# Impact of Software and IT on Metrology

Tanasko Tasić,
2t, Ljubljana, Slovenia
tanasko.tasic@guest.arnes.si

***Abstract*—State-of-the-art information technology enables variety of specific metrological applications. The first benefit for the metrology community is in significantly increased remote functionality of the measuring systems (e.g. connected in distributed legal metrology measuring systems, or remote operation of the measuring instruments in severe environmental conditions). The next significant improvement comes from the introduction of new metrological services (e.g. time service, remote calibration and remote software validation). Finally, it is important to mention the increased availability of the metrology-related information which is available on the World Wide Web. In order to take full advantage of new possibilities, they have to be implemented carefully (taking into account functionality and security issues, in the first place) with a full understanding of the background of applied technologies.**

***Key words-Distributed measuring systems, remote instruments operation, remote calibration, metrological databases, software validation, fraud protection, legal metrology, software security.***

## I. INTRODUCTION

This article gives an overview of metrology-related applications whose development has been enabled by the modern software and IT[31]. The focus of the contribution is not in the explanation of the technical implementations but rather giving an overview of the applied principles and benefits and to draw user's attention to potential risks of application of SW and IT. Furthermore, it is not an attempt to give a complete presentation of all available services, but an informative overview of the common applications which may give the reader useful information, indicate an existing solution for his problem or suggest an idea for developing some new solution.

State-of-the-art IT enables a much wider variety of metrological applications, which may be organized in three groups[30];

– Functionality of measuring instruments (distributed measuring systems),
– New metrological services (time service, remote calibration, software validation),
– Significantly increased availability of metrology-related information.

Information technology used for metrology applications covers more than the public communication networks, delivered using range of hardware realisations and different operators: optical cable, cable TV networks, wireless, fixed wire and mobile telephony (GSM, GPRS, UMTS) or public networks using secure (e.g., VPN) channels. In distributed measuring systems, especially in cases when distribution companies possess their own distribution networks (e.g. electricity), common ways of data exchange are PLC (Power Line Carrier), DLC (Distribution Line Carrier), RADIAN (Radio Application Network) and ZigBee (IEEE 802.15.4) [2], for example. Additionally, the supporting communication protocols may be general-purpose internet protocols (SMTP, HTTP, FTP) or application specific, e.g. DLMS (Device Language Message Specification; IEC 62056-46, IEC 62056-61).

From the point of view of IT security, metrology-related IT applications apply standard approaches (e.g. HTTPS, FTPS, public key infrastructure), mostly for the protection of data (to ensure correctness of measuring data) and for the authentication of involved parties.

In the background, very often as the central point of distributed measuring system there is a database system. The applications again vary from data collection/billing or dynamic tariff calculation (electricity) in legal metrology, medical diagnostics (databases of particular health states pattern signals intended for medical diagnostics), general information about metrological capabilities (e.g. national), monitoring & managing of distributed metrology systems (e.g. information about the bodies performing particular metrology tasks) and so on.

Metrology institutions worldwide are fully aware of the importance of these issues. The International Organization of Legal Metrology (OIML) had organised the Seminar on measuring instruments software as early as 1999. International Bureau of Weights and Measures (BIPM) and leading national metrology institutes organize a series of conferences on the impact of the information technology in metrology:

– BIPM/NPL [1] Workshop on the Impact of Information Technology in Metrology, Teddington, UK, 16÷19 September 2002;
– NMIJ [2] /BIPM Workshop on the Impact of Information Technology in Metrology, Tsukuba, Japan, 18÷20 May 2005[13];
– PTB [3] /BIPM Workshop on the Impact of Information Technology in Metrology, Berlin, Germany, 4÷8 June 2007[15],

[1] National Physical Laboratory, UK national metrology institute
[2] National Metrology Institute of Japan
[3] Physikalisch Technische Bundesanstalt, German national metrology institute

while the PTB continues to organise IT-related metrological workshops:

- Operating Systems in Measuring Instruments and other software problems in Legal Metrology, PTB Berlin, November 17th and 18th, 2010,
- Protection of Measurement Data in Legal Metrology and Related Challenges, PTB Berlin, November 30th and December 1st, 2011.

## II. Functionality of Measuring Instruments (Distributed Measuring Systems)

As said in a presentation at the FASIT [25] workshop, the development of legal measuring instruments began with the `iron age' (mechanical measuring instruments), continued with the `electronic age' followed by the `software'; and now we are already in the `communication age'. This statement is undoubtedly true for all areas of metrology that benefit from the state-of-the-art computer communication, web and database technologies.

Like in all other modern devices, software is taking over more and more functions in measuring instruments and systems. Besides software running on the measuring instrument computer, communications and database systems are implemented to enable distributed measuring systems, measuring data storage and their subsequent processing. In addition to gathering, storage and processing the measurement data, there are also the functionalities of maintenance of measuring systems, calibration and surveillance of the measuring instruments metrological status. Most of these services are available via public communications networks.

This progress is undoubtedly useful for the users, because it enables faster measurements, higher accuracy and opens up the possibility of various analyses and further processing. For the manufacturer the new technology simplifies realizing complex functions and gives flexibility for meeting the wishes of their customers and measuring instrument's maintenance.

### *A. Legal metrology applications*

Legal metrology instruments are subject to several instances of conformity assessments and inspections during their lifecycle. Initial conformity assessment procedure (type approval) is the prerequisite for obtaining status of the legal metrology instrument. First verification is necessary before the first use, followed by regular and extraordinary verifications and inspection examinations during the measuring instruments lifecycle.

Institutions that perform these conformity assessment procedures are both governmental and private bodies. The role of state institutions (who are responsible for operation of national metrology systems) is becoming more focussed on the collection and analysis of reports on conformity assessment procedures (from private bodies performing e.g. verification of legal measuring instruments) and occasional metrological spot checks of measuring instruments. As a consequence, huge amounts of data need to be exchanged between these institutions in order to maintain a suitable quality of the national legal metrology system. This leads to additional measuring instruments functionality, which is nowadays mostly implemented by software and information technologies.

An illustrative example is the operation of electricity meters in the deregulated energy market. In such a system, a variety of participants need to have access to the electricity meter, each of them with its own access rights. End customer receives electricity from one of the distributors. Energy consumption is processed by a metering data provider. The price of energy necessary contains shares of electricity supplier, owner of the distribution network, operator of the IT network and electricity distributor. Additional participants that also need to have access to the meter are members of the legal metrology system: the notified body (performing initial conformity assessment), the legal verification authority (performing legal verifications) and the inspection body (usually independent body performing metrological surveillance of the measuring instruments in use). And of course, the meter manufacturer and/or his representative need to have access for maintenance purposes as well.

For utility companies (electricity distribution companies, for instance) remote access significantly decreases the costs of collection of measurement data and maintenance of measuring instruments.

The highest benefit is definitely the possibility of remote update of software in measuring instruments already installed at the place of use. In case of detection of a serious bug in the measuring instrument's software, the software in all instruments of that type has to be updated. If we take as example electricity meters installed in remote mountain areas, the cost for a technician to visit an installation and physically load the new software might well be more that the original meter retail price!!

Taking into consideration the variety of involved parties, such a system has to be adequately protected and coordinated. Authentication of every participant is necessary to ensure that only entitled personnel have access to particular meter data or functionality and to assure that the correct customer is charged for the consumption.

A similar approach has been implemented in road-traffic enforcement networks [6]. In such systems automated vehicle velocity measuring stations (police radars) transmit files with evidence of offences to the place of processing. For transmission of these files it is necessary to ensure their integrity and confidentiality, as well as proper authentication of participants in the process.

Being aware of the consequences of IT-related development in the field of measuring instruments [4], legal metrology institutions have prepared guidance documents that support harmonised software validation [27] like WELMEC [11] `Software Guide (Measuring Instruments Directive 2004/22/EC)' and OIML [18] `General requirements for software controlled measuring instruments'.

### *B. Remote operation of measuring instruments*

Remote operation of measuring instruments is important in circumstances where environmental conditions are such that human presence at the time and place of performance of measurements is not possible (e.g. in a mine, in a weather station, near steel production furnaces, in space vessels) or in cases where permanent human presence is not practicable. An example of remote controlled factory testing of an electrical power monitoring system is illustrated in Fig. 1. Several measuring instruments for monitoring the electrical power parameters are connected in a computer network by different communication interfaces. Testing the functionality of measuring instruments comprises several long-lasting measurements. One session of measurement of electrical energy as a rule lasts several days. During that time reference signals need to be changed several times.

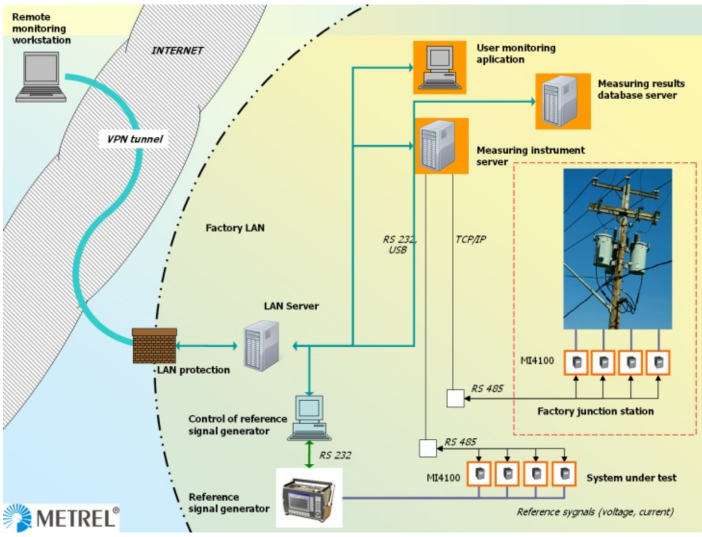


Figure 1. Remote testing of measuring instruments: an example from the company METREL d.d.® [23].

In addition, it is necessary to regularly check the functioning of the components of the system (particular measuring instruments, measuring instruments server, database server and client application). Once initiated all these checks may be performed remotely, e.g. from home, generally much more practical than driving to the testing laboratory every time that some activity is necessary.

Some of the software functionalities necessary for support of the remote measurements are already embedded in operating systems (like Microsoft® Windows™ virtual private network and remote desktop connections). Another solution is available in T&M automation tools, e.g. publishing software control applications as web pages, which can then be remotely accessed (e.g. this functionality is available in National Instruments® LabVIEW™).

### C. *Internet-supported metrological services*

Besides distributed measuring systems that are intended for on-line uninterrupted service, there are very many Internet-supported services related to various metrological activities. These can be classified as follows.

#### 1) *General metrology related services*

An example of such service is the Internet Time Service (ITS) [20], which is intended to synchronize computer clocks via the Internet. A reference clock service that runs on a WWW server responds to time requests from any Internet client by sending the time and estimated delay information in i.e. NTP protocol.

The Network Time Protocol (NTP) is one of the most accurate and flexible means of sending time over the Internet [16]. The protocol is designed to compensate for some, but not all, network time delays between the server and the client. On the World Wide Web however, time transfer delays are at the mercy of server traffic and network bottlenecks, and accuracy figures cannot be quoted as easily. NTP conveniently supports security measures for users who want more reassurance concerning the origin of the time stamp (Authenticated NTP Services), rather than insecure NTP. On the client side, the user needs to have the software that can request time over the Internet. A version of the NTP client software used to synchronize computer clocks is called Simple Network Time Protocol (SNTP). The accuracy of such services is rarely better that 0.1 s, for better accuracies it is necessary to use other methods & services, e.g. Common-View GPS method.

#### 2) *Internet enabled/supported calibrations*

The 'old-fashioned' procedure of performing calibrations, which is still used by the majority of customers and laboratories, involves transporting the instrument to be calibrated to the calibration laboratory [5]. The instrument has to be physically present in the calibration laboratory during whole calibration process. Such an approach has several disadvantages, like:

- Long instrument downtime (for home laboratory),
- Costs of the transportation,
- Calibration of the instrument in conditions different from the conditions of its routine use (e.g. other personnel, instrumentation environment, climatic environment),
- Danger of damage during the transportation.

The spread of the Internet as a communication medium and the availability of the continuously improved measurement standards enable the dissemination of calibration values from higher level standards laboratories in a different way.

There are several ways in which the Internet is used for measurement process support. From the point of view of logistics, the simplest way is if there is no need to physically transport anything (no transfer standards). This way is possible for dissemination of limited number of physical quantities (e.g. time, frequency), or in situations when measurement signal can be transmitted from the field laboratory to the reference laboratory. Other methods require either the presence of the reference standard (reference material) or presence of the transfer standard at the place where the calibration is performed. From the point of view of laboratories that need calibrations of their instruments, the benefits of internet-enabled calibrations may be summarised as:

- reduced costs;

- Easy access for customers to the higher-level laboratories;
- the measurement standards belonging to the remote laboratory does not need to be transported;
- the standards are calibrated under normal conditions of use in their home laboratory;
- the `down time' for the remote laboratory is kept to a minimum;
- uncertainties are calculated on-line by reference software in the reference laboratory;
- the results can be reviewed on-line before the calibration is completed;
- instructions and procedures can be conveyed over the Internet;
- the calibration environment and conditions can be recorded using a video or digital camera;
- the calibration chain is cut down to one link;
- calibration can be performed at any time; day or night;

Some generic IT-related issues have to be addressed, like:

- security of calibration information and results as they are transferred over the Internet (data integrity, authentication, access control and protection from viruses and worms);
- smooth operation of Internet calibrations through site fire-walls, overcoming problems of two-way communication of data through fire-walls without compromising security;
- storage of calibration results in a database for recall by users during the calibrations and the use of data warehousing to provide long-term access to calibration history;
- guidance on the procedures necessary to meet accreditation requirements in general;
- promotion of the technology to metrology areas where it may be applicable and advantageous but which have not yet taken it up.

For Internet-enabled metrology to be successful, it is essential that the software works reliably, both in terms of integrity of transmitted data and the smoothness of operation from the point of view of the user. It is also necessary to prove that the traceability of a calibration when it is carried out at a remote site can be maintained. This is a non-trivial issue as traceability covers factors such as the suitability of the calibration environment, the correct operation of the measurement equipment and, perhaps of most importance in this case, the ability of the calibration staff at the remote laboratory to carry out the required tests under the guidance provided through Web pages.

*a) Entirely remote calibrations*

An excellent example of the application of the modern technologies in metrology is use of Global Positioning System (GPS) satellite signals and internet for time synchronization and frequency calibration. The main application of the GPS system is the determination of the position of objects on the Earth's surface (primarily for military purposes). However, this is not the only application of the system. Each satellite carries either rubidium or caesium oscillators, or a combination of both, which is synchronised with UTC, [12] USNO [17] and UTC NIST [19]. Those UTCs are maintained within 100 ns of each other, and the frequency offset between the two time scales is less than $1x10^{-13}$.

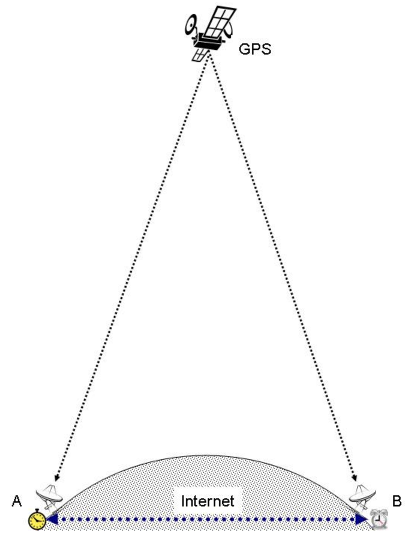


Figure 2. Common view method.

GPS receivers at locations A and B receive time information from the same satellite (which is in common view for both locations, A and B). The common view method compares two clocks or oscillators located in different places. Unlike one-way measurements that compare a clock or oscillator to GPS, a common-view measurement compares two clocks or oscillators to each other. The first scientific publications describing this system, called `Common View' appeared as early as 1980 [3]. By combining the common-view technique with the Internet, it is possible to build a common-view network that processes data in near real-time [14].

The lowest uncertainties currently achieved using the GPS Measurement Techniques for Carrier-Phase Common-view are less than 500 ps for time and less than $5 \times 10^{-15}$ for frequency.

*b) Internet-supported calibrations with additional transmission of the measurement signal*

This method will be explained using the example of the Remote Calibration of Practical Lengths by Using Low-Coherence Interferometry and Optical Fibre Network [10]. The laboratory requiring calibration has its own low-coherence interferometer (LabI) and performs measurements on a unit under calibration (UUC). The measurement signal, in the form of the interferometer signal, is transmitted via optical fibre to the reference laboratory. The reference laboratory with its associated software then determines the parameters of the UUC.

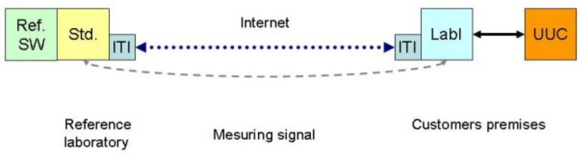


Figure 3. Internet-supported calibrations with additional transmission of the measurement signal.

ITI - IT Interface, UUC-unit under calibration, LabI - Instrument in customer's laboratory, here used as the light source, Std. - Higher level measuring standard, Ref. SW- Software associated with higher level measuring standard

Major limitation of this method is the signal loss in optical fibre between the customer premises and reference laboratory. With the state-of-the art technology affordable distance is about 20 km.

*c) Internet-supported calibrations with the local reference standard*

This approach uses a local reference standard or material (Ref S) with stable, known characteristics for the calibration of an instrument under calibration (IUC). The IUC measures characteristics of the Ref S and sends the results via the internet to the reference laboratory. After analysis of the measuring results, software in the reference laboratory calculates the calibration parameters for the IUC.

This approach is used for the calibration of instruments in many areas such as the measurement of impedance (iPIMMS [9], Primary Impedance Measurement Software for Impedance calibration of Vector Network Analysers), spectrophotometry (iColour Calibration Visible Diode Array Spectrophotometer [9]), pressure measurement [24] or ionising radiation [29].

*d) Internet-supported calibrations with travelling reference standard*

This approach is applied in areas where local reference materials or reference standards of appropriate quality are not available. The transportation of travelling standards from the reference laboratory to the customer’s laboratory is generally more convenient than the transportation of the instrument to the reference laboratory. Related costs are likely to be less as well. The procedure of calibration is the same as the one for the case of Internet–supported calibrations with local reference standard.

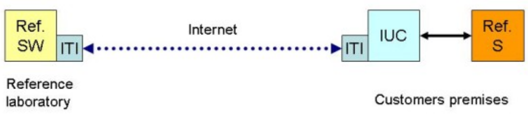


Figure 4. Internet-supported calibrations with the local reference standard.

ITI-IT Interface, Ref. S - Reference sample (material), IUC - Instrument under calibration (in customer's laboratory), Ref. SW- Reference laboratory's software

Travelling reference standards are not yet available with very high precisions; the uncertainties for this type of calibration are usually higher than the uncertainties in reference laboratories.

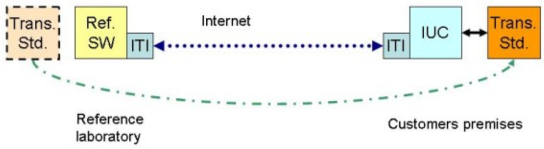


Figure 5. Internet-supported calibrations with travelling reference standard.

ITI-IT Interface, Trans. Std. - Travelling reference standard, IUC - Instrument under calibration (in customer's laboratory), Ref. SW - Reference laboratory's software

### D. *Availability of specific metrological-software validation services*

Modern laboratory measurement systems are very often highly automated in data acquisition as well as in post processing of measured data [8]. Typically, software components of such systems may consist of both commercially available software packages and custom made software, developed by the laboratory staff. In order to ensure confidence in the results provided by such systems, the software must be proven to be fit for purpose, so it is necessary to be able to properly validate it in whole and partially. Web-based software validation tools make possible for different users around the world (developers, evaluators or laboratories) to validate their software modules using black-box testing methods [28][1]. Two approaches to validation of software are identified as appropriate for web-based software validation tools: validation with the reference data sets and validation with the reference software.

Examples of available tools are the following:

- Web pages with reference software for validation of the mathematical functions,
- Web pages with reference software for validation of the standardised metrological functions,
- Web pages with reference datasets for validation of the metrological software.

Reference software enables testing of the software components. The user validates his software by comparing output parameters from his software with the output of the reference software in response to the same input parameters.

Instead of dynamically generated reference data, as explained above, the reference datasets may be static, dedicated for validation of standardised metrological functions. Reference datasets must contain both input and output parameters (expected results). During the testing of his software user applies input parameters, runs his software and then compares the results with the reference one(s).

*E. Availability of the metrology-related data*

The ease of distribution of information is the most important benefit of the internet. In the metrological community, the most important information is provided by web-hosted databases with relevant metrological information:

- Calibration/metrological resources and their capabilities. The most comprehensive database collection containing worldwide metrological information is available on the web site of the Bureau international des poids et mesures (BIPM: http://kcdb.bipm.org). It contains information about scientific work, history and technical realisation of the primary measurement standards, calibration and measurement capabilities in particular countries, units of measurement, technical committees, measurement standards, publications, conferences, key comparisons, reference materials and other metrological information;
- Research-oriented databases, e.g. PTB databases for vacuum-metrology medical research (heart bio signals);
- Information exchange centres, e.g. `virtual institutes'. These sites are dedicated to experts in particular areas of metrology. Some examples are: the Virtual Institute for Reference Materials (VIRM, http://www.virm.net/), the Virtual Institute for Thermal Metrology (Evitherm, //www.evitherm.org/) and the Virtual Institute of Energy Metrology (https://bi.offis.de/viem/tiki-index.php);
- Legal metrology databases are intended mostly for public information about nationally or internationally (EU type approval or OIML type approval certificates) approved measuring instruments, metrological standards and regulations, ongoing projects, . . . ;
- Metrology-related public information - information about approved measuring instruments, about their intended use, about control bodies and inspections;
- Databases of national metrology institutes contain variety of data: organisational, calibration and verification capabilities, scientific background for metrological procedures, presentation of achievements, metrological advices for general public, . . . ;
- Databases of reference materials or reference data, e.g. at the Institute for Reference Materials and Measurements [7].

Metrological databases may be used as the tool for monitoring the processes in a distributed metrology system. An example of such web-based database system is realised in the Slovenian National Metrology Institute [21, 26]. The implementation is adjusted to the specifics of the organisation of Slovenian metrology. MIRS is responsible for the whole scope of national metrological activities, including maintaining the system of national and reference standards for physical quantities and chemical measurements, the system of legal metrology (type approvals, verifications, precious metals) metrological surveillance of legally controlled instruments and other issues, including the Slovenian business excellence prize. Monitoring of all processes in such a system requires acquiring, manipulating and processing a large amount of data. The MIRS implementation is suitable for monitoring activities of the distributed metrology system in a small country, covering various aspects from the point of view of the responsible organisation, players, public and international partners. Besides facilitating organisational issues it gives transparent information for all members of the metrology community, from high-end metrological laboratories to the users of measuring instruments.

## III. CONSTRAINTS TO BE TAKEN INTO ACCOUNT

Besides the benefits, there are also several constraints that have to be taken into account when using modern IT technologies in metrological applications.

*A. Validation of the metrological software*

By definition[4], **validation is the** confirmation, through the provision of **objective evidence**, that the **requirements** for a specific intended use or application have been fulfilled. Basic tool for validation of the software is the testing of software. **Testing[5] is** determination of one or more characteristics of an object of conformity assessment, according to a **procedure** (3.2).

Each software application has to be suitable validated before use. From the one hand, this is the formal requirement of the international standard “ISO/IEC 17025:2005: General requirements for the competence of testing and calibration laboratories”.

But even better illustrations of importance of the validation of metrological software are the examples of consequences in cases when the proper validation had been omitted, like in the example of Mars Climate Orbiter Crash[6]. Mishap Investigation Board of the National Aeronautics and Space Agency (NASA) has determined that the reason for this accident was because two software modules which were involved in calculation of the braking force for insertion of the Orbiter in Mars’ orbit were using different units of measurement. One SW module used SI unit “newton” [N], while the other used “pound force” [lbf]. The ratio between those units is 1 lbf (“pound force”) = 4,45 N. In this case the estimated braking force was 4,45 lower than the needed one and as the consequence the Mars Climate Orbiter crashed on the Mars surface. Official conclusion was that the reason was “lack of complete end-to-end verification of navigation software”.

In addition, this is another prove of necessity of use of appropriate units of measure.

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[4] ISO 9000:2005 Quality management systems, Fundamentals and vocabulary
[5] ISO/IEC 17000:2004 Conformity assessment , Vocabulary and general principles
[6] ftp://ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf

*B. Protection aspects of the metrological software*

*1) Protection related specifics of legal merology siftware applications*

Another important aspect of application of the quality of IT in metrological application is related to functionality, especially security[7] of software. It can be best illustrated by the examples from legal metrology.

Since legal metrology applications in most cases deal with the commercial transactions, correctness of measurements and calculated prices for payment are very important. For the applied software it is important to perform the correct functionality and not some fraudulent calculations that may give unjustified financial benefit for any of the parties in transaction.

Very interesting example of such fraudulent software used in the petrol station, which was discovered in US, was presented in OIML [8] "Seminar on measuring instruments' software" as early as 1999. The software for calculation of price to be paid for purchased gasoline was modified in such a way that the calculation of price was correct for quantities that were multiple of 5 gallons. For other quantities, presented measured values was higher then really delivered, and the shape of function of fraudulent increase was like a "belly" between two neighbouring 5 gallon multiples (Fig 6). The reason for this was because the fact that metrological inspection was equipped with 5 gallon standard vessels, so during the regular checks they could not discover the fraud.

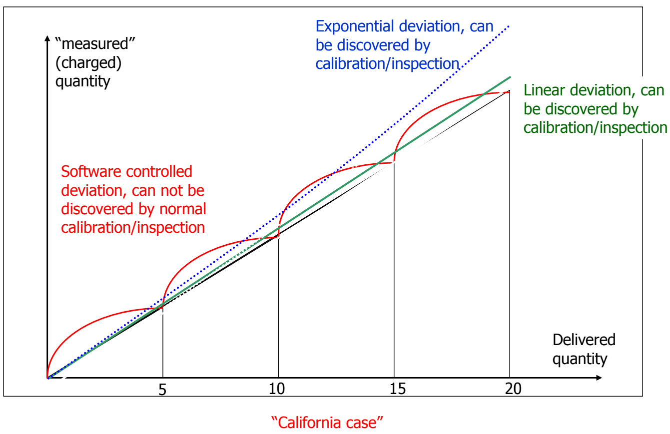
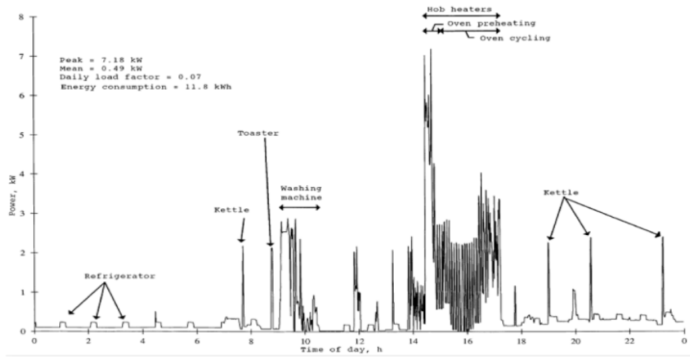



Figure 6. "California case".

*2) Protection of privacy*

Security aspects become extremely important in modern legal metrology applications, i.e. in "smart grids", because of variety of customer-related personal information which are recorded and stored within the measuring instruments and transmitted on demand to various parties included in the instrument operation. Such personal information may be abused if not suitable managed. An illustrative example is so called "load profile" of an electrical energy meter, a detailed record of energy consumption, with time resolution of several minutes. From this record it is very easy to understand daily habits of household members, starting with their presence at home and time of sleeping.




Source: Elias Leake Quinn, Smart Metering & Privacy: Existing Law and Competing Policies, Spring 2009

Figure 7. Smart meter Load profile.

## IV. Final Remarks

Benefits arising from the application of modern IT technologies for the metrology community are manifold. They may be summarised as:

- Implementation of new or improvement of the existing functionality of metrological systems (e.g. distributed measuring systems);
- Improvement of metrological services (e.g. remote calibrations, remote procedure validation tools). Benefits are both fundamental improvement in some areas (achieving lower uncertainties as in the case of time and frequency) as well as in improved quality (functionality, reliability and faster performance) of metrological services
- Increased availability of metrology-related information.

In order to take full advantage of new possibilities, they have to be implemented carefully (taking into account IT security issues, in the first place) with a full understanding of the background of applied technologies.

The services presented here are only examples of metrological services now available. In no case it is the complete list, but provides only a short overview and illustrations of the possibilities open to the users of the metrological services.

There is no guarantee that web-sites referenced in this chapter are still `alive' or correct - not transferred to another web address. Certain commercial entities, equipment, or materials are mentioned in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

[7] According to the classification form the international standard ISO/IEC 9126-1:2001, Software engineering -- Product quality -- Part 1: Quality model (revised by ISO/IEC 25010:2011"SQuaRe")
[8] The International Organization of Legal Metrology

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