NPL
National Physical Laboratory

Counting on IT

A National Measurement Newsletter

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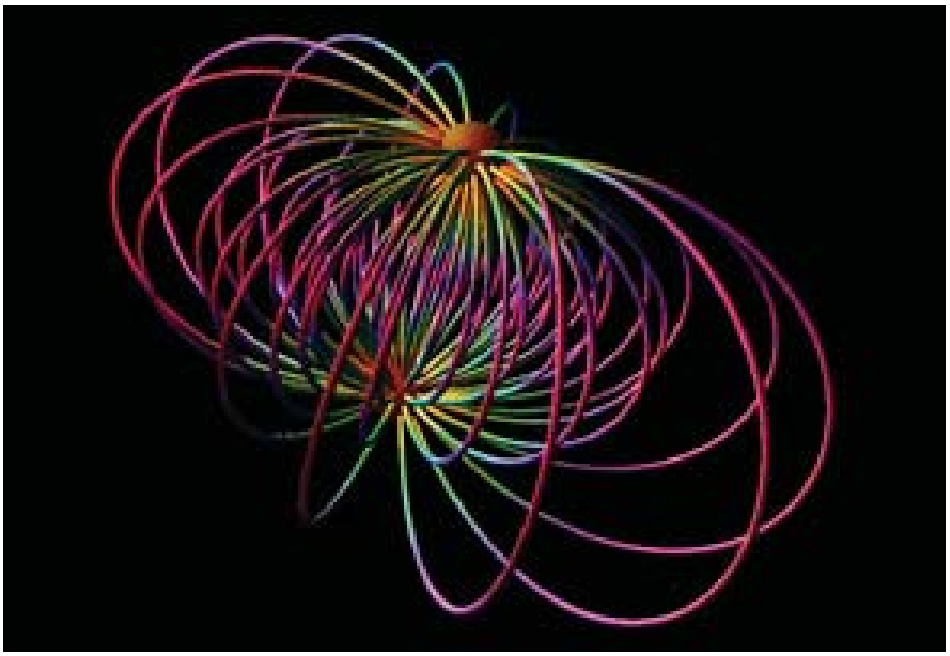

Figure 1 A VRML "world" of the magnetic field around a magnetic dipole

Contents:

Interactive web pages

A new SS*f*M good-practice guide describes how to use web technologies to access interactive web-based information.

The aim is to explain technology that allows scientific information, including mathematics and data visualisation, to be presented, enabling easier navigation on the web. The guide shows how to use sophisticated techniques that allow the user to interact with information on the web in real time, significantly enhancing the quality of information transfer, both in terms of understanding and content, as well as in terms of visual attractiveness.

A report entitled *Guidance and Tools for Interactive Web Pages*, produced by SS*f*M in 1999, proved very popular and was frequently downloaded from the SS*f*M website. Since then, the range of web technologies has expanded in scope and complexity. The new guide is an updated version of that report that covers the latest technology. It contains an extensive list of further web resources that can now be used to help implement the new technology, and includes a glossary to help the reader survive the alphabet swamp of web technology acronyms.

Most of the technology presented in the guide is based on XML (eXtensible Markup Language), which can be used to encapsulate data and to describe its structure. XML can be adapted to describe mathematics, chemical symbols, 2D and 3D graphics as well as virtual reality. VRML (Virtual Reality Modelling Language) is used to define 3D virtual reality "worlds", available over the web, and through which the user can navigate using VRML viewers. This can be used to model scientific data, allowing the user to investigate particular aspects of the data by selecting the appropriate view in the virtual reality world. *See figure 1*

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Statistics standards to support metrology 2004 – 05

SS*f*M is involved in standards activities relating to uncertainties. The work is relevant to various national and international bodies. Highlights from the first year of the programme are given here.

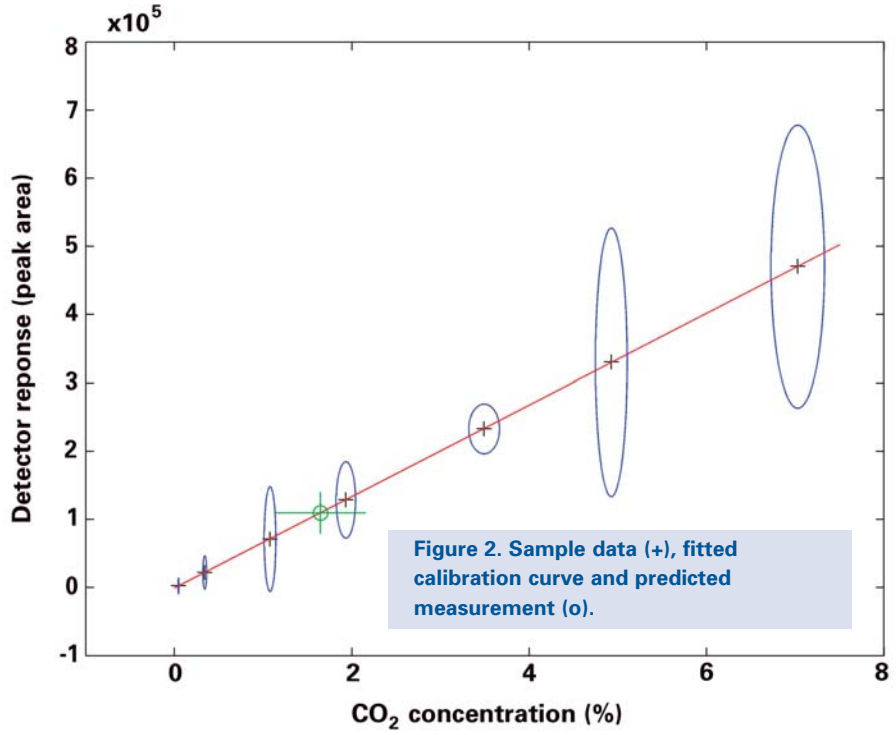

Figure 2. Sample data (+), fitted calibration curve and predicted measurement (o).

British Standard Institution (BSI)

SS*f*M is represented on BSI committee SS/6, *Precision of Test Methods*, and SS/6 Panel 3, *Measurement Uncertainty*, as convenor and secretary. Highlights include:

- Publication of *Practical guide to measurement uncertainty* (BS PD 6461-4:2004, General metrology—Part 4), which sets out procedures for evaluating the uncertainty associated with the result of a measurement. It provides advice on applying the *Guide to the Expression of Uncertainty in Measurement* (GUM) to industrial measurement problems;
- Proposal for a new work item on straight-line calibration curve models. This work would provide approaches for establishing and using such models for a variety of uncertainty structures associated with measurement standards and instrument response. It would test model validity and permit stimulus values for unknown samples to be predicted, with associated uncertainty evaluation. *See figure 2.*

International Standardization Organization (ISO)

SS*f*M provides a member on ISO/TC 69, *Applications of Statistical Methods*, and a convenor for ISO/TC 69/SC 6/WG 7, Relation ISO 5725-GUM. SC 6 is the subcommittee entitled *Measurement methods and results*.

Highlights include:

- Publication of *Guide to the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation* (ISO/TS 21748). This document gives guidance for (a) evaluation of uncertainties using data obtained from studies conducted in accordance with *Accuracy (trueness and precision) of measurement methods and results—Part 2, Basic method for the determination of repeatability and reproducibility of a standard measurement method* (ISO 5725-2:1994), and (b) comparison of collaborative study results with measurement uncertainty obtained using formal uncertainty propagation principles;
- Publication of *Measurement and uncertainty for metrological applications—repeated measurements and nested experiments* (ISO/TS 21749). This document provides guidance on the evaluation of uncertainty components relating to a designed set of measurements, based on the application of the analysis of variance (ANOVA);
- A brainstorm on the scope of WG 7, leading to a broader new title: *Statistical methods to support measurement uncertainty evaluation.*

Joint Committee for Guides in Metrology (JCGM)

SS*f*M provides a member to JCGM Working Group 1, *Measurement Uncertainty*, who leads the work on developing three supplements to the GUM. SS*f*M staff have made seven invited international presentations on these supplements. Highlights are:

- An improved version of GUM Supplement 1, *Propagation of distributions using a Monte Carlo method*, has been under development, and will shortly undergo a final review by member organizations and NMIs. Much of this supplement is based on SS*f*M Best Practice Guide No. 6, *Uncertainty Evaluation*

See: www.npl.co.uk/ssfm/download/bpg.html

- A new draft of GUM Supplement 2, *Models having more than one output quantity*, has been produced and reviewed.

A more detailed report on statistics standards (dem-es_res_002.pdf) is available for SS*f*M members on the web see: *www.npl.co.uk/ssfm/download/*

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Asymptotic least squares and non-normal sampling distributions

An ever-present problem in metrological data analysis is the presence of outliers or rogue data points. Standard model fitting approaches such as *least squares* tend to provide poor estimates of the model parameters in the presence of outliers, with the model fit skewed in an effort to accommodate the outliers at the expense of dragging the fit away from the bulk of the data.

An explanation for this behaviour is that the least squares fit provides the most likely explanation of the data under the assumption that discrepancies between the data and the model fit are normally distributed. The normal distribution assigns vanishingly small probabilities to points more than a few standard deviations away from the mean. In moving the fit towards the outliers, the least squares method balances many small reductions in the likelihoods associated with the bulk of the data points with large increases in the likelihood associated with the outliers.

If we use sampling distributions that accord higher probabilities to points far from the mean, we should be able cope better with outliers since some data points far from the model fit are expected. The student t distribution can be regarded as a generalisation of the normal distribution. It has a parameter ν that controls its shape. As ν gets larger, the student t distribution approaches a normal distribution; as ν gets smaller, points far from the mean are accorded a greater probability. See figure 3. By regarding the student t distribution as a modification of a normal distribution, we can use a modification of least squares methods — asymptotic least squares — to find the best fit model under the assumption that the discrepancies between the data and the model have a student t distribution.

Figure 4 compares a standard least squares (LS) with an asymptotic least squares (ALSt) fit of a line to data with outliers. As can be seen, the ALSt follows much more closely the main trend of the data.

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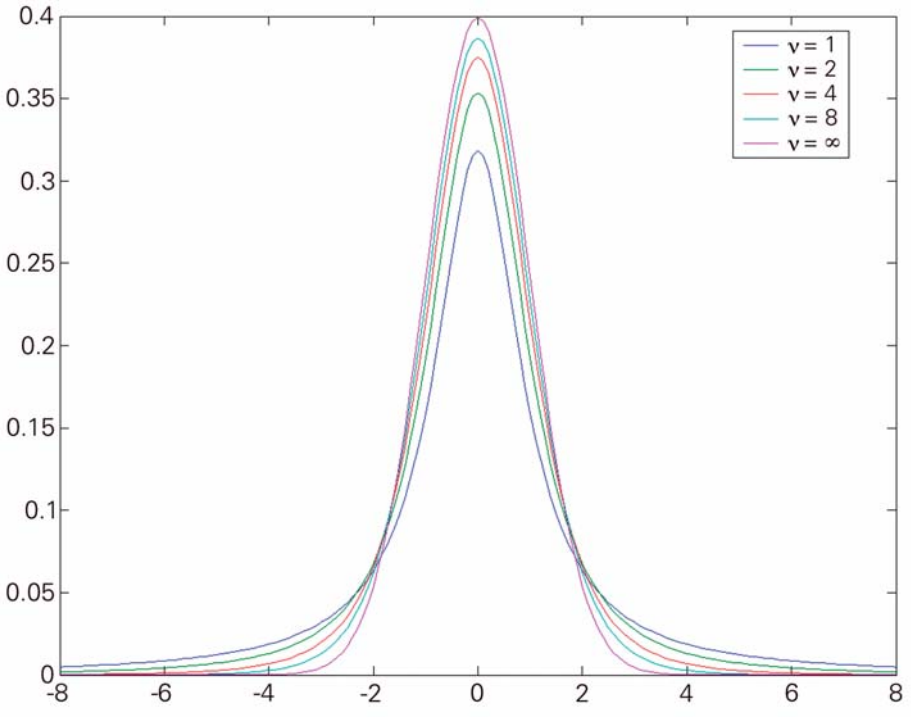

Figure 3. The student t distribution

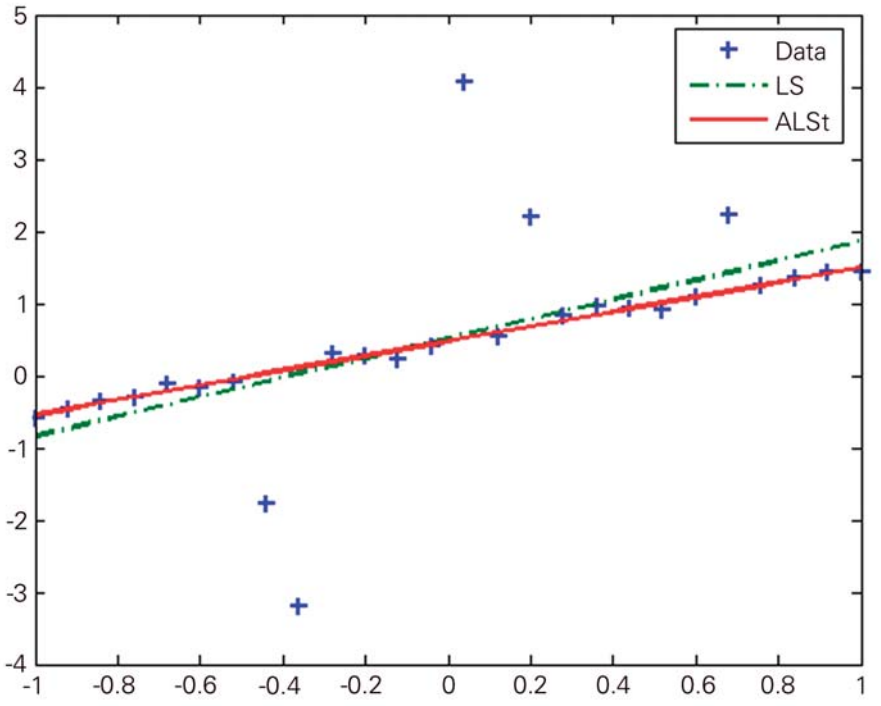

Figure 4. Least squares and asymptotic least squares line fits

Signal processing: developing good practice in metrology applications

Signal processing is a new subject for SS*f*M – as a result of a New Directions study, a range of activities on this topic has been included.

The study asked three questions:

"What do metrologists know about signal processing?"

"What do they need to know?"

"How can SS*f*M help?"

To meet the needs that were identified, we are carrying out case studies in several areas of metrology in which mathematicians and software specialists collaborate closely with experimentalists to tackle some challenging problems, such as the analysis of non-stationary signals. Case studies include analysing the environmental vibrations in NPL's Watt balance laboratories (*see figure 5*), and modelling the analogue filter employed in conditioning the electrical signal used to calibrate dynamic force machines.

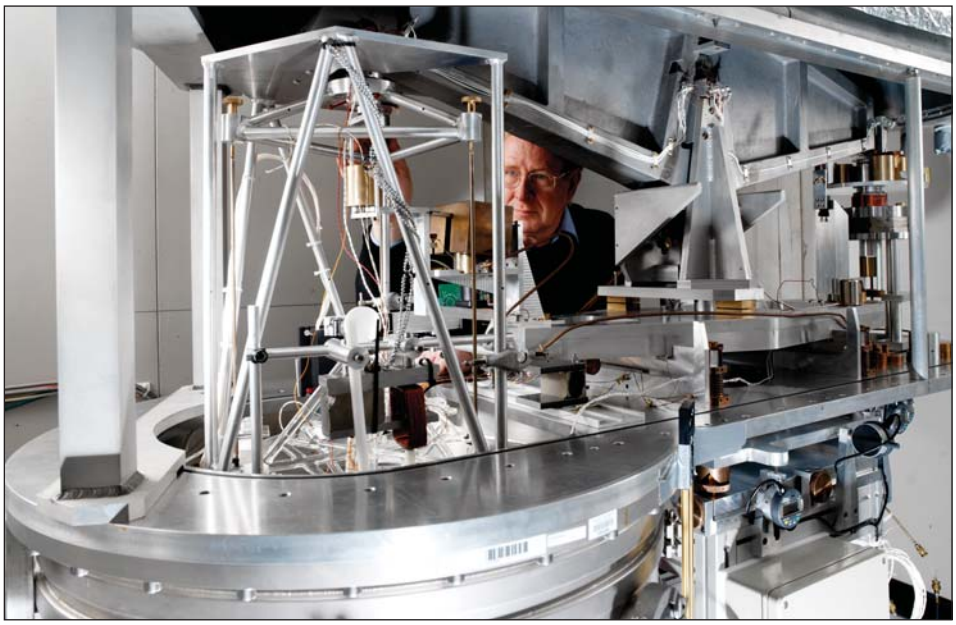

Figure 5 The Watt balance – understanding environmental vibration is vital in ensuring accurate realisation of the kilogram.

Two awareness seminars will be held to help educate metrologists about the uncertainty aspects of the signal processing methods they apply in their measurement and calibration work, and to share experiences of signal processing problems in metrology.

SS*f*M work on signal processing will form the basis of a new Good Practice Guide (due for publication in March 2007). This will help metrologists who are not specialists in this field make better use of modern signal processing tools and techniques.

The first of the awareness seminars is scheduled for the 30th November 2005. See *Forthcoming Events*, page 8.

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Generating good pseudo-random numbers

Generating pseudo-random numbers is a key part of the Monte Carlo method for uncertainty evaluation. The "randomness" of the numbers is important because it affects the quality of the results delivered by the method.

The "Hill-Wichmann" generator developed in the 1980s, has been widely used, but the cycle length of this generator (about 7×10^{12}) is now considered inadequate for some applications, and it has recently been reported that it fails some tests of randomness. To address these issues, the authors of the original generator have designed a revised version, with a cycle length of about 2×10^{36}, that passes the so-called "Big Crush" tests of randomness.

The authors have also considered how the generator may be used within a distributed or grid computing environment. Here, the issue is to ensure the "randomness" of the numbers between different processors of the grid as well as *within* each processor.

A description of the revised generator, with associated software implementations, is available on the SS*f*M website. The work will also impact on a number of SS*f*M guides, including those on uncertainty evaluation and distributed computing.

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Visualisation - a Good Practice Guide

Once a set of measurement data has been collected, the first thing most metrologists want to do is explore their data visually. As computers get more powerful, ever more sophisticated software tools become available to present data to the user.

If metrologists are making decisions based on data visualisations, it is vital that they clearly understand what features of the data are being displayed, and have complete confidence that the software is displaying the features correctly. A typical visualisation is shown in figure 6. The SS*f*M Good Practice Guide to Data Visualisation (GPG 13) helps to give users confidence in their decisions by illustrating good practice in the development, implementation and validation of visualisations.

This Guide is now being revised. More material on visualisation of uncertainties and validation of visualisations has been included, a new section on visualisation in continuous modelling has been added, and the examples section has been expanded.

Material on the parallel coordinate technique is currently being developed, including two case studies, and this will be published as a separate report. Key points and one of the examples from this report will be included in the final version of GPG 13.

The revised Guide will form the basis of a new version of the SS*f*M training course on *Visualisation of Measurement Data*, to be delivered in 2006.

SS*f*M Club members can download a draft version of the revised GPG 13.

See **www.npl.co.uk/ssfm/download/**

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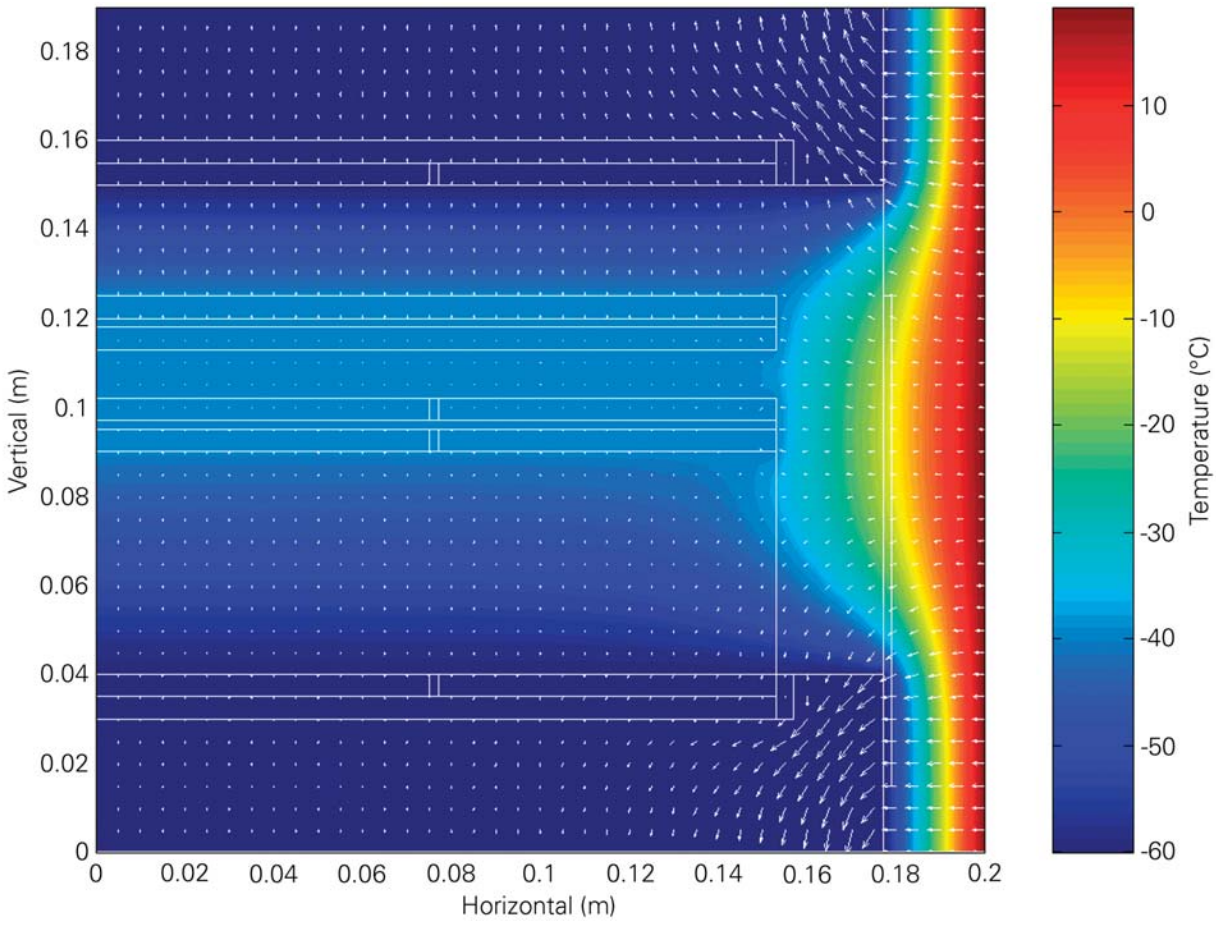

Figure 6 A visualisation of the temperature and heat flux distributions within a piece of equipment. The colour scale indicates temperature, the arrows indicate heat flux, and the straight lines are the boundaries between different parts of the equipment. The visualisations of the two quantities do not interfere with one another: the user can see the temperature distribution and the regions of maximum heat flux clearly.

Club Members' Page

From *Agilent Technologies UK Limited* – first accreditation of internet-enabled calibration

UKAS recently granted Agilent Technologies UK Limited, South Queensferry, the first ever calibration accreditation that uses Internet-enabled technology to make measurements of complex reflection and transmission coefficient parameters on RF and microwave devices. The system is *iPIMMS* – Internet Primary IMpedance Measurement System, from NPL.

The Internet forms an extended link between the client's measuring instrument – in this case a Vector Network Analyser – and NPL's dedicated software. The software controls the instrument, interfaces with the operator and collects readings from the instrument. It performs corrections during calibration, and calculates the measurement results and uncertainty.

Organisations within Europe, the Americas and the Asia-Pacific region have all operated *iPIMMS* successfully.

Top tier measurement services can now be realised and assessed independently in a harmonious manner at any location in the world because of the availability of highly accurate Internet-enabled measurement facilities, such as *iPIMMS*, together with international standards for their accreditation (i.e. ISO/IEC 17025).

For a full article and picture, see page 3 of:
www.ukas.com/Library/downloads/Information_Centre/Update/UKAS%20UPDATE%2036.pdf

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From *University of Genoa* – a package for analysing risks related to measurement uncertainty in conformance decisions

Measurements are often an objective support for decision-making, in all fields, scientific, industrial or human-related.

The Joint Committee for Guides in Metrology, considering the impact of measurement uncertainty in such decisions, is preparing a supplement to the Guide to the Expression of Uncertainty in Measurement, addressing related risk analysis.

The Measurement Laboratory at the University of Genova, (**www.dimec.unige.it/PMAR/Measurement**) has developed a prototype package, **MEAS RISK**, supporting the design of a monitoring system for optimising performance and for reducing costs.

The package includes a wide set of options in risk evaluation – consumer's and producer's risks, for a single item or for the entire production process, for both scalar and vector measurements. It has been developed and tested in accordance with current good practices for software in metrology. It may also be interfaced with the package **UNCERT**, supporting the probabilistic expression of measurement results (see *Counting on IT, 16, Autumn 2004*), in order to make best use of all available information.

Selected test cases from qualified laboratories may be submitted for treatment, by contacting the author.

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From *University of Newcastle upon Tyne* – the Software Reliability & Metrics Club

The Software Reliability & Metrics Club (SRMC) is a forum for the exchange of information between industrialists, researchers and consultants.

A busy summer of conferences for SS*f*M

The VIIth Advanced Mathematical and Computational Tools in Metrology (AMCTM) was held at the end of June at IPQ, Lisbon, Portugal and featured six SS*f*M papers, including an invited presentation by Maurice Cox on *Data evaluation of key comparisons involving several artefacts*.

Following the conference, a discussion led by Franco Pavese, IMGC, considered the future development of AMCTM activity and its links with the newly formed IMEKO technical committee on *Mathematical Tools for Measurement* (with SS*f*M represented through Alistair Forbes, its scientific secretary). At the same time as the AMCTM conference, Peter Harris attended the VIIth Laser Metrology and Machine Performance (LAMDAMAP) at Cranfield University, presenting a paper on uncertainties associated with co-ordinate data, whilst Richard Leach reported on modelling work, undertaken as part of an SS*f*M case study on measurement system design.

The 5th Algorithms for Approximation conference, sponsored by SS*f*M, was held at Chester University College in July, and Alistair Forbes gave the first invited paper on *Algorithms for structured Gauss-Markov regression*. Andrew Crampton of Huddersfield University talked about flexi-knot splines, reporting on collaborative research as part of SS*f*M. SS*f*M was also strongly represented at the International Seminar on Measurement Technology and Intelligent Instruments at the University of Huddersfield in September, with SS*f*M staff chairing two sessions and involved in four presentations including a Maurice Cox – Peter Harris keynote paper on *Measurement uncertainty and traceability* presented by Maurice.

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BIPM/NMIJ workshop on the impact of Information Technology in Metrology

NMIJ (Japan) hosted the second international workshop on *The Impact of Information Technology in Metrology* from 16th to 20th May 2005. The workshop was jointly organised by NMIJ and the Bureau International des Poids et Mesures (BIPM) with a format similar to that of the first such workshop held at NPL in 2002.

A satellite workshop (organised by Maurice Cox, NPL) focused on the problem of key comparison data evaluation, and the main workshop covered topics such as internet-enabled metrology, software validation, data analysis, data handling and uncertainty evaluation (including Monte Carlo methods). About 140 people from 24 different countries attended the two events.

Three members of the SS*f*M team attended the workshop to make presentations and contribute posters on:

- various aspects of key comparison data evaluation, including determining largest consistent subsets and treating multiple artefacts,
- Internet-enabled metrology,
- distributed and grid computing,
- supplements to the Guide to the Expression of Uncertainty in Measurement,
- data visualisation,
- software validation.

The workshop provided an excellent opportunity to disseminate the work undertaken within the SS*f*M programme. It is planned that the next workshop will be hosted by PTB (Berlin) during 2007.

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Participants share their experiences, learn about recent project results and engage in discussion on the theory and practice of measuring software properties. Over the past two decades, more than 60 events have been organised, on a range of diverse topics – all related to the achievement and measurement of software reliability. Despite the significant advances that have been made, complex IT projects still pose major measurement challenges for government and industry.

The SRMC met in London on 10 November, to debate *Software Procurement Experiences – The Good, The Bad, and the Lessons to be Learned*, an area where the need for much better measurement practice is widely acknowledged.

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Course for developing advanced engineering spreadsheet applications

Spreadsheets are widely used by scientists and engineers because of their ease of use for analysing and presenting results.

However, errors made when constructing spreadsheets are both common and often very difficult to detect (*see* http://panko.cba.hawaii.edu/ssr/). In addition, there are inherent errors in the most widely used spreadsheet packages, which can result in strange computation errors. NPL's own experience over many years is that the most effective antidote is to treat the development of a spreadsheet application as a software development project. For this approach to be most effective, it is recommended to use the macro language of the spreadsheet as much as possible to implement the application. A two day course has been developed for Excel, using a hands-on approach, to show how to treat a spreadsheet application as software development.

See www.npl.co.uk/ssfm/training/dev_spread_apps_scieng.html.

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SS*f*M at the Palace

Congratulations to Carl Dingle, a founder member of the SS*f*M working group, who was invited to attend the Queen's garden party in recognition of services to the DTI NMS.

Figure 7 Carl & Elaine Dingle at Queen's Garden Party, 19th July 2005

Forthcoming events

30th November 2005, NPL
Signal processing: developing good practice in metrology applications (seminar)
Contact: trevor.esward@npl.co.uk
www.npl.co.uk/ssfm/news/

www.npl.co.uk/news-and-events/
www.npl.co.uk/ssfm/news/

For information on SS*f*M event details and contacts visit the website: www.npl.co.uk/ssfm

6014/SEA/2k/1005