

The Australian

Metrol^ogist

The official journal of the Metrology Society of Australia



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Secretary Paul Pokorny
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STATE CONTACTS

QLD/NT Geoff Barnier
Geoff.Barnier@deedi.qld.gov.au Tel (07) 3810 6399
NSW/ACT Paul Pokorny
Paul.Pokorny@measurement.gov.au Tel (02) 8467 3584
VIC/TAS Neville Owen
Neville.Owen@measurement.gov.au Tel (03) 9644 4922
SA Mark Histed
mark.histed@triplepoint.com.au Tel (08) 8231 3455
WA David Pack
D.Pack@curtin.edu.au Tel (08) 9266 4849

TECHNICAL INTEREST GROUPS

PRESSURE METROLOGY
Convenor Randall Anderson
randall@auspressurelab.com.au Tel (03) 9431 3658
CMM and COORDINATE METROLOGY
Convenor Ashley Gracias
Ashley.Gracias@measurement.gov.au Tel (03) 9644 4908

THE AUSTRALIAN METROLOGIST

Editor
 Walter Giardini – wgiardini@optusnet.com.au

Contributing Editors
 Neville Owen Neville.Owen@measurement.gov.au
 Jane Warne J.Warne@bom.gov.au
 Jeffrey Tapping jeffrey.tapping@gmail.com
 Robert Crawford rob@lescooke.com.au
 Geoff Barnier Geoff.Barnier@deedi.qld.gov.au
 Paul Pokorny Paul.Pokorny@measurement.gov.au
 David Pack D.Pack@curtin.edu.au

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Graphic Designer Mark Orange

Advertising enquiries to Simon Henriques,
 Cambridge Publishing
 Tel (08) 63145222 Fax (08) 63145299
simonh@cambridgemedias.com.au

WALTER GIARDINI



After a short hyatus, *The Australian Metrologist* returns with this issue to bring news, events and articles to Australian metrologists. It has always been a hard slog bringing materials together for the journal, as past contributors and especially the previous editor Maurie Hooper well know. Everyone seems to have so little time these days to spend on the 'background' things like activities for one's professional association, in our case the MSA.

Maurie has been thanked before but it is worthwhile acknowledging, in this the first of the new look TAMs, the fantastic work he's done over many years producing several issues each year pretty much on his own – thanks again Maurie. We are building the next TAM on the foundations you and previous editors have built.

It is you, our members, who make the MSA what it is.

The national committee thinks that this journal is one of the important things that we as a society share. And we've also had a number of individual members tell us how much they looked forward to its regular appearance, bringing metrology news from all over the country – so here we are back again.

We now have an Editorial Team which includes state contacts and MSA members from all over Australia (see the full list of editorial team members on the contents page) which we hope will give us

better coverage of news and events happening everywhere in the country. We are aiming to bring out the new TAM twice a year and we've also obtained the services of a professional publishing company, Cambridge Publishing from WA. We hope all this means we will be able to produce a more regular (though less frequent) TAM with interesting, topical articles.

With Cambridge Publishing we will also implement an online system to submit articles, have them reviewed and go through the entire publishing process. So it will be easier than ever to have your say, advertise in TAM or publish your technical content. An introduction and instructions to use the system are shown in the box below.

Our editorial team is charged with enquiring about and ferretting out stories, news and events which are relevant and of interest to metrologists. But there is one more piece to the puzzle – You!! It is you, our members, who make the MSA what it is, so your news, your stories, your views, your letters to the editor, your articles, your advertisements, your professional concerns about our industry, your dialogue – all these are basic fuel which we hope will make TAM something to look forward to.

We hope you enjoy reading through this issue of TAM and we look forward to hearing from you with your feedback and more news for future editions.

Electronic submission of manuscripts to the journal

The Australian Metrologist welcomes authors to submit all articles, whether a letter to the editor, conference report or an original article to be peer reviewed, via our web-based Manuscript Management System.

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- Go to either the publisher's website, www.cambridgemedias.com.au, or to the TAM section of the MSA website.
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Author guidelines are available on both the MSA and Cambridge Publishing's websites.

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DANIEL BURKE



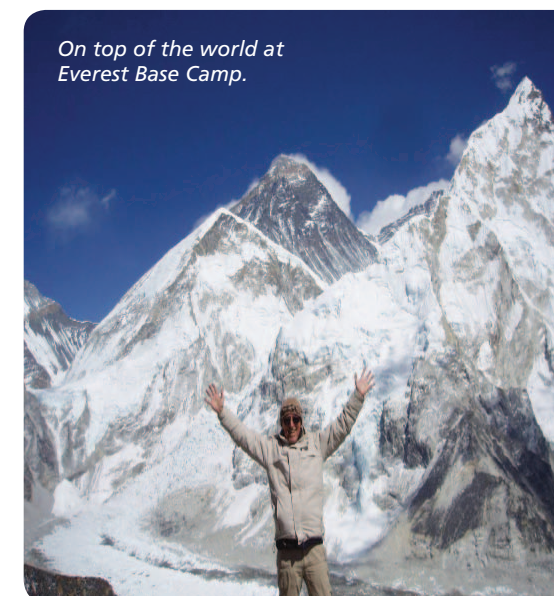
A very warm welcome back to *The Australian Metrologist*. This is the first issue for a couple of years and is the result of the groundswell of ideas among the national team and some groundbreaking work by the editorial team. Congratulations to all who have contributed to this edition.

My personal ambition for *The Australian Metrologist* is for some provocative articles that raise awareness of issues that may be contentious in the wider community. The first example of such a topic is the NSW branch's *Metrology-in-the Pub*, where we sought to explore climate measurements that have led to predictions of global warming.

We are in the middle of two conferences: *More than Kilograms and Metres*, held in Queensland in 2009 and MSA 2011, to be held in Victoria next year. Please have a look at our website for the great photographs of the 2009 conference and for news of the upcoming 2011 conference. On behalf of the Society I thank the Queensland conference organising team: Shane Brann, Max Purss, Geoff Barnier, Barry Neville, Bob Irwin, Rai Pippia and Nigel Lane, for their generous work that made this conference another success for the MSA.

The Queensland conference was a very rewarding and enjoyable experience, with an interesting variety of papers. One of my favourites was presented by an international guest from Italy, who measured airborne particulates in Brisbane locations and explored the nature of these particles, showing that many were aggregates and thus may not fit accepted models.

We have started an advertising campaign in Australian scientific journals to raise awareness in the scientific community about the science of metrology. The first advertisement (see outside back cover) appeared in the Australian Journal of Chemistry, Australian Physics and the Clinical Biochemist Reviews early this year. We plan to continue this campaign for at least a couple of years.



On top of the world at Everest Base Camp.



Lastly, I extend my sincere gratitude to all the members of the national team who continue to generously give their time to the Society. I continue to be impressed by the quality of your input at each of our gatherings.

On a personal note, I recently had a trip to Nepal where I trekked to Everest Base Camp. It was an extremely gruelling experience, but also an adrenalin-charged adventure. I'll write about it for the next issue of *The Australian Metrologist*.

The Queensland conference committee, left to right: Shane Brann, Bob Irwin, Ray Pippia, Geoff Barnier, Barry Neville, Nigel Lane and Max Purss.

Letter to the editor

Dear Editor

Calculating Algorithms Compliant with AS 2706?

I'm wondering how others approach the problem of rounding and, indeed, how do they process numbers to be rounded?

When we develop measurement values for metrological processes, do we simply use as many significant places as we can get? If we use fewer places, how do we determine the number of significant places required and how do we round to that number of places? I guess we need to ask the question, at what point does it begin to affect the measurement outcomes? In most cases this will be the resolution (digital instruments) or the readability (analogue instruments) of the measuring device we are comparing against our reference device. For NATA-accredited Measurement Science and Technology laboratories, the supplementary requirements for this field specify that calibration results "should be rounded to the readability of the instrument being calibrated". Additionally, there is also a need to express the measurement uncertainty as a rounded value (typically not more than two significant places).

AS 2706-2003 "Numerical values – Rounding and interpretation of limiting values" provides an excellent presentation of the terminology (section 2) and procedures (section 3) for the rounding of numbers. Section 3 also provides an example of why rounding should only be made once, which would, for example, support a case against rounding the values from a reference device to be used in calibrating a test device when the values would again be rounded to the readability/resolution (it serves no purpose to present calibration values to more significant places than can be determined from a scale or display).

Section 3.2 identifies the procedures for rounding to one unit in the last place retained and defines the rules as follows:

- (a) Choose the rounding (up or down) that is the nearer. In general, this will be evident, as follows:
- (i.) If the figure in the place following the last place to be retained is 0, 1, 2, 3 or 4 (whether or not followed by other figures), keep the existing figure in the last place to be retained (rounding down).
- (ii.) If the figure in the place following the last place to be retained is 5, followed by other figures not all zero, or is 6, 7, 8 or 9 (whether or not followed by other figures), increase the existing figure in the last place by 1 (rounding up).

Section 3.3 explains the procedures for rounding to five units or two units in the last place retained (very useful where the readability of analogue instruments is involved as the readability is in part determined by the scale interval). This is defined through the following rules:

- (a) Choose the rounding (up or down) that is the nearer. In general, this will be evident.
- (b) If, despite the use of all the figures that can be obtained from the data, the figures to be discarded fall exactly midway between two alternative, prospective rounded values, and there is no evidence to indicate in which direction to round, choose the round value that is the product of twice the rounding interval and an integer.

Section 3.4 describes the more common rounding procedures employed by

computers and calculators. These are:

- (a) *Truncation*. That is, simply removing the unwanted figures with no adjustment to the last figure of the 'rounded' number.
- (b) *Always rounding up*. When the discarded figures fall exactly midway between two successive round values.
- (c) *Variable*. This appears to be a feature of some computers that store numbers in binary form. It is often evident as a dependency on the figure before the last place to be retained as well as on the figure after. Moreover, the changeover from rounding up to rounding down can occur elsewhere than at the midway position between two successive round values.

Any computer or calculator rounding procedure used for rounding our metrological values should be checked (by direct experiment if there is no published information) before accepting any rounded values produced. Since most of us like to employ a computer or calculator to develop uncertainty, test and calibration values, perhaps we could also use it to produce the final reported values – but only if it conforms to AS 2706. I've tested a number of devices and a range of software and, in cases where the value to be rounded falls exactly midway between two successive round values, found that the majority round by truncation or most commonly by always rounding up. Has any one encountered an arithmetic or function-based solution that provides rounding to the requirements of AS 2706? Something spreadsheet-based might provide flexibility in use?

Robert Crawford

MSA 2009 conference

GEOFF BARNIER

Queensland and conference committee member

The venue for the 8th Biennial Conference of the Metrology Society of Australia was Surfair Marcoola; right on the beach on Queensland's Sunshine Coast and it ran from Wednesday 30 September to Friday 2 October 2009. In true relaxed Queensland spirit, delegates were greeted by the committee suitably attired in brightly coloured Hawaiian shirts, which set the mood for the conference.

The committee was pleased to see that some delegates took full advantage of the facilities, bringing along their family and partners who were treated to day trips on days two and three. Feedback from the attendees was very positive and many said they were most impressed by the venue.

Registration on day one was followed by the traditional NATA starter function, where old friendships were renewed and new ones made, well into the night. The facilities and weather were ideal, so the conference got off to a great start. The title and theme of the conference *More than Kilograms and Metres* was chosen to highlight the diversity of our industry and the membership of the MSA. A packed timetable of interesting papers presented over the following two days reflected this. The conference was opened by Dr Peter Fisk, who introduced the keynote speaker Professor Peter Andrews, Queensland Chief Scientist. Dr Andrews spoke about the problem of the lack of maths and science teachers coming through the tertiary system, as well as the lack of engineers and scientists graduating and the effect it has on industry.

Taking full advantage of the setting, lunch each day was served by the pool. After a hard day at the office, a few slipped over to the beach for a surf before attending the conference dinner, which was a great social evening.

To kick off day three, guest speaker Professor Mark Kendall, Director of the Australian Institute for Bioengineering and



Nanotechnology at the University of Queensland addressed the plenary session. His group is developing a nanopatch that has the potential to deliver 32 vaccines, just by pressing the patch on the skin for approximately one minute. After the final day of presentations the conference finished with the annual MSA AGM and BBQ by the pool.

We were 'honoured' to see that the conference had attracted the media. Mr Tom Rudd from Nobby Creek, west of the great divide, (aka Noel Sheridan), representing the Country Life newspaper, showed enthusiastic interest asking questions throughout the presentations, even helping with proceedings during the conference dinner.

The committee would like to express their sincerest appreciation to all the members who helped out in the preparation of the conference, including reviewing the papers, to the MSA National Committee and the sponsors for their support and also to all the members who attended. We hope it was beneficial and enjoyable.



The Australian Metrologist welcomes contributions to the letters page, comments, opinions, questions, etc.

MSA 2009 conference



Around the states

NSW/ACT

Greetings! Like other states/territories in the MSA, we try and come up with interesting events and technical visits of interest to our members (or potential members ...) Do you remember the 'Hypotheticals' evening, or the Greenhouse Gas Inventory talk, the talk on Software Testing, or the visits to the RTA Camera Enforcement Centre, the CSIRO Fire Testing Facility and the NMI chemical labs?

Our last event on the evening of 26 May, at the Greengate Hotel in Killara, Sydney. This was a member-based discussion billed as *Climate Metrology-in-the Pub* on the metrology of climate science, with prepared short presentations from members. Several lab visits are also planned and will be advised when confirmed.

On 15 August, NMI is holding an Open Day and MSA is expected to have a stand. Later in the year, a speaker nominated by Engineers Australia/IEEE/IET will give a talk at the NMI in Lindfield, as part of their Thursday Technical Series – this is an annual reciprocal arrangement of MSA NSW with Engineers Australia.

Please note that with the recent departure of CSIRO's Dale Hughes from his role as the contact for the ACT (very many thanks, Dale), NSW now takes on this area.

We are always on the lookout for new members of our NSW/ACT committee, so why not get in touch with us if you want to contribute, meet other metrologists and *make things happen ...*

Also, if your email address has changed recently, or you have recently acquired one, please let us know.

We have a question – we are thinking of arranging regular MSA member meetings in NSW, perhaps incorporating NSW committee meetings, to be held, say, on a certain day every month or two months – would that be a good idea? At the moment, meetings only occur when specific talks, visits or events are organised.

Looking forward to some feedback and meeting you at future activities.

Paul Pokorny, Paul.Pokorny@measurement.gov.au

VIC/TAS

The MSA Victorian subcommittee has been very quiet of late, with no meetings or tours for some time. Our recent gatherings have been held either at the Mettler Toledo offices in Turner Street, Port Melbourne, or at the National Measurement Institute Victorian offices in Bertie Street, Port Melbourne. Our last presentation was held at the NATA Melbourne offices, where Dale Hughes entertained a small group with his very interesting talk on the activities of the wind energy industry in Australia. Since that time, a small, dedicated group of volunteer members has maintained some contact and has been trying to come up with a valuable tour or a reason for a meeting.

Over the years, we have arranged laboratory and factory tours of various organisations that might be of interest to members, but we have run out of volunteers and new locations prepared to open their doors and entertain fellow MSA members. We desperately need new ideas and new locations or we need to revisit some of the best locations. Industry tours can be members showing other members around their own labs, or can be manufacturers showing off their latest offerings to a targeted and interested audience.

If you have a workplace that you are prepared to open up for an evening, or if you are a supplier that is looking to demonstrate a new capability, then you can access the MSA as a resource to get a gathering of like-minded people together to look, ask and generally be impressed. Please contact me and we will make it happen.

Neville Owen, Neville.Owen@measurement.com.au

WA

In 2008 the National Measurement Institute created two awards in recognition of World Metrology Day. The awards acknowledge and celebrate outstanding achievement in measurement research and/or excellence in practical measurements in the fields of academia, research or industry in Australia. This year both awards were awarded to Western Australians!

The Barry Inglis Medal went to Prof Michael Tobar of the University of Western Australia, who has worked at the leading edge of sophisticated frequency control systems for many years, leading to patents of inventions with commercial applications. In particular, his work with oscillators forms the basis for the next generation of radar, telecommunications and precision measurement applications.

The NMI Prize went to Prof Eric May, also of the University of Western Australia, for his contribution to gas measurements and the successful application of measurement techniques to resolving industrial problems.

David Pack, D.Pack@edu.curtin.au

QLD/NT

Queensland is still suffering a 'hangover' after organising the successful 2009 MSA biennial conference held in September/October last year. While it was a rewarding experience, the break has been welcome with no recent formal local events being arranged. However, we did have a 'debriefing' dinner at the Oxley Hotel on 16 December 2009.

Recently, the 'state coordinator' title has been changed to 'state contact'. Without a state contact in the NT, we welcome the NT members who join with QLD. I have now accepted the role as a central contact for both QLD and NT, providing liaison to the national committee.

Moving forward, an email was sent out in February to all QLD and NT members looking for ideas and suggestions for local events. Thank you to those who took the time to reply. If you didn't receive the email, let me know and I'll make sure you're added to the mailing list. If anyone has any new ideas for local events, let me know.

A visit to the Railway Workshops at Redbank may be the next event.

Geoff Barnier, Geoff.Barnier@deedi.qld.gov.au

SA

Mark Histed has put his hand up for state contact for SA. Mark is thinking about activities for the MSA in South Australia – please contact me with all suggestions

Mark Histed, mark.histed@triplepoint.com.au

Historic single system of weights and measures

A new national trade measurement system to come 1 July 2010

In late 2008, historic legislation was introduced into federal Parliament to establish the legal framework for a single system of weights and measures for Australia, replacing the previously fragmented situation that existed across each state and territory. The area of trade measurement had previously been identified by the Council of Australian Governments (COAG) as one of the 10 'hot spots' in need of urgent regulatory reform. On 1 July 2010, a new national system of trade measurement will commence under the administration and regulatory oversight of the National Measurement Institute (NMI), a division of the Australian Government's Department of Innovation, Industry, Science and Research (DIISR).

Measurements taken in the context of trade and regulation are immensely important. We buy, sell and make all sorts of commercial and consumer decisions based on weight, length, area, amount of substance, energy usage, traffic and environmental laws ... the list is endless. Economic and social life could barely progress beyond the most basic functions without the support of a well-founded, reliable system of measurements, which everyone can believe and act upon with

confidence and trust. An estimated \$400 billion a year in trade transactions relies on measurement.

Currently about 800 Australian firms, employing more than 2,000 people, repair and verify measuring instruments under trade measurement legislation. If they operate across state borders they require different licences for each state. These are granted under different criteria, attract different fees and have different reporting requirements. Under the new system, there will be one licence, one set of criteria and one fee for work nationwide. The aim is that the new national system will cut red tape, while maintaining the accuracy and reliability of trade measuring instruments such as scales, fuel dispensers and weighbridges.

At the heart of the legislation are two key features:

- A national trade measurement system is to be administered by the Commonwealth from 1 July 2010.



- The establishment of an Average Quantity System (AQS) that will be an internationally recognised system for confirming that pre-packaged items, including food and beverages, contain the stated quantities.

The AQS will allow producers and packers of pre-packaged goods to meet requirements at lower cost by introducing statistical sampling methods to show that the measured contents of pre-packaged goods are accurate. This has been welcomed by the wine industry, which itself estimates the AQS will save wine producers up to \$19 million a year, and other major packers. The AQS has already been adopted in New Zealand and by many of Australia's major trading partners, including Japan, the European Union and the United States.

Q&A

Q: When will the new regulations start?

A: While the regulations commenced in September 2009, most of the regulations that impact on business will only come into effect on 1 July 2010, which is the transition date.

Q: What are the new regulations?

A: The new regulations are based on the Uniform Trade Measurement Legislation (UTML) currently administered by the state and territory governments. They cover:

- The use of measuring instruments for trade.
- Testing and verification of measuring instruments for trade.
- Transactions by measurement.
- Pre-packaged articles.
- Licensing of public weighbridges and instrument-verifying businesses (servicing licensees).

Q: What has changed under the new regulations?

A: The only significant change has been the introduction of AQS regulations under the 'shortfall' provisions of the regulations. From 1 July 2010, industries can choose to comply with the AQS standards or the existing UTML standards.

Sources

This article was prepared from information found in the following publications.

National Measurement Institute (NMI). Guide to the New National Trade Measurement Regulations, November 2009.

Emerson C. Media release from the office of the Minister for Small Business.

National Measurement Institute (NMI). New National Trade Measurement Regulations brochure.

Computer time and traceability

MJ WOUTERS AND RB WARRINGTON

National Measurement Institute, PO Box 264, Lindfield, NSW 2070

Abstract

A wide variety of applications depend on computer time. For example, computers are used to measure the duration of a phone call and charge accordingly; to vary the price of a motorway toll or train ticket throughout the day; and to timestamp financial transactions, legal documents and even calibration measurements.

In all of these cases, the computer is effectively making *time measurements* which should be accurate and reliable. In most cases, the integrity of computer timing depends on the accuracy and reliability of an external reference clock and of the method used to synchronise to this reference. The National Measurement Institute (NMI) disseminates Australia's reference timescale UTC(AUS) using several different methods. Where computer time is required for a legal purpose, computer time may also need to be formally *traceable* to UTC(AUS), which requires that the uncertainty of synchronisation is known – that is, the magnitude of any residual time offset remaining after synchronisation must be able to be measured or estimated.

This article covers a number of aspects of computer timing, including methods used to ensure the accuracy, reliability and traceability of computer timing for a wide variety of applications.

Introduction

The rapid spread of computers and computer networks into many everyday activities has created a demand for precise and accurate electronic timestamps. Timestamps can be used in three ways: to establish the time of an event, the duration of an event and the time-order of a sequence of events.

The provision of timestamps is a relatively new responsibility for time and frequency laboratories. The traditional role of these laboratories has been the dissemination of frequency standards to provide traceability of frequency and time interval measurements. The National Measurement Institute (NMI) maintains Australia's national standard for frequency, using a small ensemble of atomic clocks, but has been only formally responsible for time of day since 1 July 1998, when this responsibility transferred from the Australian Surveying and Land Information Group (now Geoscience Australia) to the CSIRO National Measurement Laboratory (now NMI). The realisation of Coordinated Universal Time (UTC) maintained by NMI is Australia's legal standard for time of day, as established in Section 8AA of the *National Measurement Act 1960* (Cth).

A key part of this responsibility is dissemination of these standards to the wider community, to support accurate and reliable measurement throughout Australia. At present, although some calibration of frequency standards is conducted on site at NMI facilities, a significant part of the dissemination of frequency and all dissemination of UTC(AUS) is by computer-based methods.

There are many applications which require accurate and precise timestamps, including:

1. Logging of financial transactions.

2. Time-based charging. For example, the charge for a telephone call may depend on both the length of the call and the time of day it was made.

3. Security systems. A security system consists of a mix of access control and monitoring devices. It can often be important to establish the sequence of events in an incident to identify security flaws, or an accurate time to provide evidence for prosecution.

4. Electronic notary services and intellectual property protection. It can be particularly important to establish the date that an electronic document was created and also that the document has not been modified since that date. For example, the document might be a contract, or describe an invention.

5. Emergency services. Like security systems, accident investigation can draw on many independent sources to establish a sequence of events and this requires independent timestamps to be related to a common time scale. Moreover, litigation involving the perceived failure of emergency services to respond to an emergency call in a reasonable time has sometimes hinged upon records of the response and, in particular, the times at which actions were taken.

6. Calibration services. In a calibration laboratory, timestamped observations might be used for a simple calibration of a stopwatch. A series of timestamped phase measurements for an oscillator can also be used to determine frequency.

Because time is a physical quantity, applying a timestamp or 'telling the time' necessarily involves making a physical measurement. Like any such measurement, there are in principle three separate but key requirements for electronic timestamps. The first is the *accuracy* of a single timestamp. The second is *reliability*, by which we mean continuous availability and sustained accuracy to underpin application over extended periods. The third is *traceability*, which may, for example, be particularly important in a metrological or legal context but has the much more general function of ensuring the integrity of measurements for any application.

Traceability

The term 'traceability' has a specific metrological definition ¹:

The property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons *all having stated uncertainties* (italics added).

This definition thus allows for an extended chain of comparisons through intermediate references, provided that each link in the chain has a stated uncertainty or tolerance. For time, as for any physical measurement, establishing metrological traceability, therefore, means relating the local clock to a national reference, including evaluating uncertainty for each intermediate link in the chain.

However, computer time can be unlike other physical measurements in three key respects, which arise in practice when establishing traceability. The first is that it may be necessary to *explicitly* select particular external reference clocks or synchronisation methods, to replace operating system defaults, which may keep approximate time but not support traceability. The second is that particular synchronisation methods may require additional information or processing to evaluate uncertainty; this point is discussed further in Section 7. The third and most important is that time is a continuous quantity and must, therefore, in principle, be checked continuously (unlike, for example, a reference mass). Synchronisation events consequently happen frequently, much more frequently than calibrations of standards or devices and must record the full history of clock corrections applied. This is important to support traceability.

Clocks in computers

Computers based on x86 processors have two clocks. One, the real-time clock (RTC), stores time of day information and is backed up by a battery so that the system time is maintained while the PC is powered down. When the PC reboots, the operating system usually reads the RTC to initially set the system time. The resolution of the RTC is only one second, so the PC time can only be set to the nearest second using this clock.

PCs also contain a 1.19 MHz quartz crystal oscillator and three 16-bit counter/timers, one of which is used for generating the system timer interrupt (typically at 1 kHz). This timer is used for a higher resolution clock by counting the number of interruptions

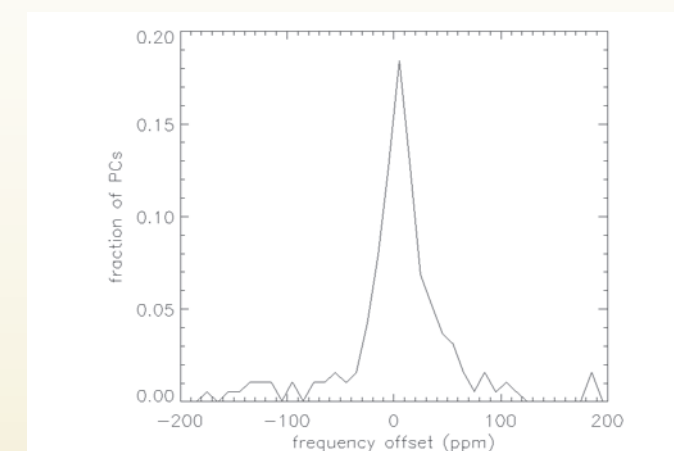


Figure 1 Survey of accuracy of crystal oscillators in PCs.

since the system powered up and is the clock used internally by PC operating systems. This clock is sometimes called the software clock.

The crystal oscillator is a low-quality device, usually with much less accuracy than a cheap watch. Figure 1 shows the results of a survey of the crystal accuracies of about 200 computers conducted by NMI. While about 30 % are better than 10ppm, about 15 % are worse than 100ppm, which corresponds to a drift of about 10 seconds per day.

For most PCs, then, an external reference is required to provide accurate time. The external reference should be reliable and the synchronisation method should provide the accuracy and traceability needed for the intended application.

Improving PC time

A PC can be provided with a better time reference by installing an add-on card and software. For example, the time reference on this card could be a higher quality crystal oscillator, a GPS receiver or an external timing signal in a standard format such as IRIG-B. The software either continuously adjusts the PC time using the reference or provides a library for user applications to directly obtain a timestamp from the card. This is a relatively expensive solution.

Other solutions involve obtaining a timestamp from an external source using a long-range communications link. For example, many national metrology institutes provide telephone dial-up services for synchronising computers. A serial modem is required to use these services. The client computer makes a call to the time server, establishing a serial data connection. The time server then outputs a sequence of time codes. A special character is used to mark the epoch of each time code. At the client computer, the arrival time of the epoch marker is recorded, so that the difference between the client time and the server time can then be computed and the client time adjusted.

The NMI operates a dial-up time server implementing the Automated Computer Time Service (ACTS) protocol², developed by the National Institute of Standards and Technology (NIST) in the USA.

Dial-up time services have been largely superseded by internet-based synchronisation methods such as the Network Time Protocol (NTP), which is described below.

Network delays

A network is a group of computers that is able to pass information to each other via some connection which could be wire, optical fibre or microwaves. We are interested in the particular case where this information is a timestamp to be used for synchronising a local clock to an external reference. Although the physical network connections involve signals that are for most purposes instantaneous, there are many sources of substantial delays in a practical network. These delays clearly affect the accuracy of synchronisation achievable across the network.

Measurable delays can occur even when computers are directly connected to each other. For example, on an ethernet network,

if two computers try to transmit simultaneously, they will both back off and try again a random time later. This happens after the packet containing the timestamp has been constructed, so the timestamp is now wrong by an unknown amount.

When there is no direct connection between two computers, much larger delays can occur. In particular, when travelling between networks, network packets have to be sent via special devices called routers that know where to direct the packets. The router must examine each packet and send it on to its destination. This takes a measurable time. On a busy router, packets may have to queue up before they are sent on. This may happen many times as a packet traverses large or complex networks. When entering the destination network, a packet will almost certainly pass through a firewall, where once again it will be queued and examined before being passed on to its final destination.

The dynamic nature of computer networks means that propagation delays change over time. The failure of one network segment might mean that a packet is routed along an entirely different path, with a different delay. Changes in network activity through the day also introduce variable delays.

To account for these delays and to maximise the accuracy of synchronisation, delays must therefore be measured for each successive transmission. It is not adequate to characterise the delay between the server and client once, even if this could be done reliably. The NTP, described in the next section, is designed to continuously measure the delays so that they can be corrected for.

The NTP

The NTP ^{3,4} allows a reference server to serve time to many remote clients over the internet. Top-level (Stratum 1) servers are directly connected to an accurate and reliable clock, which becomes the reference for the clients. A client can itself become a lower level (Stratum 2 or lower) server, in a hierarchy which helps to minimise traffic and promote synchronisation within a network tree. Synchronisation of a client can be continuous and completely automatic.

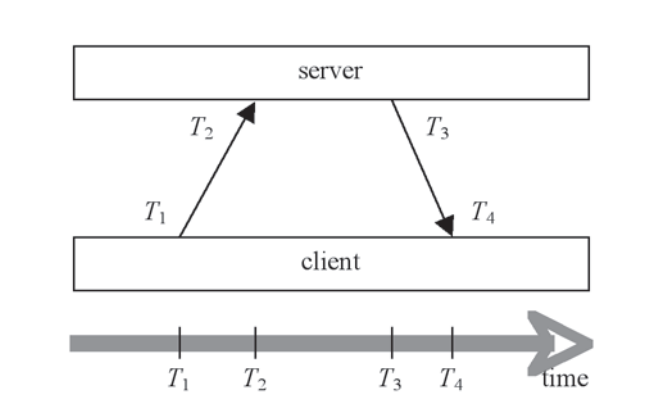


Figure 2 Timestamps in an NTP exchange.

A typical NTP exchange between client and server proceeds as follows (Figure 2):

- (1) The client constructs an NTP request, putting a timestamp (T_1) in the packet to record the time the packet was sent. The packet is then sent to the server.

- (2) The server receives the packet and immediately puts the receipt timestamp (T_2) into the packet. The packet is then queued for sending back to the client.
- (3) Immediately before sending the packet back to the client, the server inserts another timestamp to record the time of reply (T_3).
- (4) The client receives the packet and immediately timestamps it (T_4). The client can then calculate a correction to its clock which includes an estimate of the delays.

Note that T_1 and T_4 are obtained from the client clock and T_2 and T_3 from the server clock. The apparent offset of the client clock from the server is then estimated from:

$$[(T_2 - T_1) + (T_3 - T_4)] / 2 \quad (1)$$

and the round trip delay δ is estimated from:

$$\delta = (T_4 - T_1) - (T_3 - T_2). \quad (2)$$

It is assumed in equation (1) that the network delays are symmetric³.

Note that because only the total round trip time can be measured, delays must be assumed to be symmetric, but this will not be perfectly true in general. Grossly asymmetric delays can occur: for instance on an overseas connection, the outbound connection might be via submarine fibre, whereas the reply might be routed via a satellite.

It should also be noted that the sophistication of NTP client software varies considerably. In particular, simpler implementations of the NTP protocol may not correct for the network delay. More advanced implementations may also attempt to estimate the frequency correction to the PC crystal oscillator from the history of time offsets and to extrapolate clock corrections using this estimated frequency offset. This means that the system time drifts less between synchronisations and also minimises the error accumulated over periods where the server is unreachable.

Traceability of NTP

Computer timestamps may require formal traceability for metrological or legal applications. Because NTP is widely used to synchronise PC clocks, it is important to consider to what extent NTP can support formal traceability and what information may be required to establish traceability. The principal uncertainty is usually the unavoidable network delays, as estimated by equation ².

Traceability must be established at both the server and the client computer. On the server side, NMI maintains a network of NTP servers distributed around Australia to disseminate UTC(AUS). These are generally Stratum 1 servers with a local atomic clock. In the case of NMI's Sydney NTP server, this clock is UTC(AUS) directly. For NMI's Melbourne and Perth NTP servers, the reference clock is continuously compared to UTC(AUS) via a GPS Common-View link ⁵, establishing traceability independently of the network and giving an uncertainty in the time offset of the local reference of less than 10ns. Because the server clock is an oscillator steered by software, with associated noise and potential systematic errors, it is desirable to have an unambiguous record of the time offset of the PC clock. This is obtained with hardware and software that measure the server time against the local reference. This establishes the server time with respect to UTC(AUS) to within a few tens of microseconds.

The minimum requirement for traceability at the client computer is a continuous record demonstrating synchronisation to a traceable time server including a full history of the adjustments made to the client PC clock. NTP client software can typically be configured to automatically record all of the desired information on the client computer. Each synchronisation also requires an estimate of the associated uncertainty, which is principally due to potential systematic error in the estimate of network delay. While it is not possible to make any deduction about asymmetry in the network path, the round-trip delay δ can be used as an upper limit on the associated uncertainty. In Australia, with a good network connection, this is typically no more than 100ms.

For many applications, it may be sufficient to demonstrate traceability at the 100ms-level on the client computer. However, some applications may have additional requirements. For example, if a lower uncertainty is required, it may be necessary to install a new Stratum 1 server within the client network (to minimise network delays) and to establish traceability for the server reference clock by an alternative method.

As a second example, it may be desirable for a separate party, such as NMI, to formally report on the traceability of the client PC clock, either for independent oversight or simply to minimise the processing required on the client side. Although straightforward in principle, complications can arise in practice. Consider the specific case where a client requires a report from NMI stating an uncertainty with respect to UTC(AUS). Only the client side has all the information needed to evaluate the round-trip delay δ and obtain this uncertainty; with reference to Figure 2, the server has three of the required timestamps but is missing the time the client received a reply (T_4). The required log files must, therefore, be sent somehow to NMI for processing and ideally this process should be automatic. Difficulties can arise here because of network security policies which forbid the required network connections. This is a particular problem in corporate and government networks.

The ideal solution would allow full client records to be collected automatically by the NTP server as part of an NTP exchange. This would avoid any conflict with network security policy (since the NTP exchange is already permitted) and improve the integrity of the information collected (since it would be held by an independent third party such as NMI). Additionally, the information would be collected on the fly from the client software so that tampering with the data would require significant technical expertise. However, to implement this solution, an extension to the NTP protocol is required, to allow the server to collect the missing information not available in a standard NTP exchange.

Design of an extended NTP protocol

NMI has developed an extended NTP protocol as described above, to support the dissemination of UTC(AUS) and to enable formal reporting on synchronisation state of remote clients with full traceability. The extended protocol uses custom extension fields provided for in the NTP framework ^{4,6}.

Version 4 of the NTP protocol defines an extension field within the NTP packet that is intended to be used for cryptographic authentication of the packet's contents. In principle, however, it

can be used to carry arbitrary data. While other possibilities exist for storing extra data within an NTP packet, we decided to use the extension field since this is much more flexible, at the cost of slightly more complex modifications to client and server code.

In addition to the four timestamps, other information is generally needed by the server. In particular, the server needs to be able to identify where a packet has come from. The source IP address for an NTP request is not in general a unique identifier. A customer may have multiple NTP clients on a private network, which all appear to originate from a single public internet address. In the NMI scheme, each client is identified by a unique number, which is also relayed in the NTP exchange using the extended protocol. Identifying clients by a unique number has other advantages. Smaller organisations tend to change their internet service provider (ISP) relatively frequently and each time a client changes ISP, their IP address will change. A separate identifier independent of IP address reduces administration time.

It is desirable that the custom NTP client still works with standard NTP servers. For example, a customer may have their own, local NTP server that can serve more stable time than is achievable over the internet and this server may reject an NTP request using the custom extended protocol. Compatibility is maintained by identifying NMI servers in the NTP client configuration file and ensuring that the client only sends custom NTP packets to these servers. Other servers just receive standard NTP packets.

Implementation of the extended NTP protocol

We are using the reference implementation of NTP as the basis for an implementation of our modified version of NTP ⁶. The reference implementation is freely available and is used in a number of commercial products. To implement our extensions, changes to code at both the client and server side are required. To simplify the changes at the server side, logging of client data is done by a separate program, which examines all incoming network traffic and picks out NTP packets for logging. The need for a modified client has the disadvantage that it is necessary to provide continuing support for a number of operating systems at any one time.

The modified client software then works in the following way. Each time it receives a reply to an NTP request, the client stores the four timestamps for the complete transaction. The next time it sends an NTP request, these four timestamps are written into the extension field, along with other information such as the client identifier.

At the server side, the special NTP packets are detected by the logging program and recorded. They also pass to the NTP server software, where they are treated as normal NTP requests. The response goes back to the client, which stores the arrival time for the next request. It should be noted that a client typically sends an NTP request once every 20 minutes or so; a modern PC can, therefore, comfortably handle a million or so NTP clients.

Client logs accumulated at NMI's remote NTP servers are first returned to the Sydney site; this does not reintroduce security

constraints, because this transfer is within NMI infrastructure. Automated processing, reporting and then archiving of these logs takes place. Depending on customer requirements, daily, weekly or monthly reports can be generated.

At present, we have made the necessary changes to NTP client and server software and conducted some preliminary laboratory testing. The next step is to undertake further testing by running this software 'in the wild', to confirm the performance achievable on real-world networks.

Conclusion

Accuracy, reliability and traceability of computer time are increasingly critical in a wide variety of applications. Supporting these requirements, and particularly traceability, requires ongoing evolution of Australia's standards and dissemination infrastructure to underpin these applications.

As part of this evolution, we have designed and implemented changes to the reference implementation of NTP that allow remote logging of a PC's synchronisation in a way that is convenient to

users and that provides assurance of the integrity of the data. This forms the last link in the chain for establishing complete traceability of a single PC's time to national standards.

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2. Further information is available at < <http://www.measurement.gov.au/time> >.
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4. Mills DL. Computer Network Time Synchronization: The Network Time Protocol. Boca Raton, FL, UWA: CRC Press, 2006.
5. Warrington RB *et al.* GPS Time and Frequency Transfer and Remote Calibration, Proceedings of the Sixth Biennial Conference of the Metrology Society of Australia, 2005, pp 181–187.
6. Further information is available at < <http://www.ntp.org> >.

MSA Technical Interest Groups

Pressure Metrology

The main focus of the pressure interest group recently has been the writing of two test methods for use in Australia. The MSA Test Method 1 covers the testing of pressure calibrators and digital pressure indicators and is particularly important for pressure testing facilities, because there has been no method available to date. This means each facility would write their own test method, resulting in instruments being given a varied treatment and the absence of minimum test requirements.

The MSA Test Method 2 was produced at the same time to cover the testing of dial-type pressure indicators, replacing AS 1349 for gauge testing. This has overcome shortcomings in AS 1349, which were not being addressed. In particular, it addresses the treatment of uncertainty of measurement and the newer accuracy standards from European manufacturers.

The National Association for Testing Authorities (NATA) has accepted the standards for use in accredited laboratories. The two methods are available for free download from www.metrology.asn.au and we welcome your feedback on any impact you may have experienced from their introduction. From our experience and feedback received so far, there has been a positive response to their introduction.

At the MSA 2009 conference, the pressure interest group gathered and discussed the prospect of examining the testing of oxygen gauges as a possible area for our group to look at next. We have to be careful with this issue because of safety concerns where an error may lead to an explosion or fire. However, we are currently seeking experience from members regarding this issue, which might be used to help provide advice on the subject.

Work is continuing on providing better communication methods with members of interest groups in the MSA and we will communicate to you shortly on how you can opt in and out of groups. For now, please feel free to email me if you wish to be included at < Randall@auspressurelab.com.au >.

CMM and Coordinate Metrology

A meeting of the MSA Coordinate Measuring Machine (CMM) technical group was held at MSA 2009, where the coordinator of the group, Ashley Gracias of the National Measurement Institute (NMI), presented the results and some conclusions from the CMM round robin conducted over the previous three years. Alistair Prosser from Thales gave a presentation on probing characteristics and some recent developments in probing. This was followed by a general discussion about planned activities of the CMM technical group. If you have any enquiries, suggestions or ideas, please contact < Ashley.Gracias@measurement.gov.au >.

Opening of NMI's flowmeter facility at Londonderry

PAUL POKORNY

Wednesday 17 February 2010 was a special day, marking the end of a long process that started with the transition of the National Standards Commission (NSC) to become part of the National Measurement Institute (NMI) in 2004. The day marked the official opening in new premises of the Flowmeter Facility of the NMI at Londonderry, western Sydney, NSW, by the Honourable Richard Marles, Parliamentary Secretary for the federal Department of Innovation, Industry, Science and Resources (DIISR). The facility has been delivering services to industry since September 2009.

The Londonderry site is a unique facility in Australia, where flowmeters for a wide range of hydrocarbon fuels (petrol, diesel, LPG and compressed natural gas) are calibrated. Volume delivery measurements in the petroleum industry are ultimately traceable to this facility, assuring their accuracy. Located next to WorkCover's TestSafe testing centre, it is quite a bit further (the other side of Sydney) from the main NMI centre at Lindfield.

Meters calibrated at this facility are used to calibrate and check the measurement of fuel dispensing, from small-capacity vehicle fuel dispensers to high-capacity meters used in production plants and ports. In addition, calibration services are provided for bulk liquid flow for countries in our region such as New Zealand, Papua New Guinea and Fiji.

Speeches were given by Mr Marles, NMI's CEO, Dr Laurie Besley and Dr Peter Fisk to an audience of about 80 guests. Dr Fisk made a point of thanking the various contractors and consultants, many of whom were represented and with whose effective cooperation the many technical and regulatory hurdles were addressed.

Simon Dignan, the officer-in-charge (also involved from the outset), was introduced and the unveiling was carried out by Mr Marles and the local member, the Honourable David Bradbury MP. Simon Dignan and Dr Mark Ballico then showed the VIPs around with refreshments and general tours were also arranged for the other visitors.

What can the facility do? The key pieces of equipment are called 'volume provers'. Provers are displacement devices, which discharge known volumes in known times through the meter under test. Using a 60 L piston prover, petroleum product flowmeters with flow rates from seven to 4000 L/min can be handled. Very high pressures can be developed in this process. Actual liquid fuels are not used, but substitutes of equivalent flow characteristics to petrol and diesel, (known as NORPAR and D130, respectively are used – also known as Test Fluids A and B). Fluid A has a density of 750 kg/m³ and a kinematic viscosity of 2.6 mm²/s and the figures for Fluid B are 810 kg/m³ and 5.7 mm²/s, respectively.

As far as liquid petroleum gas is concerned, using a 40 L piston prover, flow

rates from four to 1700 L/min can be accommodated, using two gas blends, one mainly propane and other mainly butane. In addition, compressed natural gas (CNG) meters can be calibrated from one to 100 kg/min. Service station flowmeters are also tested, using a gravimetric technique and for both LPG and liquid hydrocarbon systems, compensated flow rate uncertainties of less than ±0.03 % are achieved.

The flowmeters calibrated at the facility are, in turn, used to calibrate everything from small fuel vehicle dispensers to the very high capacity units found in factories and port facilities. The whole facility must operate with a minimum of two staff, each fully aware and in agreement with the other's actions. A great deal of design effort (and money) has gone into making the construction of the building consistent with best practice for high-pressure flow work, with intrinsically safe and fail-safe systems in place. Comprehensive safety operating procedures are in place. The data acquisition is via graphical user interface-type mimic panels and the many valves and controls are firmly under PLC control. Care was taken to use completely proven technologies throughout.

The operation is already very busy in its work, proving formal traceability to Australian national standards and in due course it is intended that it will be NATA-accredited



NMI open day

On 9 November 2009, the new laboratory facility at NMI Port Melbourne was formally opened by the Hon. Richard Marles MP, Parliamentary Secretary to the Minister for Industry, Innovation, Science and Research. Also present were Patricia Kelly, Secretary to the Department, and the Hon. Michael Danby, MP for Melbourne Ports. The NMI management team present included NMI CEO, Dr Laurie Besley, and general managers James Roberts (Analytical Services), Dr Peter Fisk (Physical Metrology) and Dr Valerie Villiere (Legal Metrology).

The new facility brings together under one roof the combined capabilities of Analytical Services, providing a wide range of food testing services, Physical Metrology, providing extensive calibration service and Legal Metrology, providing inspection and verification of trade services.

Over 180 guests attended the opening, including clients of NMI, equipment and instrument suppliers and key members of the construction team that completed the building and fit out of this special-purpose building. Other notable guests included Dr Barry Inglis, former CEO of NMI and Dr Sandra Hart, former general manager of Australian Government Analytical Laboratories (AGAL). As Master of Ceremonies, Dr Laurie Besley introduced Ben Reys, NMI Port Melbourne business development manager – food and biomedicine, who gave an overview of the site and its activities. Patricia Kelly then introduced the Parliamentary Secretary, who formally opened the facility by unveiling a commemorative plaque.



A large turnout of local and interstate metrologists and notable visitors attended the opening.

The VIP party and another nine groups were then given a comprehensive tour of the facility and the opportunity to view the facility's capabilities. Over 40 poster displays describing current activities and staff were on hand to highlight the operation of instruments and the advanced capabilities available. Key areas highlighted in the Analytical Services branch were antimicrobial residues in meat, milk and seafood, folic acid in bread-making flour, water- and fat-soluble vitamins, low level vitamin D analogues, melamine residues, agricultural pesticides in food, food labelling and mercury analysis.

NEVILLE OWEN



Sam Barone describes an automation analysis station to Mr Marles.

In the Physical Metrology branch the tour included a description of the many capabilities including determination of surface roughness, flatness and roundness. The calibration of gauge block and length bars, angle standards, plug and ring gauges. A brief description highlighted measurement projects being conducted by NMI on sphericity and cylindricity, the definition of the kilogram and the establishment of a pressure scale. Demonstrations were conducted of the Coordinate Measuring Machine (CMM), high-pressure calibration systems and the reference facility providing traceability for vehicle speed measurement.

Also highlighted was the low-energy-design, precision, environmental temperature control system, which maintains the 400 m² Physical Metrology laboratory at better than ± 0.3 °C. Based on a Canadian design, this is the first implementation of this kind in Australia.

On the day of the opening, outdoor temperatures climbed well above 30 °C, so the laboratory tours provided a refreshing respite prior to afternoon tea served under the marquee, where guests took the opportunity to network with colleagues and ask numerous questions of staff.



Mr Marles at the controls of the NMI's Coordinate Measuring Machine.

EVENTS

Sunday 4 – Thursday 8 July 2010

The Royal Australian Chemical Institute (RACI) National Convention in conjunction with the 12th IUPAC International Congress on Pesticide Chemistry (ICPC)
The new Melbourne Convention Centre, VIC

4–6 August 2010

North American Coordinate Metrology Association (NACMA) annual workshop
Minneapolis, Minnesota, USA
Web www.iigdt.com/nacma
For background information about NACMA: www.acmc-canada.ca

23–27 August 2010

Australian Acoustical Society 20th International Congress on Acoustics
This congress is held every three years and provides the opportunity for all acousticians to meet and discuss recent advances in their fields of interest.
The Sydney Convention Centre, NSW

5–9 December 2010

19th Australian Institute of Physics (AIP) Congress incorporating the 35th Australian Conference on Optical Fibre Technology (AIP/ACOFT 2010)
The new Melbourne Convention and Exhibition Centre, VIC



Two of Australia's top science organisations join forces for National Science Week. See hard core measurement, physics and engineering research in action. Our doors are open, so come along!

What: Open Day 2010

Who: The National Measurement Institute (NMI) and CSIRO Materials Science and Engineering

When: 10am - 4pm Sunday 15 August 2010

Where: The National Measurement Institute, Bradfield Road, West Lindfield, NSW

Visit: www.measurement.gov.au/openday for the full program.

Contact: communications@measurement.gov.au or 02-8467 3771



