

# Metrology Matters

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# Metrology Matters

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Metrology is a science – it is the discipline of measurement. Applied metrology includes the undertaking and planning of measurement, as well as the evaluation of its effectiveness. Metrology includes parameters known as S.I. units (the *Système International d'Unités* or the International System of Units) such as temperature, mass and time. But the mass of applied metrology in manufacturing and engineering is dimensional, encompassing size, shape and form. For any business the correct and proportionate application of metrology is a mission-critical factor in delivering quality products and services, driving cost efficiency and continuous improvement, including return on investment (ROI). One of the enemies of successful metrology is a 'Pandora's-box mentality', whereby businesses believe it's easier to assume accurate measurement just happens in this digital age. Many potentially successful businesses have floundered by investing huge resources on that false and fatal assumption. Metrology as an applied philosophy involves utilising tools and processes where appropriate to drive improvement. It can be considered akin to Lean in its application.

Metrology should underpin every major aspect of the manufacturing process. Quality starts with the initial design. Good design is recognised as a crucial building block but, ironically, design for metrology is an important early step that is often missed. It provides assurance that the datum and tolerance of a part is realistic, achievable and cost efficient. Keeping measurement high on the agenda and effectively managed throughout the entire manufacturing process helps to mitigate against costly temporary fixes and corrective actions. Underinvestment in the adequate resourcing for applying effective metrology is often the norm. Measurement in itself doesn't result in a tangible product and is therefore seen as an indirect function. However, if measurement is effectively applied across a business, it can underpin all the vital decision-making processes – from conception to shipping – on which the business ultimately stands or falls. Whether these include simple production decisions, continuous improvements, cost-reduction initiatives, future product development or sales tools, all are totally dependent on the validity and quality of the data obtained in measurement.

Today, companies compete in a globally competitive market, this involves finely balancing manufacturing costs and quality. Poor data means poor business intelligence, threatening the prospects of the enterprise with confusing key process indicators. Metrology, applied correctly from the start, ensures competitive advantage by keeping costs down and quality high. Investment in metrology planning, process control and maintenance cycles prevents major issues appearing downstream. Product recalls, litigation and reputational damage are high-cost activities that can often be avoided.

The argument over 100% inspection versus process control has long been won, with process control now the norm. Last century, the capability of measurement technology

usually exceeded that required of the tolerances of the day. The consequence of this was the onset of complacency about measurement, where the button-press and tick-box culture undermined skills and investment. That has all changed. Today, manufacturing processes are more demanding, tolerances have become ever tighter and that culture of complacency has impacted enormously on the effective application of metrology and measurement. Effective and efficient metrology in this brave new world of global competition, tech-savvy markets and value chains is no longer a 'nice-to-have', it's a must-have in order to ensure the competitiveness and survival of any business.

# 21st Century Challenge

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Manufacturing processes are now more complex and this trend will continue affecting areas such as new material coatings, additive manufacturing and innovative alloys. Tolerances and specifications will become even more exact and precise, driven hard by customer demands in the global market that are sometimes unnecessarily. This will challenge measurement as never before – not only in terms of the measurement tools and processes that will be required, but also in new variations of un-quantified uncertainties that will inevitably arise. New areas of risk, including both threats and opportunities, need to be fully understood.

Industries such as aerospace (who are highly influential in setting supply chain agendas) are already investigating more fit-for-purpose methods of achieving supplier quality audit (SQA). Less often but more thorough audits will be the new norm. Metrology is now firmly prioritised in that agenda and improving those technical areas even further are stated priorities in supplier quality improvement. The automotive and medical devices sectors are not far behind. Previously having a coordinate measuring machine (CMM) onsite was enough for an auditor but it won't be in the near future. Additionally the continual evolution of international standards will have considerable bearing on the methods used by an organisation in maintaining global competitiveness and recruiting and retaining customers worldwide.

Businesses and their respective supply chains could find themselves on either side of a great divide, namely the haves and the have-nots. In terms of technology, processes and skills, the balance will need to be maintained as the bar is raised. If you find yourself left as a have-not and resorting to risk-taking, cutting corners and box-ticking, then the future looks bleak. Short termism and apparent competitiveness may appear alluring initially, but the rate of change of technology coupled with process advances will soon leave you behind. Wise investments driven by sound measurement coupled with the development of engaged customer relationships, will keep you riding the wave. One possible future scenario would be the option to lease or utilise pay-per-use tariffs on technology and the expansion of the contracting-out of measurement technology and skills. New technology with both higher capacity and capability will not only cost more to purchase but will also be more expensive to maintain and calibrate. Consideration has to be given to upskilling and training of the workforce in mastering these new technologies. This is an area where many companies traditionally struggle. For example, in a scenario such as new-part introduction (NPI) even more metrology and measurement will be required to determine process data and stability more promptly. However based on that initial data, large reductions in measurement resource needs will then be possible. A more flexible approach will be necessary unless you are proficient in resource and logistical management or capable of amassing and storing measurement equipment for peak-use only.

The current link between computer-aided design (CAD) and measurement systems software is all about translation and interface – there is no complete and direct linkage in mainstream systems. There has been a growth in measurement systems that can capture mass surface data and in the case of computed tomography (CT), utilising x-ray technology the whole object is captured. This produces a cloud of sampled measured points that represents the measured object. A comparison can be made between the CAD nominal and geometry constructed for evaluation. Such techniques will continue to become more sophisticated, especially when sharing and amalgamating data with other measurement systems.

A question arises: when CAD and measurement inevitably touch, will this be driven by the CAD vendors or by the manufacturers of measurement equipment? They both have different perspectives and both are looking to drive the next generation of measuring devices. This will also challenge our current thinking on measurement strategies, including determining dimensioning and tolerancing. The ultimate question is: how do we truly reflect the positive functional outcome of the part through measurement? The development of new international standards and appropriate adaptations of existing standards will have to take place just to keep on top of technological developments in manufacturing techniques as well as metrology technologies. The probable result of a shift to collection systems, which use combined technology and mass-data, will be a shift to post-measurement analysis with topography of free-form surfaces and key geometrical feature reconstruction taking place automatically as a post process. However this may be almost instantaneous with data collected in shorter time spans. The proficiency of a company to continuously improve and adapt will be paramount in its effective risk management. Understanding what really counts, knowing what actually adds value and investing appropriately in those areas may have once been considered prudent but now it's mandatory for competitive growth. Metrology is a vital and significant discipline in this shaping and influencing of a modern manufacturing business.

# Trends in Metrology

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The media is rife with stories of quality failures across all industries and sectors. Government, trade associations, institutes and businesses talk of an engineering skills shortage. This has become a skills crisis in some areas. In metrology there is a dearth of measurement professionals at all levels. Metrology has been neglected when compared to other key industrial skills. This lack of investment in measurement along with a flourishing and often confusing technology boom has created a perfect storm that is now breaking. We need to shift the paradigm and quickly.

Traditionally, in the pre-digital age career paths in measurement, such as inspectors and metrology experts, came via the tool room or from experienced machinists. Few formal qualifications existed but metrology content was a crucial element of some apprenticeships. The advent of technology supported by computers, for example coordinate measuring machines (CMM), changed the emphasis of these core skills to technology-related skills. This trend continues apace. However, the effort applied and money spent on technology skills tends to far outstrip the corresponding investments in the underpinning measurement skills of those that must then go on to use the requisite technologies. The tool room and the skilled manual machinist have all but disappeared. The traditional pipeline has dried up and not been replaced. This lack of skilled measurement people is recognised by most manufacturing companies, from inspectors to site metrologists. This is compounded by an equivalent shortage of experienced metrology trainers within training organisations and colleges, where worrying tales of bad practice are taught and perpetuated abound. Over-simplified course materials delivered by people with no relevant measurement experience only serves to exasperate an already frustrating and exposed situation. This raises a Catch-22: is metrology becoming overcomplicated by superficially simplifying the skills needed to execute it appropriately?

This lack of measurement professionals has led to a culture of organisations poaching people rather than nurturing their own talent. Employees are either incentivised to stay or enticed away. Both of these conclude in spiralling wage demands. This happens all the way along the supply chain, not just in the smaller supply chain companies but also among the large companies at the top. Larger organisations can be seen poaching from their own supply chain, which is a remarkably shortsighted approach to the growing skills shortage and only defers the problem rather than fixes it. As organisations in the supply chain lose skilled people they become reluctant or unable to replace them. If they manage to replace them they often fear further poaching of the upskilled replacements, this drives a cautious lack of investment in their own upskilling. This un-virtuous circle guarantees the flow of newly skilled measurement specialists remains stifled – a trend that will only continue if we leave it unchecked. Metrology offers an interesting and valued career with continual development and changing and interesting technology. With manufacturing growth forecasts, metrology offers new starters exciting opportunities. The potential for workforce diversity is good in metrology, with new talent potentially available if we can provide the gateways, opportunities and career pathways to bring that new talent in.



Metrology has historically been about component measurement and verification and only a few sectors, such as packaging are measuring to assure an automated production line process. In-process measurement in highly automated production is used to detect and remove defective parts that may cause stoppages in those automated lines, and this is becoming more prevalent as automation spreads. For example, the neck ring of a cola bottle is not for the drinker's benefit, its function is purely to help move the bottle around the plant during the automated manufacturing and filling processes. The growth of automation in the wider manufacturing sectors and the automation of large-volume assembly is now driving a new trend in metrology, namely process-driven metrology.

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# Organisational Views

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The measurement landscape is complex. From an equipment and technology perspective the consolidation of measuring equipment brands into large, international organisations is enabling unprecedented investment in new technologies and software development. It also means technology innovation is picked up and brought to market quickly, sometimes through acquisition of compatible technologies.

With regard to skills and training there are examples of good intentions but generally there is a lack of clear skills pathways and qualifications. Metrology is an undervalued profession and it needs leadership and direction and to give it a deserved professional footing – something we at Coventry University are keen to make happen. By organising as a community, metrology and measurement could benefit from a raised profile within employer skills, gaining wider recognition and support through both private and public funding. We are also addressing employer's need for apprenticeships and undergraduate degrees that have better metrology content underpinning them. As new measurement technology and software evolves those skills need to be given higher priority with a greater understanding of the core underpinning themes such as uncertainty, gauge capability, traceability and measurement strategy, with new technologies to meet corresponding technology-specific idiosyncrasies. These and other metrology tools lead to good data generation and confidence in process stability. Good data enables better decision-making. Conversely, bad data will confuse, undermine and ultimately derail improvement initiatives.

No one entity or event is responsible for the decline in metrology skills. All organisations from government and trade organisations to stakeholders need to put some thought to metrology. But we cannot hide the fact that many employers also need to look at how they are mapping and investing in skills development. Even with the best technology and a competent workforce you could still end up stagnant, fixed in the past and repeating mistakes. Especially if you do not consider how metrology can drive and monitor improvement. As required skills become more advanced, so increases the lead times to train a competent workforce in utilising those skills. A three-year apprenticeship or graduate programme is an important base but by no means the complete picture. The finished article, by immersion within a business, will take additional time and the ability to continually adapt lifelong learning and development to keep abreast of technology. This needs to be addressed both at a national level, to prepare a pool of talent, and within individual company pipelines of trainees with a clear progression plan. One option is a collaborative group managing an industry pool of new, skilled, talent – something we at Coventry University are keen to explore with employer support. The alternative, as mentioned earlier, is short termism, with the problems of employee poaching, rising salaries or the acceptance of low skilled staff as a fait accompli. More than two million new engineers will be needed by 2020. Half of these will replace those due to retire in that timescale. Companies have to start planning for this now. This loss of tacit expertise and knowledge cannot be underestimated.

# Building on Success

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The current coalition government, and indeed all the major political parties, are very keen to see the UK manufacturing base expand, with the focus on advanced manufacturing and added-value manufacturing. They are still investing and funding is available for the right initiatives across the UK. The drive is in employer-valued training, creating skills pathways and delivering courses that student's want and employer's need. One challenge is that metrology has no single coherent voice and there isn't any significant employer-led representation. Leadership is essential.

At Coventry University we are working towards this but we need support and help from both industry and major stakeholders, so please get involved. We are passionate and ambitious in raising awareness, and we want to collaborate with other parties in creating a momentum capable of delivering an organised strategy for the future. We welcome any organisation to contact us and share this passion to help make this happen. We already offer skills and training for measurement specialists as well as providing qualifications for those wishing to progress into higher education. We also conduct consultancy and research in metrology and across manufacturing and engineering. We are working hard to make sure our undergraduate and post-graduate courses are fit for purpose with respect to manufacturing and engineering needs. In this we have been highly successful but there is much more to do.

Various landscape changes will have a significant impact on skills planning in the immediate future and the new trailblazer apprenticeships are a great opportunity to drive measurement apprenticeships, but they come with a caveat. There is a danger of fragmentation of exactly what the apprenticeship covers, however a cohesive employer-led initiative, in conjunction with Coventry University and others, could drive this ambition for the benefit of all.

'Big bang' failures have become rare, today's failures are far more subtle and gradual but still lethal. A steady, creeping decline into obsolescence can happen without businesses truly realising what is going wrong, and more importantly understanding why.

We can launch ingenious new technologies and effectively trade in the world markets, however that initial advantage must be coupled with sustainable skills underpinning those innovations. New advanced manufacturing start-ups attract new talent, but without a corresponding skills development plan that energy and momentum will soon be lost. This will result in an inevitable race to the bottom – losing that important balance between manufacturing cost and quality.

# A Community for Change

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All the world's metrology problems cannot be cured in one fell swoop. We don't understand them all fully yet and in a fast-changing landscape this is likely to remain the case. There is no magic bullet that will solve these challenges and it is certainly not just a case of throwing money at these issues. Poor metrology is hitting big and small, rich and poor companies equally. We need an open, honest, adult dialogue to stimulate debate, leading to a process of reflection and then change. Proactive engagement with likeminded people can lead to practice that has clear intent and direction with a commensurate high profile able to be mapped to stakeholder funding and support.

Passion, resolve and ambition are mandatory in dealing with the metrology challenge but it must be tempered with realism. In skills training a passionate, well-intentioned fool is more dangerous than a charlatan. Incremental, sustainable steps as opposed to giant leaps initiate the journey of improvement and this often starts by understanding the root cause of the problem – a lack of core skills in the workforce.

Quality managers and engineers will recognise many of the points raised and point to the frustration of having little support outside of quality circles. Ensuring metrology connects with company production costs and improvement benefits, with visible returns on investment, are all ways to get wider attention (particularly from the finance director) for effectively tackling measurement issues.

Aligning future needs and mapped to technology developments with effective and efficient skills management, acquiring new talent and the utilisation of appropriate tools and competencies will focus efforts in dealing with the challenge of innovation and change. Progression planning, succession planning and the understanding of what qualifications exist are important in the recruitment and retention of a successful workforce. But these individual elements cannot be done in isolation.

To compete on the world stage a measurement community driving the skills, needs, qualifications and standards are needed. A powerful, consistent, cohesive influential voice representing all the relevant stakeholders would be a very significant asset for UK plc. We at Coventry University want to be at the heart of that ambition.

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