actions. The QC20 ballbar is very intuitive, and its user interface provides an efficient and consistent approach across all our key machining platforms."



Dan Thomas, Senior Plant Maintenance Engineer

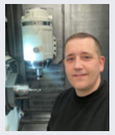
Our XL-80 laser interferometer offers high-performance measurement and calibration of motion systems in our factories. The XL-80 system is quick and easy to set up and offers solutions for a range of applications. We use it for axis calibration for new machines, whenever we move a machine, or when we perform a significant maintenance activity. Unlike laser tracker systems, XL-80 measures a machine's geometric errors independently, which means specific errors can be isolated and the data used to compensate and improve machine performance.



AxiSet™ Check-Up: quick, easy and automated set-up and health checking for multi-axis machine tools

- **Measure and report on machine performance in minutes.**
- **Achieve accurate and consistent results using fully automated probing tests.**
- **Track machine performance over time using the AxiSet Check-Up app, which displays measurement data graphically.**

"Using AxiSet Check-Up calibration software on our large milling and turning machines allows us to accurately align all axes of the machine. This, combined with frequent health checks and automatic updates of the parameters, helps keep machines finely tuned and minimizes the need for maintenance callouts. This eliminates human error, reduces downtime, and increases productivity."



Craig McCarthy, Development Engineer

For the calibration of our large mill-turn machines, our AxiSet™ Check-Up software helps us to maximize the stability of the environment and the machine. We can analyze the performance of rotary axes and identify any problems caused by poor machine alignment, geometry and pivot point errors, which could cause extended process setting times and non-conforming parts. When used alongside our QC20 ballbar and XL-80 laser interferometer, AxiSet Check-Up provides an unparalleled solution for machine diagnosis.

Our technologies help us to maintain machines that we know are reliable and capable of producing correct components first time, every time. A great example of how an innovative new product can transform the accuracy of a machine is our XM-60 multi-axis calibrator. We use XM-60 on our new large 6 m bed machines for flatness and straightness compensation. It allows us to achieve better representation of straightness errors on longer axes. As manufacturing tolerances tighten, we've found this is the only way to achieve the level of accuracy we require for this machining application.

XM-60 multi-axis calibrator: one-pass full machine geometry measurement and correction

- **Measure all six degrees of freedom in any orientation from a single set-up.**
- **View results while the test is in progress for added reassurance.**
- **Minimize human error with automatic sign detection and graphical alignment.**

"We use the XM-60 multi-axis calibrator for axis measurement and error compensation on our largest 5-axis milling machines. The benefit of using XM-60 is its ability to reduce errors within the machine, which allows us to achieve very tight tolerances on our larger parts. The product is very user-friendly and allows for easy multiple axis compensation."

Carwyn Davies, Production Engineer

INSIDE Rrenishaw'S MANUFACTURING

1.

Process foundation continued...

Six degrees of freedom

Any object moving in 3D space has six degrees of freedom and therefore six potential types of error in motion. These are linear, horizontal straightness, vertical straightness, pitch, yaw and roll. For systems with more than one linear motion path, such as 5-axis milling machines, the six types of error in each path will combine to form the overall motion error.

Each of the six types of movement represents a value that must be captured and tracked to ensure accuracy. Using the XM-60 multi-axis calibrator to measure the errors of all six degrees of freedom simultaneously and directly for any orientation of motion, is a huge benefit in today's increasingly automated manufacturing environments.

XM-60 multi-axis calibrator

Renishaw encoders: precision motion and accuracy embedded in our manufacturing

Use of our own industrial metrology products has helped us to transform the quality and productivity of our output. However, there's another critical Renishaw technology that contributes significantly to the performance of our factory operations.

Motion systems used in manufacturing, such as CNC machine tools and co-ordinate measuring machines (CMMs), demand high levels of accuracy and performance. As we've learned from the Process foundation layer of the Pyramid, the quality of every component produced on a machine tool depends on the stability of the process and the accuracy of the machine.

We design and supply cutting-edge position encoder technology to the world's precision measurement, automation and manufacturing industries. We offer a wide range of high-speed, absolute and incremental, linear and rotary encoder systems to meet the diverse requirements of industrial automation.

Our encoders measure and track the linear and rotary position, velocity, and direction of motion in various applications. This ensures the accuracy, reliability and performance of machines with motion systems.

Although we don't use our encoders to actively maintain the elements of the Pyramid, they're fundamental to the performance and operation of the motion systems used in the manufacture of our products. As well as being integrated into the machine tools and CMMs we use, our encoders are also found within several of our products. For example, Renishaw encoders support the fast, accurate and repeatable range of motion on our exceptional Equator™ gauging system. The motorized probe head on our REVO® 5-axis metrology system (pictured left) also offers ultra-fast yet accurate synchronized motion thanks to Renishaw encoders.

Our encoder technology is incorporated into the specialized test rigs we use to evaluate and verify the performance, accuracy, repeatability and functionality of our products. We're so confident in the performance of our encoders that we rely on them to verify products.

Renishaw encoders support the impressive range of motion within our REVO 5-axis metrology system.

Faster, automated set-up allows our machines to spend more time performing their central objective: cutting metal.

www.renishaw.com/ots

2.

Process setting
Ensure that the first cut is accurate

Building on the stability introduced by the Process foundation layer, Process setting controls help to eliminate human error by automating manual processes. Just before metal cutting starts, we perform Process setting activities on our machine tools to establish the relationships between the machine, the parts and the tools. When we know the location of the parts, the size of the tools, and the machine offsets, we can predict whether processes will be successful.

The following automated, predictive controls are applied to remove large variations and prepare for the machining process just before metal cutting starts:

- **Machine setting**
- **Part setting**
- **Tool setting**

We use our repeatable probing technologies to automate setting activities. Automation allows us to set up our metal-cutting operations up to ten times quicker than manual methods.

Machine setting controls establish relationships between the key moving elements of a machine, such as the alignment and position of the milling spindle and the machine bed, or the pivot point of the milling spindle on a mill-turn machine. The effects of uncorrected machine errors are often mistaken for other sources of process variation. Thermal drift, for example, causes variation in even the most stable environment, causing errors that result in extended setting times and process non-conformance. On-machine probing checks can measure these errors, so that machine-specific work offsets can be calculated.

We use a range of contact and non-contact tool setting systems to determine geometric information about the cutting tools on our machines. On-machine tool setters measure the length, radius and/or diameter of the tool, and even the condition of the cutting edge. After critical machining processes, we'll either use the same tool setting system or a dedicated broken tool detection device to identify tool wear or breakage.

Tool setting activities improve our manufacturing processes and allow us to:

- **Check that the correct tool for the scheduled machining program has been loaded**
- **Adjust for tool wear**
- **Automate tool offset updates**

Depending on the size and type of machine, we choose either contact or non-contact laser beam-based systems for the precise setting of our cutting tool parameters. For tooling and part set-up on milling machines, for example, we use our compact TS27R contact tool setting probe (hard-wired signal transmission) and our OTS 3D touch-trigger tool setter (optical signal transmission).

Part setting traditionally involves human intervention, but we use probing to automate workpiece setting and establish work offsets. Our process involves using a tool setter to find the end of the tool. We then machine a test cut feature and inspect where the tool impacted the part geometry and determine the size, orientation and position of the feature. By comparing expected tool position values with actual measurements, we can identify any part-loading errors before machining starts and apply work offsets for accurate part set-up.

On our large turning machines, we use the RP3 tool-setting kinematic probe for workpiece set-up. Its short body length provides advantages in tool setting applications. For tool setting on lathes where space is at a premium, we use a 'plug in' arm, such as the HPRA high-precision removable arm, which is manually located inside the machine, locked into a repeatable kinematic location, and then removed once the tool setting process is complete.

3.

In-process control
Give your process the best chance of success

With stable machining conditions and the ability to make predictions about whether processes will be successful, we can implement the In-process control layer of the Pyramid. These controls are embedded within our metal-cutting processes and allow us to respond to the part and the conditions on the day.

The following necessary active controls are applied to enable automated in-process measurement during metal cutting:

- **On-machine gauging**
- **Off-machine gauging**
- **Tool condition monitoring**

The in-process measurement and verification (gauging) of part dimensions and tolerances allows us to optimize machining processes. We use recent data trends to keep machining processes centered by adapting metal cutting for variations such as part distortion, tool deflection and thermal effects. Making real-time automated adjustments to the machining process means that parts can be made 'right first time'. It improves machining capability and reduces rework and scrap.

For in-cycle inspection we use Inspection Plus, the industry-standard macro package for machine tool probing. It's compatible with all major machine tool controller platforms and offers easy-to-use probing cycles for our machine tool probes. Cycles range from basic part set-up and inspection through to more complex vector and angular inspection routines. Our engineers find this machine-resident package easy to learn and simple to program. Experienced users can create and execute cycles using traditional G-code techniques. New or less-experienced users can use one of the available programming tools, such as the GoProbe smartphone app or the Set and Inspect graphical user interface (GUI).

In-process activities pave the way for closed-loop process automation and allow us to perform unattended CNC machining operations.

RAMTIC transformed the quality and productivity of our manufacturing, ensuring we can manufacture high-quality products competitively.

RAMTIC: simplify, standardize and control

At Renishaw, we developed a bespoke flexible automation system, which allows us to perform 'lights out' manufacturing and increase production in our machine shops. The Renishaw Automated Milling, Turning and Inspection Center (RAMTIC) enables us to implement very lean manufacturing using our own integrated metrology products.

Away from the machines, we create product 'kits', which contain all the cutting tools and raw materials required to machine the products. The kits are transported by a mobile pallet system and docked at the correct machine tool. Once the kits are connected to the machining center, together with all the digital information required to machine the parts, no further intervention is required. RAMTIC is a closed-loop system, so the level of off-machine inspection required for parts machined using RAMTIC is minimal. However, we do perform basic checks and cosmetic off-machine inspections.

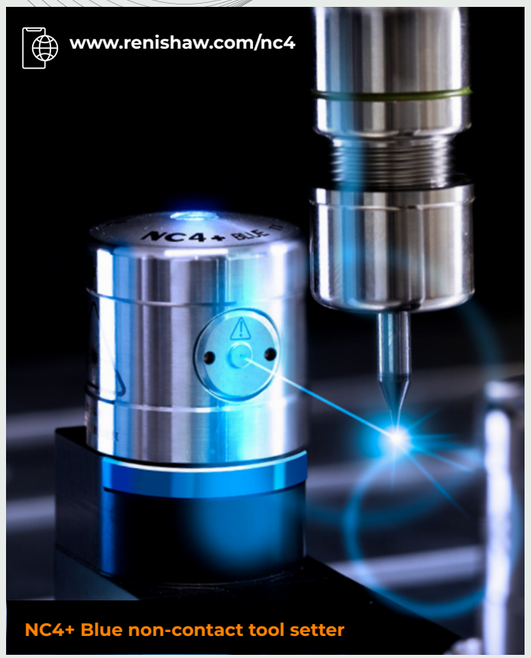
Of course, we use probing for part and work co-ordinate setting. However, when used for in-process activities, such as feature inspection, probing can also be used to keep processes under control, reducing the need for post-process inspection. Bringing CMM metrology to the shop floor has enabled us to get the maximum value from our hardware – especially in our high-volume production areas.

NC4+ Blue: accurate tool condition monitoring for closed-loop process control

- **Measure very small tools and minimize tool-to-tool measurement errors.**
- **Smart environmental protection technologies ensure fast, reliable tool measurement optimized for production conditions.**
- **Use our range of smartphone and on-machine apps for user-friendly programming, reporting and data streaming.**

"We use non-contact laser tool setters and touch-trigger spindle probes in all our RAMTIC milling machines. We use a non-contact tool setter to accurately set up tooling, in conjunction with a high-accuracy OMP400 probing system to enable us to control our processes, ensuring the parts we manufacture are within the correct specifications. These products are used in conjunction with a dedicated artifact, which allows us to monitor the machine for growth and make in-process adjustments if required. These procedures are all carried out automatically without the need for manual intervention from a machine operator, which gives us a fully automated process."

Simon Milliner, Senior Production Engineer



NC4+ Blue non-contact tool setter

For high-performance in-process feature inspection on our milling and turning machines, we use a combination of standard-accuracy kinematic resistive touch-trigger probes and high-accuracy strain gauge probes. The high-accuracy probes feature our patented RENGAGE™ strain gauge technology. This combines a precise silicon strain gauge sensor with ultra-compact electronics for submicron repeatability and excellent 3D measurement capability. RENGAGE technology is ideal for measuring complex 3D part geometries on our vertical machining centers and multi-tasking machines.

We have a range of different probes with RENGAGE technology; each tailored for a specific application and machine type. An ultra-low trigger force also helps to eliminate surface and form damage, which is ideal for inspecting delicate workpieces.

All our kinematic and strain gauge probes are available in a range of sizes and offer either radio or optical signal transmission. We select the appropriate probe and communication protocol options to suit the individual machines, parts and applications involved.

RENGAGE™ strain gauge technology

INSIDE RENISHAW'S MANUFACTURING

3.

In-process control continued...

We use our MP250 high-accuracy touch-trigger probe for feature inspection on our grinding machines.

www.renishaw.com/mp250

For part set-up, geometry verification, and feature inspection on our cutter grinding machines, we use our specialized MP250 miniature strain gauge probes. This probe features
a double-diaphragm sealing, which can withstand use in the harsh environments found in grinding machines.

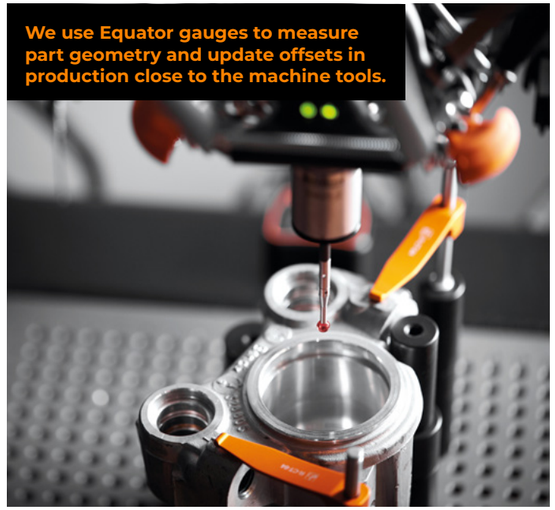
Some machined features may require more complex measurement to validate process performance. Here, we use our highly automated Equator gauging system with IPC (intelligent process control) software for high-speed comparative gauging with automated feedback. Compatible with a range of CNC controller systems, the Equator gauge can measure and verify parts close to the machine and compensate for variation, such as changes in the thermal conditions of the shop-floor environment.

The Equator system has provided us with an efficient solution for monitoring and controlling processes in manufacturing environments. It can measure multiple features on a part in a single measurement cycle and can be reprogrammed quickly to measure new parts or features, without the need for time-consuming retooling. The results from the measurement of several parts can feed back offset corrections to the CNC control. This allows us to fully automate machine tool offset updates with closed-loop feedback.

We recently invested in several new lathes, which we use to machine one of the most complex individual components we've ever made – the body of our TONiC™ rotary incremental encoder. We've incorporated Equator gauging into the process to inspect over 200 features during the production of this single part. We collect the measurement data, and the IPC software supplies closed-loop process control feedback to update the machine tool controllers and keep the cutting parameters within the tolerance bands.

We're planning to incorporate this process into the production of all our encoder bodies.

Process control adds value and builds confidence at every step of the manufacturing process.



We use Equator gauges to measure part geometry and update offsets in production close to the machine tools.

Equator™ gauging system: shop floor process control close to the point of manufacture

- **Accurate between 5 °C and 50 °C, and capable of scanning speeds up to 200 mm/s.**
- **Intelligent process control software for updating tool offsets automatically.**
- **Can be fully integrated into automated smart factory production lines.**

"Using the Equator system alongside our sliding head machines offers a method of controlling the machining process. We can automatically adjust tool offsets with the data feedback from the Equator gauge. This enables us to adopt a much simpler process for the control of our complex high-volume prismatic piece parts for the machine operators to follow."

Roger Burleigh, Senior Production Engineer

www.renishaw.com/equator

INSIDE RENISHAW'S MANUFACTURING

4.

Post-process monitoring

Monitor manufacturing outcomes to verify part quality and optimize future processes

The top layer of the Pyramid involves reporting activities that provide information about the outcome of completed processes. Post-process monitoring activities don't impact the 'finished' part but rather provide information that can influence the manufacture of subsequent parts and processing activities.

The following necessary informative controls are applied to provide a final assessment of process outcomes after metal-cutting and machining processes are complete:

- **On-machine process verification**
- **Off-line part verification**

On-machine process verification tells us whether processes have performed as expected. We use probing to measure features on the part while it's still in the machining fixture. The primary purpose of our machines is to make good parts, so any on-machine verification we do is focused on the process just completed, not checking every feature on the part. We recommend on-machine verification for large, complex, high-value parts, where a capable off-line inspection process doesn't exist, or where the lead time and cost of moving parts is high. Checking the part before it's moved gives us confidence in its conformance prior to any further operations.

The spindle probing activities we perform give us confidence in our machine foundations and process capabilities, so many of our processes don't require the top layer of the Pyramid. However, for some industries this final verification is necessary to confirm that a safety-critical part is good, meets design intent, and can be supplied to the customer.

Off-line part verification involves full inspection against specification. This typically involves using a CMM, which enables fast, comprehensive measurement of complex shapes, as well as sophisticated analysis and reporting.

For our CMM-based final component inspection, we use our 3- and 5-axis probing systems which have a range of tactile touch-trigger and scanning measurement options. With its advanced head, sensor, and control technology, our REVO® 5-axis measurement system delivers unprecedented measuring speed without the reduction in accuracy inherent to conventional techniques. REVO technology delivers high-speed, high-accuracy scanning of machined surfaces with very tight flatness and straightness tolerances. Single point final inspection simply doesn't achieve the accuracy we require for these types of parts.

REVO® 5-axis measurement system: unprecedented measurement accuracy at ultra-high speed

- **Reduces cycle times by up to 50% and provides actionable data faster.**
- **Offers multifunctional capability on a single CMM with a range of specialized interchangeable sensor types.**
- **Uses infinite positioning and 5-axis synchronized motion to minimize dynamic errors at ultra-high measuring speeds.**

"We use the REVO system for the inspection of large, milled components. The product enables us to scan dense point clouds quickly, significantly reducing inspection cycle time. Not having fixed index positions in the head allows us to use part co-ordinates for probe angles when inspecting. This means we don't need to accurately position or align parts prior to inspection. The extended styli lengths also allow us to measure a large range of features."

Alan Jones, Production Engineer

INSIDE RENISHAW'S MANUFACTURING

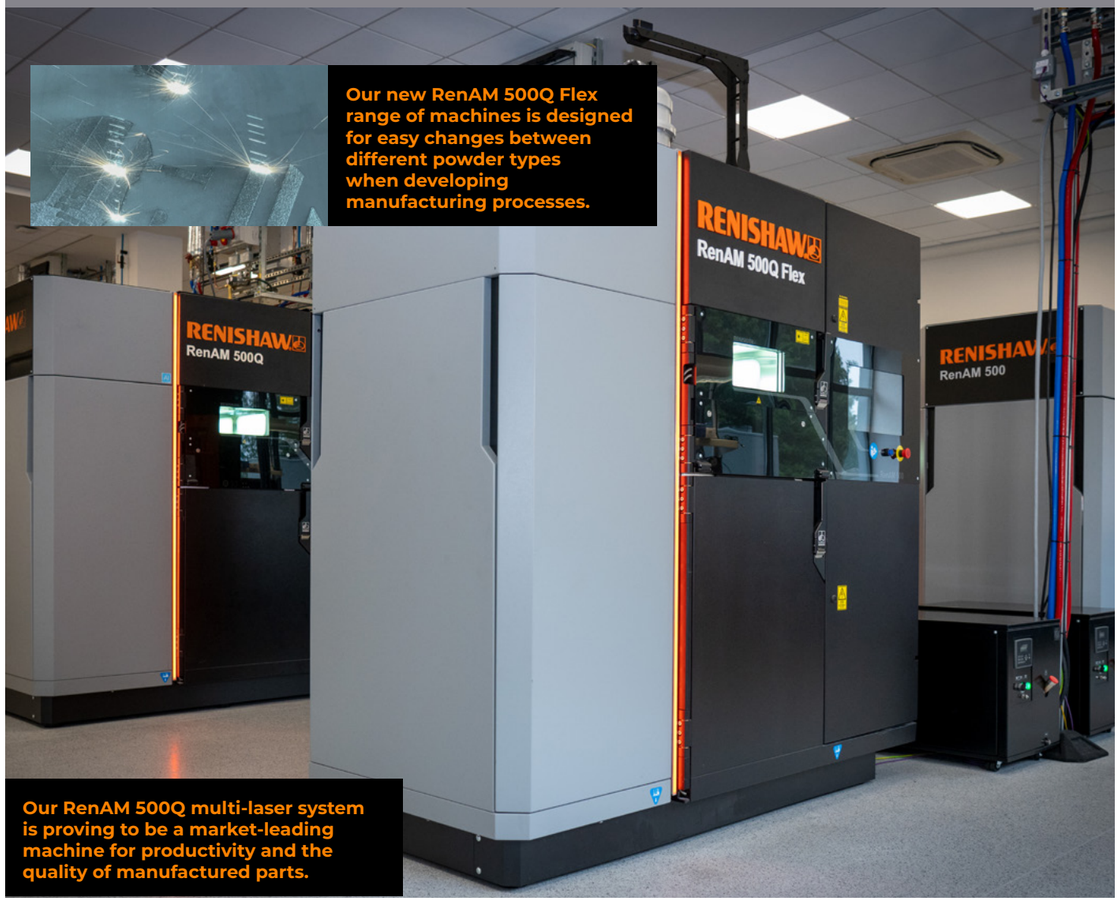
Additive manufacturing at Renishaw

In addition to metrology, we're also innovators in additive manufacturing (AM). We design and produce industrial machines, which create complex 3D metal components direct from a digital file. Together with our expertise in process development, we use our AM technology to support our manufacturing operations.

All AM parts require some degree of downstream finishing (to achieve the desired surface finish or feature tolerance) and inspection (to give confidence that parts meet design intent with full process traceability). We're the only company in the 3D printing industry that offers end-to-end technologies and expertise that support the total AM process chain. This includes the design, monitoring, and build of all AM processes, and any required downstream processing, using our industrial metrology solutions.

Additive manufacturing gives product developers like ours the design freedom to create increasingly innovative and efficient products faster than ever. Our vision is to accelerate the adoption of metal 3D printing as a viable high-volume production process, by demonstrating successful use of AM in our own manufacturing. AM is now a mainstream option for volume manufacturing, and we discuss the use of AM in our 'Future business models' feature on page 15.

It's vital that AM systems can be easily integrated with other manufacturing technologies as part of a smart manufacturing environment. We've adopted an 'open systems' approach, where our hardware and software platforms can easily connect with third-party design and production planning packages.



Our new RenAM 500Q Flex range of machines is designed for easy changes between different powder types when developing manufacturing processes.

Our RenAM 500Q multi-laser system is proving to be a market-leading machine for productivity and the quality of manufactured parts.

Ultimately, process variation causes waste and inefficiency, leads to high quality costs and staffing levels, and results in late deliveries and poor traceability. The secret to consistent, automated and productive machining is understanding where variation comes from and dealing with it at source.

We implement our Pyramid controls from the bottom up – each layer building on the one below to progressively remove variation. Integrating metrology into CNC processes allows us to increase our levels of automation, reduce process drift, and reduce the need for skilled intervention.

Process data relating to all the checks, measures and decisions made throughout our processes are collected, stored and analyzed. This data reveals what has impacted part quality and supports optimization, fault finding and continuous improvement. You can read more about how we've harnessed our manufacturing data in our Connectivity feature on page 5.

Backed by innovative technology, proven methods, and expert support, our Productive Process Pyramid provides a framework which you, too, can use to identify and control variation in your factory.

Always investing in our manufacturing

We announced a significant new investment at our Miskin site in South Wales (UK), to increase manufacturing capacity and to help meet our Net Zero emissions targets.

An investment of around £65 million will see a phased development of 460,000 ft² (42,700 m²) of additional low-carbon buildings at the 193-acre site to the west of Cardiff, consisting of two new production halls and an employee welfare facility.

The existing production halls will also be refurbished to reduce their greenhouse gas (GHG) emissions. This significant investment will almost double the footprint of the site which Renishaw acquired in 2011 and currently accommodates around 700 employees.

Although several Renishaw facilities across the globe contribute to the manufacture and production of our products, our main manufacturing sites are in the UK, Ireland and India.

CASE STUDY

RenAM 500Q powers mass production of medical components for Permedica

For many years, the medical industry has used additive manufacturing (AM) to develop low volume parts, such as medical prototypes, bespoke implants and surgical implants and aids. We have collaborated with medical devices specialist, Permedica, to develop AM processes for the mass production of medical components in the healthcare sector, driving industry innovation.

Background

Permedica was founded in Lecco, Italy, in 1986 by Marco Perego and started as a distributor in the medical sector, focusing on developing and selling orthopedic implants for hip, knee and shoulder arthroplasty. Permedica occupies one of the largest and most modern medical production facilities in Europe, dedicated to promoting continuous growth and innovation in the orthopedic sector.

One of the driving forces behind the company's success is its people, both in design and production, because quality is at the heart of everything it does. Talented engineers and technicians enable Permedica to rapidly respond to market changes and requirements in orthopedics and dental industries. The company's commitment to the research, development and manufacture of cutting-edge joint replacement products is facilitating its continuous expansion.

CASE STUDY

RenAM 500Q powers mass production of medical components for Permedica

Challenge

"We established a partnership with Renishaw early on in the company's development," *explained Federico Perego, Sales Manager at Permedica.* ***"One of the strengths of our company is our ability to seek out and recognize potential partners who can be effective companions, providers of solutions and bearers of innovation. We feel that it is essential for us to have rock-solid, healthy relationships with whoever we choose to engage with as partners. Only through mutual trust, respect and strong collaboration can significant goals be achieved."***

Renishaw has provided Permedica with touch probes for CMMs and machine tools, as well as laser systems for tool setting operations for many years. We therefore play a crucial role in the production chain, with every single part produced by the company undergoing dimensional checks. The technicians appreciate the ease of use of Renishaw systems and they like how they can be applied to most brands of machines.

In recent years, Permedica began using AM alongside traditional production methods. This approach allowed the company to condense the production line while opening up the possibility of creating bespoke products for individual patients.

"Product customization is, for all intents and purposes, still a small niche of the market. However, it has two great advantages: the first is that it broadens our capability, and the second is that it is probable there will be a strong push towards it from an engineering perspective because it is where the market is heading. So, being at the cutting edge of it is crucial."

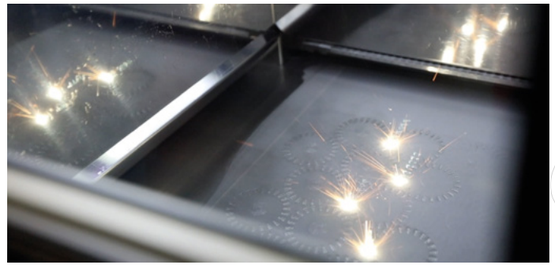
Permedica had previously used two 3D printing machines from another supplier. Both machines were equipped with just a single laser and therefore capable of offering only limited performance. Based on the company's desire to develop the area of additive manufacturing, it decided to search for a new system that performed better and improved productivity.

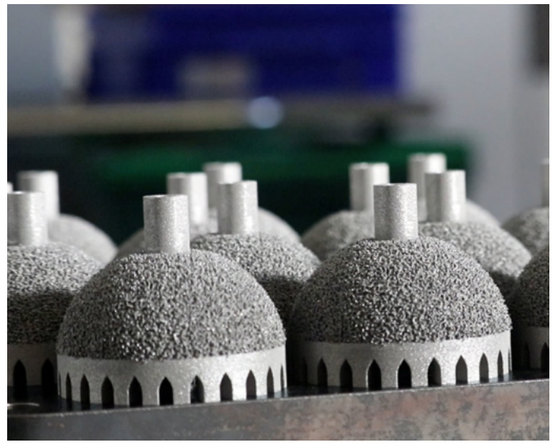
Solution

"When searching for a new AM machine, we found ourselves looking closely at the Renishaw RenAM 500Q and it immediately struck us as a very interesting solution," *explained Perego.* ***"This was down to several reasons, first and foremost the production area, which has an impressive four sintering lasers. This feature allows us to achieve a remarkably higher level of production and a reduced cycle time per unit produced as compared with the single laser machines we already had in our workshop.***

"The RenAM 500Q is a fully automatic machine, including powder sieving operations, meaning that there is no need for operators to oversee this step, saving a great deal of time. Due to our existing relationship with, and knowledge of, Renishaw, we knew that this was the product to go for."

By speeding up the process by up to four times, the RenAM 500Q system broadens the market appeal of metal additive manufacturing into applications that were previously uneconomic, driving the technology into new industries. The RenAM 500Q is designed to scale up AM technology to suit larger production volumes, enabling Permedica to use the system for mass production of standard parts instead of custom applications. Its working volume (250 mm × 250 mm × 350 mm) and four lasers enable the company to meet demanding production volumes and speeds. The system also features automated powder and waste handling systems that enable consistent process quality, reduce operator intervention time and ensure high standards of system safety.





Results

By installing the RenAM 500Q system, Permedica experienced increased throughput and found that the mechanical properties of parts manufactured on the machine were superior. This enabled the company to extend the production of other parts using AM. Permedica purchased two additional RenAM 500Q systems in 2022, allowing them to meet increased demand for mass-produced medical components in the healthcare market.

"The presence of the four lasers effectively puts us in a position to operate with significant production volumes," *explained Perego.* ***"This expresses just how versatile the Renishaw machine is, making it the crown jewel in our production set-up."***

Permedica noted that one of the biggest challenges when implementing a new technology is taking the time to install the equipment effectively, fine-tune the process and train staff.

"We have found Renishaw to be a solid, reliable partner capable of supporting us quickly and assisting us in the challenging task of increasing productivity, reducing lead times and minimizing waste," *continued Perego.* ***"In my eyes, these goals have certainly been achieved, not least thanks to the presence of a team dedicated entirely to additive manufacturing which has been with us every step of the way over these past four years of operation.***

"It is also important to mention the quality and versatility of the Renishaw software that runs the RenAM 500Q. Operationally speaking, the part execution files are transferred from our CAD/CAM system to the machine for all the work of translating the files. I have to say that there have never been any sort of conflicts, inaccuracies or uncertainties, which is a sign that Renishaw has certainly put in a great deal of work in this regard too," concluded Perego.

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