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BRINGING PRECISE MEASUREMENT TO THE WORKPLACE

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Abstract: For many years the traditional way of calibrating standards at the highest level was for companies to bring their standards to a National Metrology Institute (NMI). 'New' technologies such as the Internet are now changing these long standing techniques as is the existence of commercial 'quantum based' standards of high quality. This places new obligations on NMIs to work in new ways and to develop new partnerships to transfer expertise to industrial users.

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1 THE 'OLD' SYSTEMS

In the mid 1960s and early 70s, most National Metrology Institutes (NMIs) used to be virtually the only standards and calibration laboratory in their country. Almost all calibrations were carried out there against either primary or secondary/working level standards. The concept of industrial laboratory accreditation was virtually unknown although a few of the 'high-tech' companies in aeroplane or motor vehicle manufacture or in the traditional large engineering and process industries maintained in-house calibration or 'standards' laboratories. As a consequence, the NMIs employed large of numbers of people engaged almost exclusively on relatively routine measurements. There were close relationships only with a small number of major companies. As a consequence, awareness amongst industry more generally, of the importance of measurement to product quality and industrial competitiveness was largely an underdeveloped area of national, let alone international, policy making or was a concern of the majority of companies.

In the mid to late 70s, world trade was increasing, and multi-national companies were being created. The industrial trend was to mergers which at the same time addressed issues of industrial overcapacity particularly as the newly emerging economies were driving out weakly performing, uncompetitive companies in the 'western' world. The response of many western governments was a mixture of semi-protective industrial policies, and financial encouragements for restructuring or adoption of 'new' technologies. For the NMIs there was a focussing of work onto market needs and on promotional campaigns to show the advantages of 'metrology for quality' Much of this challenged and changed the work of the older NMIs, as they copied some of the newer ones which were integrated into national industrial research organisations and which already had a very clear 'competitiveness' mission. All this was, of course, at the same time as the rise of international standards that led eventually to ISO 9000 or its national/regional variants. The related concepts of traceability and the rapid rise in demand for calibration put great strain on the calibration work of NMIs and, very rapidly, there was a market need for formally "accredited" laboratories which could take on routine calibration and develop a commercial and profitable business. The 80s and 90s have seen these trends continue with:

- more and more accredited calibration and testing laboratories;
- more and more new demands from industry for new or enhanced measurement services with many industries now demanding accuracies which approach those at the NMIs; and
- a recognition of globalisation and the need for NMIs to regroup with the growing acceptance that, particularly within the formal and semi-formal economic blocs, they have to depend on each other for services rather than provide comprehensive coverage on a county-by-county basis.

Now we live in a trade dominated world as all those concerned with the Comite International des Poids et Mesures' Mutual Recognition Arrangement know all too well. We have new industries, particularly service sector industry making important contribution to national economies, and which lead to a whole new range of measurement needs, particularly in chemistry, pharmaceuticals, medical products and the 'measurement of appearance' in consumer led industries like food and fashion.
So NMIs have a new set of challenges:

- changes to the industrial activity patterns within many economies with the need to raise measurement awareness and tackle measurement problems in the 'new industries, many of which have attracted the attention of regulators and consumer protection bodies and many of which do not always recognise the benefits of measurement, traceability and uncertainty;
- new techniques of making measurements. These range from the emergence of quantum based, highly accurate measuring equipment such as atomic clocks, high performance lasers or Josephson Junction based electrical instruments. In addition, we are seeing NMIs looking at how Internet based measurements can be used - in some cases - for calibrations; and
- a need to come closer to the needs of the market for calibration services.

Against this background, this paper now goes on to discuss a number of issues that need to be faced up to by national laboratories as well as the users and suppliers of measurement equipment. In some cases, the solutions are cultural; in others, technical. In all cases, new skills are required of NMI staff as well as new forms of knowledge and technology transfer.

2 THE NEEDS OF THE INDUSTRIAL MARKET

Companies that are customers of NMIs and that use their calibration and testing services or those of high-performing accredited or secondary laboratories have a number of needs: access to calibration services, the results of which are accepted world wide; rapid turn-around of calibrations; and more and more accurate calibrations. Satisfying the needs of 'new' industries and real-time measurements is a further trend. Each of these will now be examined in turn.

First, easy access to quality assured, SI-traceable calibrations accepted world wide. These are required by formal quality systems such as ISO Guide 25/Standard 17025 by end users and are, increasingly, used to satisfy the needs of Regulators and legislators. These requirements lead first to publicity from NMIs for their services so that all users are aware of what is on offer and secondly to requirements from users for mutual confidence by all parties in the results produced by laboratories within the various national measurement systems. Companies are also starting to look outside their own country for services because not all NMIs cover all areas of measurement, either as a matter of national policy, through budgetary constraints, or because they are starting the slow and sensitive process of becoming more dependent on each other through collaboration and sharing of services. Together with the explosion of world trade which relies on measurement, these shifts to mutual dependence and on the supply of services outside of the country of origin - something relatively new for many NMIs - have been recognised and are dealt with in the Mutual Recognition Arrangement (MRA) for Calibration and Measurement Certificates for NMIs launched by the International Committee for Weights and Measures under the Convention of the Metre [1]. This MRA requires all participants to publish their technical capabilities, to have them assessed by experts from other laboratories and to have evidence of how well NMIs agree in their realisation of SI units and quantities. Users can therefore look for themselves, on the Internet, at the technical capability of any NMI within the MRA and can, with full confidence, choose to use its calibration services rather than those of their national laboratory and have the results of these services accepted world-wide. They can also use the MRA data base to search for NMIs that can satisfy their needs if they are not available nationally. This easy access and the widespread and cheap availability of information will drive globalisation of the calibration service market and will enable users to choose the supplier that best meets their needs. There are implications here for national policy makers, especially if they see alternatives to the traditional way of ensuring access to calibrations and to technical help without having to pay as much as they have in the past. As the MRA is implemented it will be a real test of market economics.

Secondly, there is the issue of rapid turnarounds. Companies that have to send their standards away for calibration already do not have them available for in-house use. This can lead to costly duplication if continuity of an internal service is essential, or to a tendency to increase the calibration interval if calibrations are expensive. NMIs are therefore having to concentrate more and more on reducing turnaround times, or providing better customer information and management information systems that a customer can access so as to find out where equipment is in the calibration process. Some calibrations will always require reasonable periods of time away from the workplace because of the need for stability or because NMIs only can (through their own resource limitations) provide the service at certain times. But there is now no longer any excuse for the situations, which we have all seen from time to time, in which customers' equipment is left alone whilst a metrologist pursues some other activity. This market sensitivity is now fast becoming built into service delivery and is, in some cases, more important to a customer than the actual price of a calibration.

But perhaps the most exciting opportunity for service provision at the point of use is that offered by wide band, cheap Internet communication. In some cases it has the power to revolutionise traditional calibration cultures and actually take the NMI capability to the customer directly rather than vice versa.

A few NMIs are exploring what can be done and could soon be offering suitable services on a trial basis. Amongst those that NPL is pursuing is Internet based calibrations of Automatic Network Analysers in which we are using the Internet to transfer national standard measurement accuracy direct to the end-user (i.e. via a one-link traceability chain!). The end-users who might benefit from such a facility are likely to include accredited laboratories, as well as manufacturing facilities where direct access to such high levels of accuracy could improve production yields. This will be achieved using NPL's Primary Impedance Measurements System (PIMMS), which is operated within our RF and Microwave Guided-Wave Group. This system uses a PC to transfer data to, and from, an Automatic Network Analyser (ANA) which acts as the measuring instrument. The PC runs a series of programs for ANA configuration control, data acquisition from the ANA, data transfer back to the ANA (effecting calibration), and analysing the uncertainty of measurement.

The interfaces to the PIMMS suite of programs are being modified to enable the system to be operated over the Internet. This means that, in principle, *any* ANA at any location, with (subscriber) Internet access to NPL's PIMMS software, will be able to achieve measurements of similar accuracy to the national standard. This 'bringing of the NMI directly to the user' is putting a premium on other related NMI services such as technical advice and, unless NMIs take some steps to ensure routine face to face contact with users then the opportunities to maintain contact with industrial needs may be lost.

Thirdly, on responding to the needs for increased need for accuracy, the NMI's traditional, and still very valid approach, is to work to improve the current performance of their SI unit or quantity. In most cases this is a question of tackling systematic uncertainties. Occasionally technology itself can come to the rescue and new ways of realising a quantity can be found. There are many examples, particularly of 'quantum-based' step changes in capability: the laser to replace the Krypon lamp as a length standard; atomic replacing quartz clocks as timepieces; cryogenic radiometers and detectors replacing lamps as sources in photometry and radiometry; and Josephson Junctions replacing passive sources of voltage. Such devices used to remain in the NMI but over recent years and as suppliers have seen enough demand for them, companies are now making and selling instruments based on the same quantum processes that NMIs use to realise SI quantities at the highest level. For example, there are hundreds if not thousands of excellent commercial caesium clocks, several suppliers of highly accurate stabilised lasers and a number of manufacturers of Josephson-based voltage standards. This direct access by the market of high performance devices and instruments is, of course, very welcome and NMIs should not feel that their core role is challenged. In fact and in view of various concerns expressed by CIPM [2, 3, 4] and others about uncritical use of what are occasionally called 'intrinsic standards', the role of the NMI is different, but important. Simply buying a box and switching it on does not give a purchaser, automatically, the same capability as an experienced NMI. Nor does it guarantee the 'right' answer. If metrology was that easy, then NMIs which compare their standards would always be within statistical error and all the comparisons needed to validate the CIPM's MRA would not be necessary. The practical world is different: comparisons do reveal differences between independent realisations which in some cases are very significant. Validation of capability and the training of expert users will be a new opportunity for NMIs and will, at the same time, diffuse metrology best practice still further throughout the user community.

The needs of 'new' industries and indeed addressing some of the 'real time' practical measurement problems are the last topic to be addressed in this short review. 'New' users such as Internet based or 'e-commerce' industries often require highly accurate timing for recording share dealings or for purchase of utility services (electricity or gas) in liberalised markets. Precise timing and net-based systems based on UTC are being advocated by a number of companies. Even here it is not as simple as many may think and considerable care must be taken to account for timing delays in transmission systems.

Finally, the most challenging of the 'new' market needs fall into two categories: measurement of 'appearance', and real time measurement, especially in the process industry. The response has been a combination of the traditional and the novel. 'Appearance' measurement - quantities like gloss, and a range of quantities used to display products under different lighting conditions or presentation media (TV tube, flat panel display, printed photographs etc.) combine 'hard' physical or chemical measurements with the subjective and varying responses of, say the human eye or ear. Yet these are precisely the quantities that a consumer uses to judge textiles, combinations of coloured products, or the relative sound reproduction of hi-fi systems. They are therefore also the selling points of the marketer and innovator. How can the consumer choose and differentiate? How can they compare different claims (washes whiter than our competitors' products, gives a shine to your pet's fur…)? Semi-subjective measurements are moving away from the carefully controlled conditions of the laboratory into the supermarket and are presenting exciting new challenges. The manufacturers, particularly cost and quality conscious ones, are also wanting to move from carefully controlled

conditions to the aggressive and hostile measurements of the production process itself. Better process measurement means better control of the critical elements in the process and so more consistent, and better, quality. The new area of data fusion is bringing together makers of sensors, process modellers, systems designers and mathematicians to unify a variety of often very different measurements from different points in the process to derive critical combinations of measurements. If one or more of these starts to change then inference systems can point to likely process weaknesses and potential failures. The concept is not especially new but the types of measurement, the techniques for fusion of the data and its eventual separation, and the range of industries interested in this area are growing. For NMIs it means that the market is looking for systems solutions rather than discrete measurements.

3 SUMMARY

This short paper has reviewed many of the current issues and trends that are driving change forward in the increasingly global world of metrology. In some areas NMIs are coping such as in the moves, through the CIPM's MRA, to increase confidence in measurements world-wide. In other areas, new solutions are needed, particularly in the apparent conflict which balances the need to collaborate and depend on each other, with a mission to support national industrial competitiveness. Over the next few years, NMIs and Governments will be working towards a solution which meets the needs of industrial customers in all the areas discussed. The solutions may be radical and may involve changes in the ways in which we organise ourselves or 'do business'. So NMIs have to be adaptable and to continue to place themselves at the service of users: The future will be challenging … and different.

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