CHALLENGES AND CHANCES OF INTERNET METROLOGY

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Abstract - "Every field of endeavour, especially in engineering, is dynamic. What we taught today is discarded tomorrow. **The problems don't change but our answers to them do change**" [1]

It took hundreds of years to

- a global standard for the requirements of process-oriented quality management systems (**ISO9000:2000**) [www.iso.ch/iso/en/prods-services/otherpubs/Qualitymanagement.html].
- the current version of the International Vocabulary of Basic and General Terms in Metrology (**VIM:1993**) [www.iso.ch/iso/en/prods-services/otherpubs/Metrology.html]
- the current version of the International System of Units (**SI:1971**) [www.bipm.fr/enus/3_SI] and
- the Guide to the Expression of Uncertainties in Measurement **(GUM ISO:1995**) [www.iso.ch/iso/en/prods-services/otherpubs/Metrology.html].

In history of sensors & instrumentation, measurement & testing, measuring data processing & measuring data evaluation, gauging & calibration a new chapter is opened by Internet Metrology (Web Metrology, Web-based Metrology, Internet-based Metrology)).

Aim of the paper is to show, that now web-based **collaboration** in a customer-oriented Internet Metrology is up-to-date. Internet Metrology is a big chance especially for small and medium sized enterprises (SME) to shorten their gap in quality management in competition with large enterprises. Internet metrology is going far beyond the fundamental tasks of legal metrology but it will strengthen their power.

Keywords: Internet Metrology, Measurement, Web-based Collaboration

1. INTRODUCTION & PURPOSE

Complex situations are not characterized by its area or branch, its space or volume, its time or duration but only by *missing of general and/or individual knowledge*. A simple indication for complex situations is the feeling of a burden because the HOW TO is unknown.

Measurement is a fundamental method for ***experimental knowledge acquisition*** in complex situations. No lack in knowledge needs no measurements [2].

Metrology is the body of knowledge about sensors & instruments, measurement & testing, measuring data processing & measuring data evaluation, gauging & calibration. Metrology to-day is tangle and unlimited for individuals. Knowledge-based web-working is the actual method of choice for the reduction of the complexity of metrology itself [3].

Legal Metrology is a branch of metrology which supports legal regulations with a reliable and uniform system of measurements to ensure the protection and safety of people and environment, to maintain correct measurements in commerce and transport and to verify measured values in science and technology.

Quality Metrology is a special branch of metrology to fulfil requirements for quality management systems after ISO 9000:2000 [4], [5].

Internet Metrology (iMET) is an innovative enabling web working method applying information society technologies (IST) to measurement engineering. iMET gives first in history of man the chance to assemble, evaluate and organize the abundant documented experiences about sensors & instrumentation, measurement & testing, measuring data processing & measuring data evaluation, gauging & calibration in a generic system [6], [7], [8].

Synonyms for web working (w) are: networking (n), internet working (i), electronic working (e), distance working (d), digital working (d).

Purpose of the paper is the complex situation (missing knowledge, open question):

- HOW TO develop quality measuring systems for tool testing
- in small and medium sized enterprises (SME) in Europe
- for realization of the new requirements of ISO 9000:2000
- with information society technologies (IST)?

2. THE SUBJECTS AND THEIR UNSOLVED PROBLEMS

Since generations **mechanical production processes** are characterized by big numbers of cutting processes with twist drills (Fig.1), milling cutters (Fig.2) and indexable inserts (Fig.3).

Figure 1 Twist drills
[www.guehring.de]

Figure 2. Milling cutters
[www.guehring.de]

Figure 3. Indexable inserts
[www.walter-ag.com]

Since generations **mechanical measuring processes** are characterized by big numbers of measuring processes with plain gages (Fig.4), thread gages (Fig.5) and gage blocks (Fig.6).

Figure 4. Plain gages
[www.threadcheck.com]

Figure 5. Thread gages
[www.vtgage.com]

Figure 6. Gage blocks
[www.starrett.com]

Since generations **precise calibration processes** of mechanical measuring tools and mechanical cutting tools are mastered with one and multi coordinate measuring instruments.
These coordinate measuring instruments have since generations the same fundamental functional principles and mechano-optical design (Fig.7)

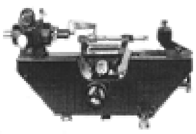
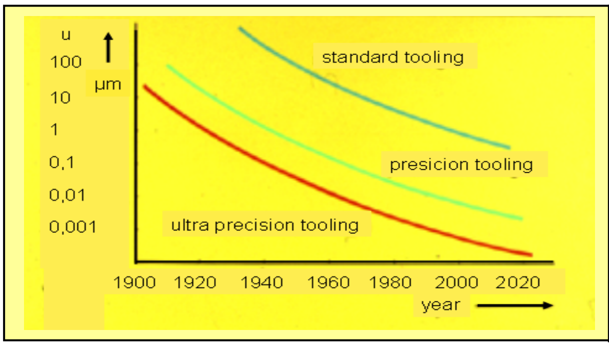
Year		society technology	driving forces	innovative background	one coordinate instruments	multi coordinate instruments	sigma
2010		information	 individual wellness	knowledge information wireless networked collaborative globalised adaptive objective			nm
1990		information + industrial	 personal computer	data intelligent automated motorized electronic objectified			µm
1950		industrial	 automobile	matter energy mechanical optical subjective			mm

Figure 7. Development of coordinate measuring instruments and their environment

The markets are marked by increasing competition, cost pressure, and more and more accuracy requirements (Fig.8). The designers of manufacturing and measuring tools therefore enhance the technological intelligence of their tools (Fig. 9) by using the trends of information technology (Fig.10). The levels of information processing are increasing (Fig.11) while at the same time the costs are decreasing (Fig.12). Comfort, precision and affordability are enhancing (Fig.13)



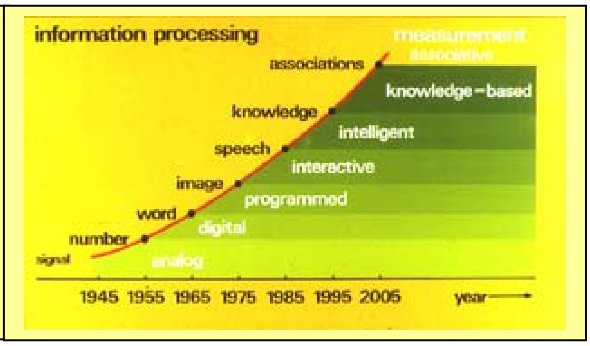


Figure 8. Accuracy trends in manufacturing and measurement

Figure 9. Trends in measurement technology and information processing

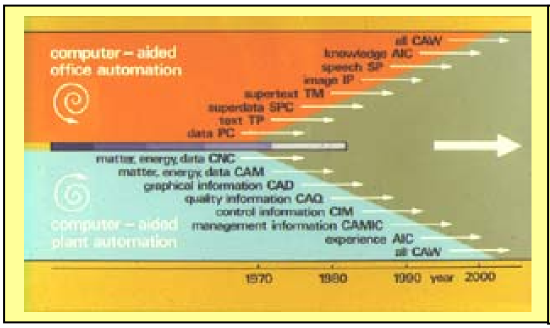


Figure 10. Trends in information technology

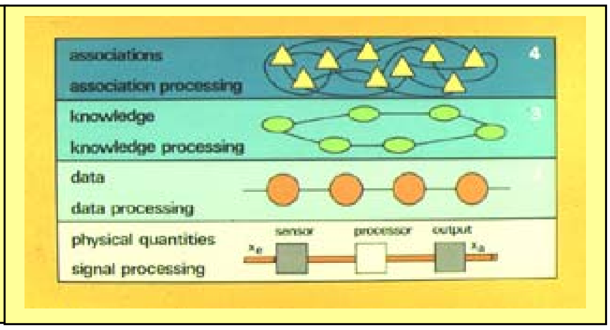


Figure 11. Trends in information proccessing

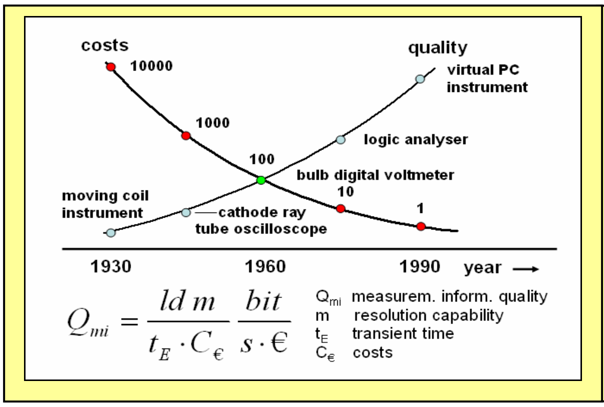


Figure 12. Trends in cost [9] p.122

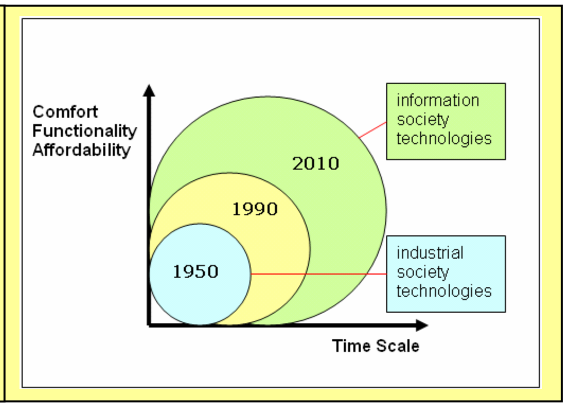


Figure 13. Trends in comfort & affordability

For twist drills - as an example - the big number of precise quality parameters (Fig.14) are measured with opto-mechanical multi sensor systems (Fig 15).

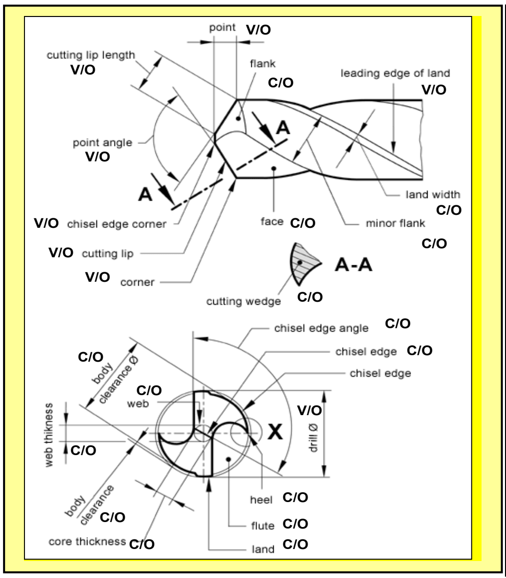


Figure 14. Quality parameters of a twist drill [www.okm-jena.de]

Figure 15. Optical coordinate measuring machine with twist drill [www.okm-jena.de]

General goal is to organize a seamless transfer between virtual und real design, manufacturing and testing (Fig.16), to extend the convergence between plant and office automation (Fig.10) und to master precise processes in a closed loop quality management system (Fig17).

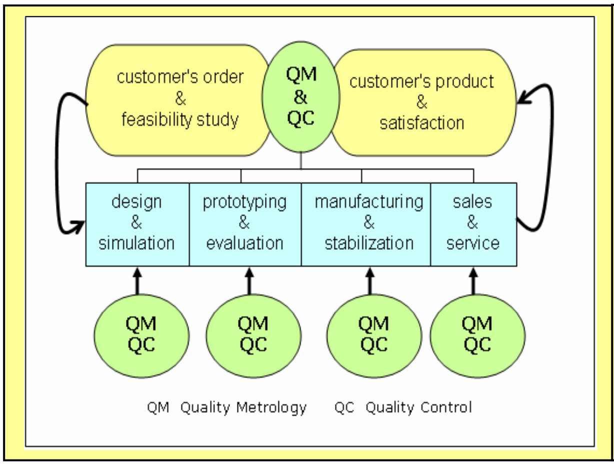


Figure 16. Quality assurance in small quality loops

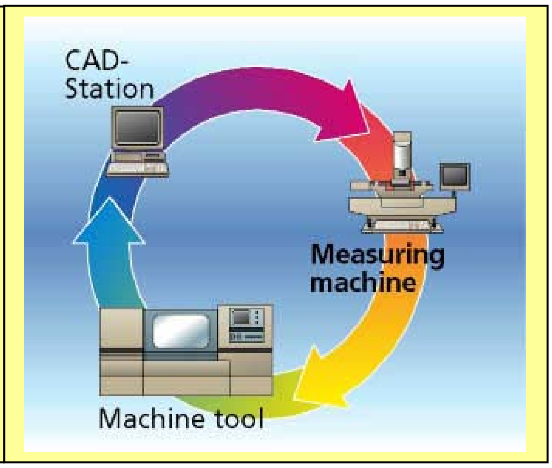


Figure 17. Closed loop quality management system

Reproducible tooling accuracy with an uncertainty of 1 requires measurement accuracy with an uncertainty of 0.1 (Berndt's law). The measurement accuracy and uncertainty is influenced by the measurement task, instrument hardware, instrument software, application software, environmental conditions (temperature, humidity, vibrations), measurement strategy, measurement standards, calibration status, clamping of measurement object, level of objectivation and automation and last but not least of the competence of the measurement person and the persons individual constitution.

For precise manufacturing and measuring processes large enterprises normally are well equipped with modern plants, measurement laboratories, experienced specialists and networks for collaboration. Support is necessary for small and medium sized enterprises which are not yet on the same level.

Small and medium sized enterprises (SME) (Fig.18) are the success factors of competitive and dynamic knowledge-based economies in Europe (Fig.19), capable of sustainable economic growth, more and better jobs and greater social cohesion. They must be equipped with intelligent manufacturing systems (IMS) and easy-to-use interfaces. The objective is to provide businesses, individuals, public administrations, and other organisations with the means to fully contribute to, and benefit from, the development of a trusted knowledge-based economy, whilst at the same time improving the quality of work and working life and support life-long continuous learning to improve work skills. Research will also aim at a better understanding of the socio-economic drivers and impact of ***information society technologies*** development [europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_294/l_29420021029en00010043.pdf]

sized enterprises	max. number of employees	max. turnover on million ECU
micro	10	not defined
small	50	7
medium	250	40

Figure 18. Definition of small and medium sized enterprises in Europe [europa.eu.int/ISPO/ecommerce/sme/definition.html]

Figure 19. Member countries of the European Union (EU)
[www.maps.com/explore/atlas/political/europe.html]

Selected statistical data about SME in Europe are (Fig.20):

Total number of **small and medium** sized **enterprises** in Europe	18.600.000
Total number of large enterprises in Europe	35.000
Total number of **employees** in Europe	110.000.000
Average number of employers per enterprise	6
Internet users worldwide*	400.000.000
Average Internet take-up in SME in Europe*	70 %

Figure 20. Statistical data about SME in Europe
[europa.eu.int/comm/enterprise/enterprise_policy/analysis/doc/eurob5de.pdf]
*[europa.eu.int/ISPO/ecommerce/documents/Just_numbers.pdf]

New production concepts (NPC) in SME need to be designed based on breakthrough organisational, ***quality*** and technological developments, supporting new products, processes and services. The goal is to support the transformation of the European industry towards a more knowledge-based and added value industry with improved competitiveness and sustainability. To this end it is vital to provide the industrial systems of the future with the necessary tools for efficient life-cycle design, production, use and recovery, decreasing at the same time internal and external costs and reducing major accident hazards. Appropriate organisational models and improved knowledge management should support technological developments and innovation routes (Fig.21). Decisive are not only hardware and software, but also **people** and the **way in which they learn and share knowledge**. In this domain of activity, an international dimension is evident. A wide innovation range is expected in a number of industrial sectors, particularly the traditional ones, with the final goal of increased competitiveness and increased private investment in research. Collaboration between research and industry is necessary. The major outcome would be a framework for "manufacturing in 2010" based on improved co-ordination and integration of research efforts at European level in a multilingual society (Fig.19) [www.cordis.lu/fp6/sp1_wp.htm] No. 3, p. 7.

Advances	Elements
Industry collaboration	Electronic commerce Teaming among organizations Long-term supplier relationships Virtual enterprises
Adaptive enterprises	Agile enterprises Reduced lead time Reduced cycle time Activity-based accounting Lean enterprises Knowledge-based enterprises
High-performance organizati-ons	Virtual co-location of people High performance work teams Cross-functional teams
Life-cycle perspective	Standardization of parts and reduction in number of parts Integrated product and process development Life-cycle design Cost as an independent variable accounting
Advanced manufacturing tech-nology	Flexible assembly Soft tooling Single piece fabrication Rapid prototyping Three-dimensional digital modeling High-speed machining Simulation and modeling Predictive process control technologies Adaptive machine control Tool-less assembly Nanotechnology Biotechnology Embedded sensors Generative numerical control Flip chip technologies
Environmentally compatible manufacturing	Cleaning systems Material selection, storage, and disposal
Shared information environ-ment	Data interchange standards Internet, intranets, and browser technology Intelligent agents Seamless data environment Telecommunications Distance learning

Figure 21. Commercial manufacturing advances and elements [www.nap.edu/readingroom/books/defman/ch3_t1.html]

New in history the **defense manufacturing** will take advantage of technology advances being pioneered by the commercial technology sector (COTS) in areas applicable to defense products (Fig.21). A growing trend among government and defense manufacturers is the adoption of commercial "best practices." In addition, many companies have combined commercial and defense manufacturing processes and products to take advantage of economies of scale in facilities, resources, and organizational structure. The advantages of COTS hardware and software include much lower development costs, tested reliability and performance, and substantially shorter product cycles [www.nap.edu/readingroom/books/defman/ch3.html].

The business world and society served by **standards** are changing rapidly. Global trade means that today's products are built from components sourced around the world, which must fit together and perform as expected. Product life-cycles are becoming shorter and the pace of technological development is accelerating. Consumers demand ever-higher levels of safety, performance, reliability and sustainability. All these developments mean that the role of standards is more important than ever [www.bsi.org.uk/NSS/index.xalter].

Standardized Quality Management Systems (QMS) are the backbones of SME. The new generic process- and customer-oriented quality management system standard ISO 9000:2000 states requirements for what the organization must do to manage processes influencing quality, to build essential competencies and strengthen innovation (Fig 22).

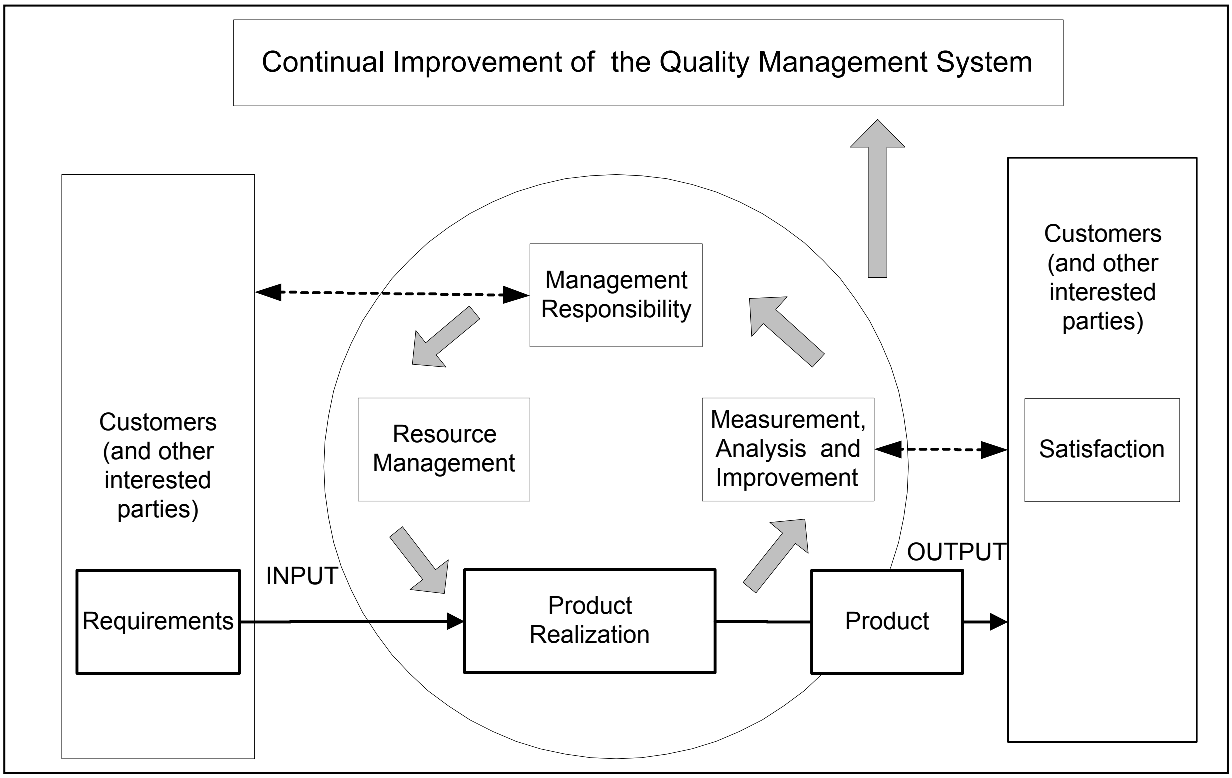


Figure 22. Model of new process-oriented quality management system ISO 9000:2000

Key: → value adding activities ⇢ information flow [www.iso.ch]

The value of information and knowledge for enterprises, organisations and individuals will change fundamentally. In measurement and information technology main interest is shifting from decentralized instrumental high lights to profitable content and web-based sharing of measurement information.

The new demands for quality metrology (Fig.23) are:

- Measurement of customer satisfaction
- Measurement of continual improvement
- Measurement of systems, processes, goods and services
- Measurement of the performance of the quality management system.

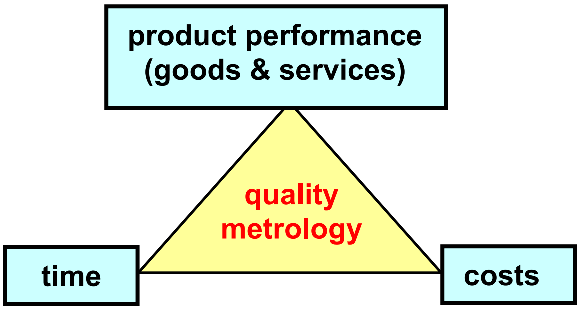


Figure 23. Optimization triangle for quality, productivity and added value

Quality metrology is the objective basis of all new quality concepts in design, production, service and administration of ***information societies*** (Figs.24 to 29) [ISO 9000:2000]. In certifiable quality management systems the quality **requirements** [ISO 9000:2000-3.1.2] must be **measured** [ISO 9000:2000-3.10.2] and **documented** [ISO 9000:2000-3.7.2].

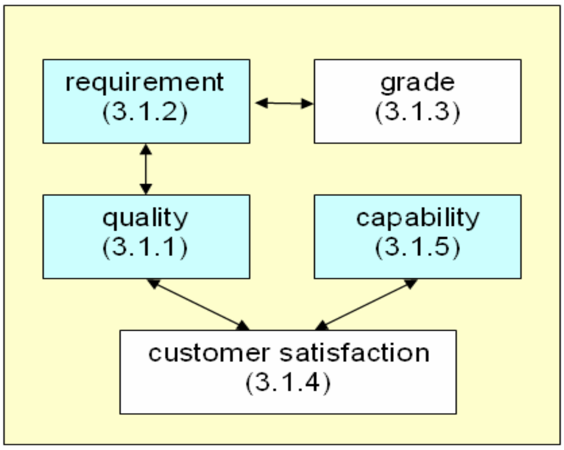


Figure 24. Concepts relating to quality

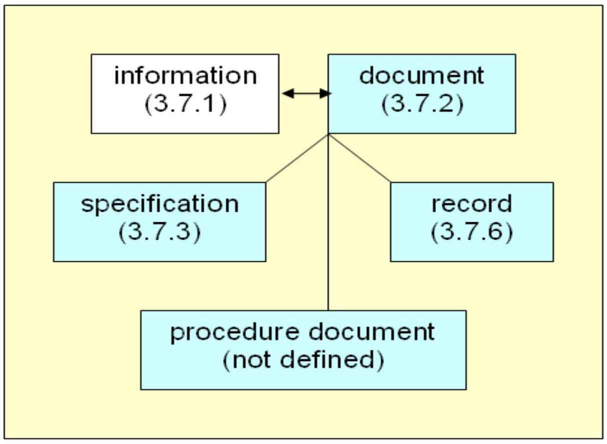


Figure 25. Concept relating to documents

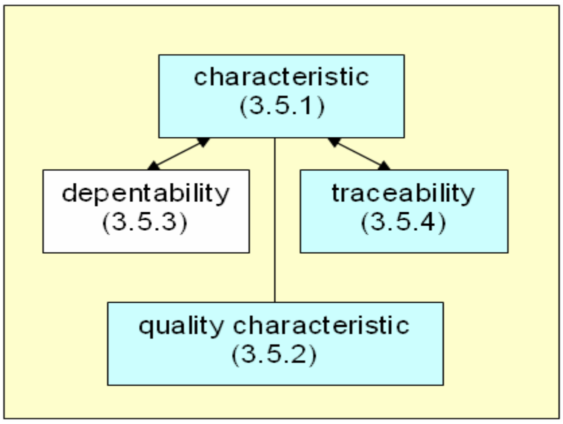


Figure 26. Concepts relating to characteristic

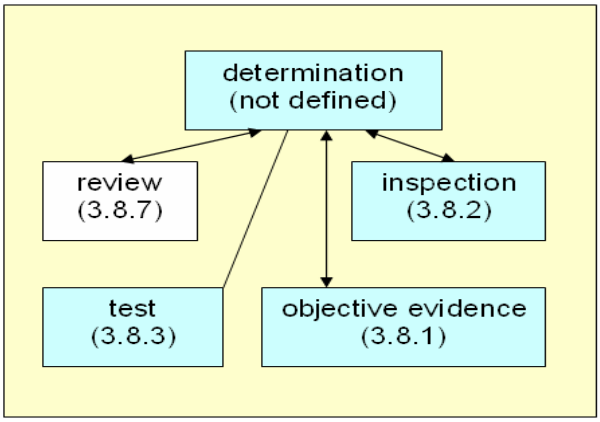


Figure 27. Concepts relating to examination

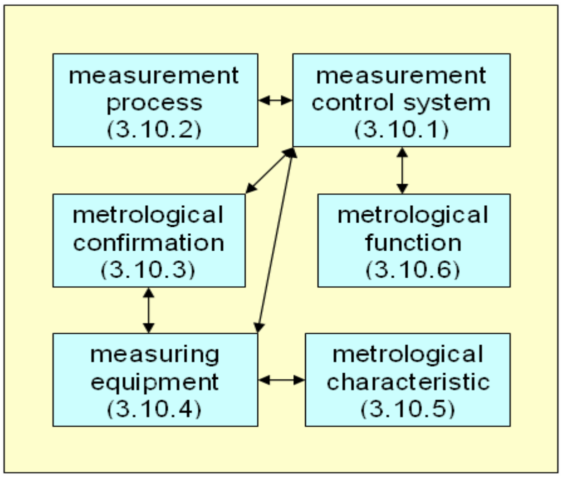


Figure 28. Concepts relating to measurements

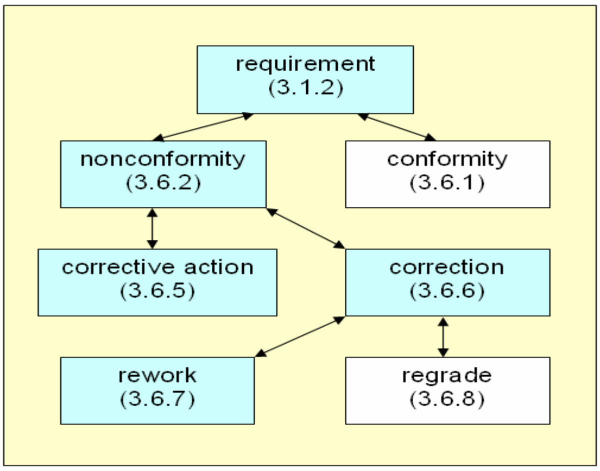


Figure 29. Concepts relating to conformity

Unsolved problems in quality metrology for SME are fundamental gaps in

Terminology & standardization management:
- Application of different definitions for the same terms
- Application of different software for the same tasks
- Application of different measurement standards for the same measurands.

Documentation & distribution management:
- Missing functional reliability of documentations due to product-oriented approaches
- Missing quick comprehension due to text-oriented documents and interfaces
- Missing real-time actuality of documents due to print-oriented distributions.

Knowledge & collaboration management:
- Hidden or unknown documentations due to firm policy or price
- Insufficient work skills in quality metrology due to underdeveloped continuous learning
- Underdeveloped individual collaboration due to traditional costs and difficulties.

3. INNOVATIVE CHANCES OF INTERNET METROLOGY FOR SME

The innovative and sustainable approach of Internet metrology (iMET) is the development and application of web-based modular visualized virtual application solution providers (iASP) for quality metrology. Internet metrology has direct influence on information competence, web-based collaboration, continuous learning and knowledge sharing in SME. The quality capability of SME will be improved. Added value is increased comfort, better functionality and affordability through application of information society technologies in SME. Internet metrology is necessary, to be prepared for the practical use of
- the second Internet wave (pay-by-content),
- the third wireless generation (Bluetooth & UMTS) and
- the application of complex knowledge-based adaptive systems (Fig.30).

The **scientific goals** are:
1. Digitalisation & standardization of precise and reliable quality measurements
2. Visualization & virtualisation of comprehensible and valid process documentations
3. Web-based knowledge & collaboration management for self-learning and work skill enhancement.

The **technical goals** are:
1. development of next generation learning solutions by application of information society technologies in field experiments with web-based modular visualized virtual application solution providers in quality metrology for small end medium sized enterprises

2. demonstration of next generation learning solutions by application of information society technologies in field experiments with web-based modular visualized virtual application solution providers in quality metrology for small end medium sized enterprises
3. realisation of added value with comfortable, affordable and real-time features where
   - comfort is characterised by adequate satisfaction of users in SME
   - affordability is characterized by quality metrology payable by users in SME
   - real-time is characterised by applicability every time, every where, on demand.

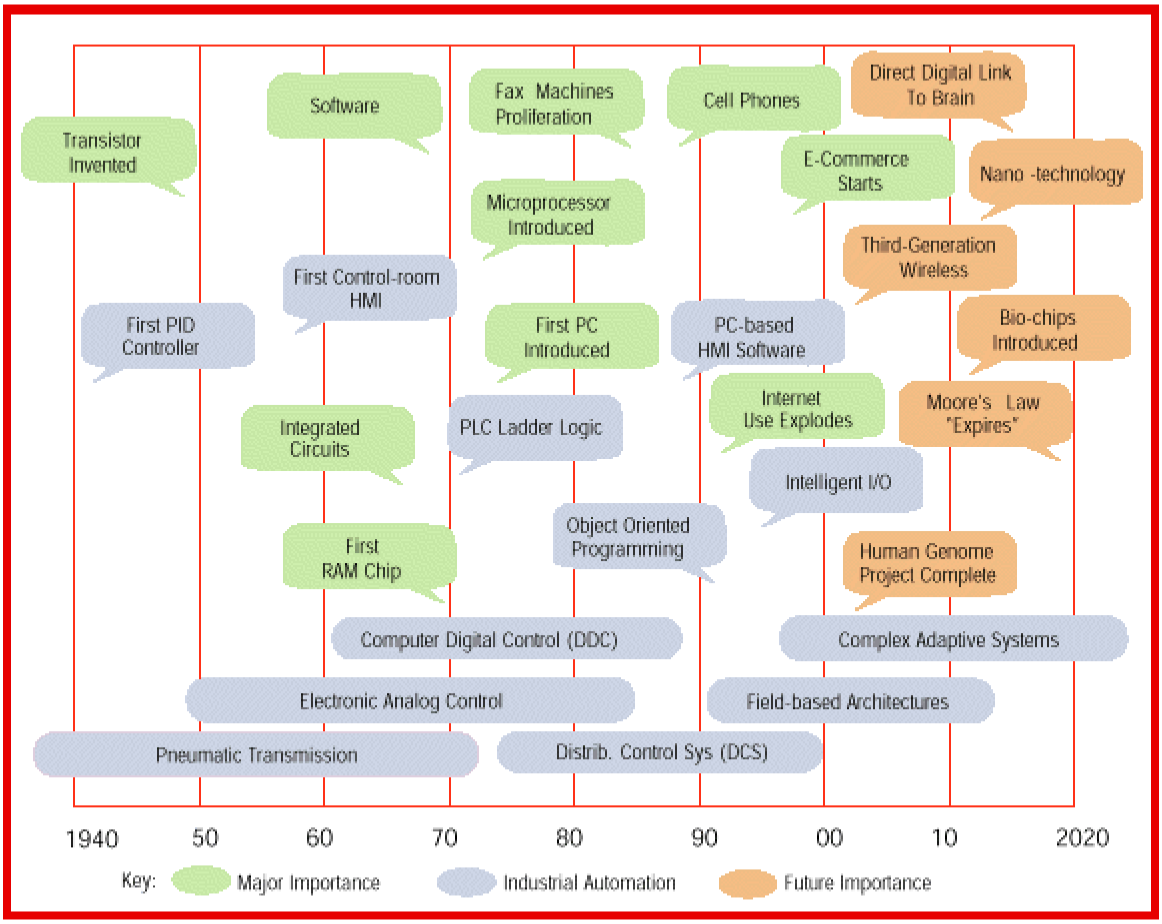


Figure 30. Major events and life cycles relating to automation & knowledge working [www.jimpinto.com/writings/frontiers.html]

To reach the technical goals proprietary solutions should be avoided. Therefore the following tools of information society technologies can be recommended to apply

- industrial standardized operation system (MS Windows) [www.microsoft.com]
- international accepted presentation system (MS Power Point) [www.microsoft.com]
- compatible rich media system (MS Producer) [www.microsoft.com]
- automatic voice-typing system (IBM Via Voice 10) [www.linguatec.de]
- automatic translation system (linguatec Personal Translator) [www.linguatec.de]
- global network system (Internet) [www.isoc.org]
- standardized file transfer protocol (TCP/IP) [www.webopedia.com/TERM/T/TCP_IP.html]
- independent knowledge sharing system (CoSharing/Netviewer) [www.netviewer.de]
- portable computer (Notebook, Tablet, Pocket PC) [www.dell.com]
- standardized wireless short range data transfer (Bluetooth) [www.bluetooth.com]
- standardized wireless long range data transfer (UMTS) [www.umts-forum.org]

The **methodological goals** are
1. bigger share of digital work than paper work (Fig.31)
2. bigger share of images than text (Fig.32)
3. bigger share of virtual world than real world (Fig.33).

The comparison of paper work and digital work, of text and images in multilingual societies and of real world and virtual world in metrology shows the sustainable advances of digital work, images and virtualization.

P A P E R W O R K content: **black box except for buying (-)**, **order: email or Fax (-)**, **delivery: by mail (-)**, **time: delayed (-)**, **data format: printed letter (-)**, **carrier: paper (-)**, **mass: high (-)**, **price: high (-)**, **source: original (+)/second hand (-)**, **work: toilsome (-)**

D I G I T A L W O R K content: visible (+), **order: click (+)**, **delivery: click (+)**, **time: on demand (+)**, **data format: doc/pdf/ppt-file (+)**, **carrier: Internet (+), mass: low (+), price: free (+)**, **source: original (+)/second hand (-)**, **work: comfortable (+)**

Figure 31. Comparison of information sources for traditional and innovative quality measurements

T E X T language: specific (-), context: sensible (-), distribution: local (-), comprehension: difficult (-), technical realization: simple (+), data capacity: low (+)

I M A G E language: unspecific (+), context: robust (+), distribution: global (+), comprehension: simple (+), technical realization: extensive (-), data capacity: high (-)

Figure 32. Comparison of information carriers for traditional and innovative process documentations

R E A L W O R L D design: expensive (-), production: expensive (-), test: expensive (-), data transfer: subjective (-), collaboration: delayed (-), product: real (+)

V I R T U A L W O R L D design: low-budget (+), production: low-budget (+), test: low-budget (+), data transfer: objective (+), collaboration: on demand (+), product: material virtual (-)/intellectual real (+)

Figure 33. Comparison of collaboration and work skill enhancement in traditional and innovative environments.

4. FIRST STEPS TO INTERNET METROLOGY FOR SME

4.1 Practical Examples for Terms & Definitions

The International Vocabulary of Basic and General Terms in Metrology (VIM) is an international agreement on terminology, prepared as a collaborative work of experts appointed by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML *((for explanation of the acronyms see www.google.com))*. This vocabulary covers subjects relating to measurement and includes information on the determination of physical constants and other fundamental properties of materials and substances.

p-Vocabulary:
VIM 1993, 60 p., bilingual, ISBN 92-67-01075-1, CHF 71,00
Address for order: www.iso.ch/iso/en/prods-services/otherpubs/Metrology.html .

e-Vocabularies:
www.cornnet.nl/~mlbroens/vim.htm
www.sp.se/metrology/eng/terminology.htm
www.usm.mzt.si/ENGLISH/SPLOSNO/slovar.htm
www.iupac.org/publications/analytical_compendium/Cha18sec436.pdf

4.2 Practical Examples for Visualization & Virtualization

Recent task is the development and introduction of digital branch portals for the collection and appropriation of the actual body of knowledge in key fields of measurement theory and practice + its modularization for higher flexibility + its visualization for quicker comprehension + its virtualization for digital simulation and real-time knowledge transfer.

The **NIST/SEMATECH e-Handbook of Statistical Methods** has the goal to help scientists and engineers incorporate statistical methods in their work as efficiently as possible, very comfortable and free of charge [www.itl.nist.gov/div898/handbook/22.02.2003]. The applied EDA method (exploratory data analysis) is a generalized application of visualization and virtualization (Fig.34). **Visualization** is the central power of rich media, especially for SME. Images are gunshots into the brain because they are functioning so fast. Images need no translation into other languages.

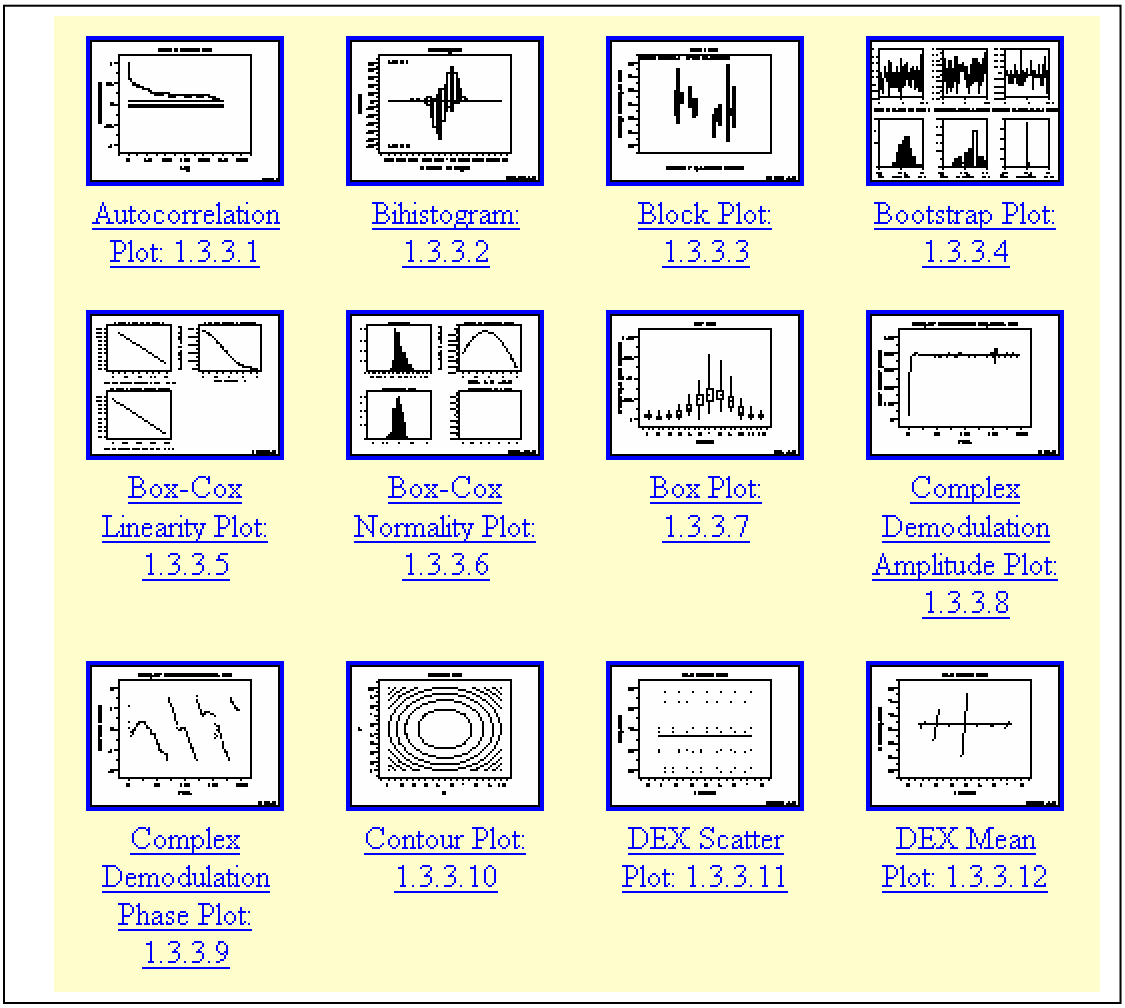


Figure 34. Gallery of selected visualized plots in alphabetical order [www.itl.nist.gov/div898/handbook/eda/section3/eda33.htm 22.03.2003]

4.3 Practical Examples for Web-based Workplaces and Collaboration

The success story of measurement, instrumentation and quality control in production and process engineering is long and impressive. For all that it can not be neglected that methods, instruments and algorithms are developed by people with different knowledge, tools, aims and capabilities. Global markets are generating increasing needs for international harmonization, unification, standardization, evaluation and validation of hardware, software, firmware and methods. Internet metrology is the royal path for global testing & calibration + evaluation & certification + knowledge sharing & continuous learning + collaboration management (Fig.35).

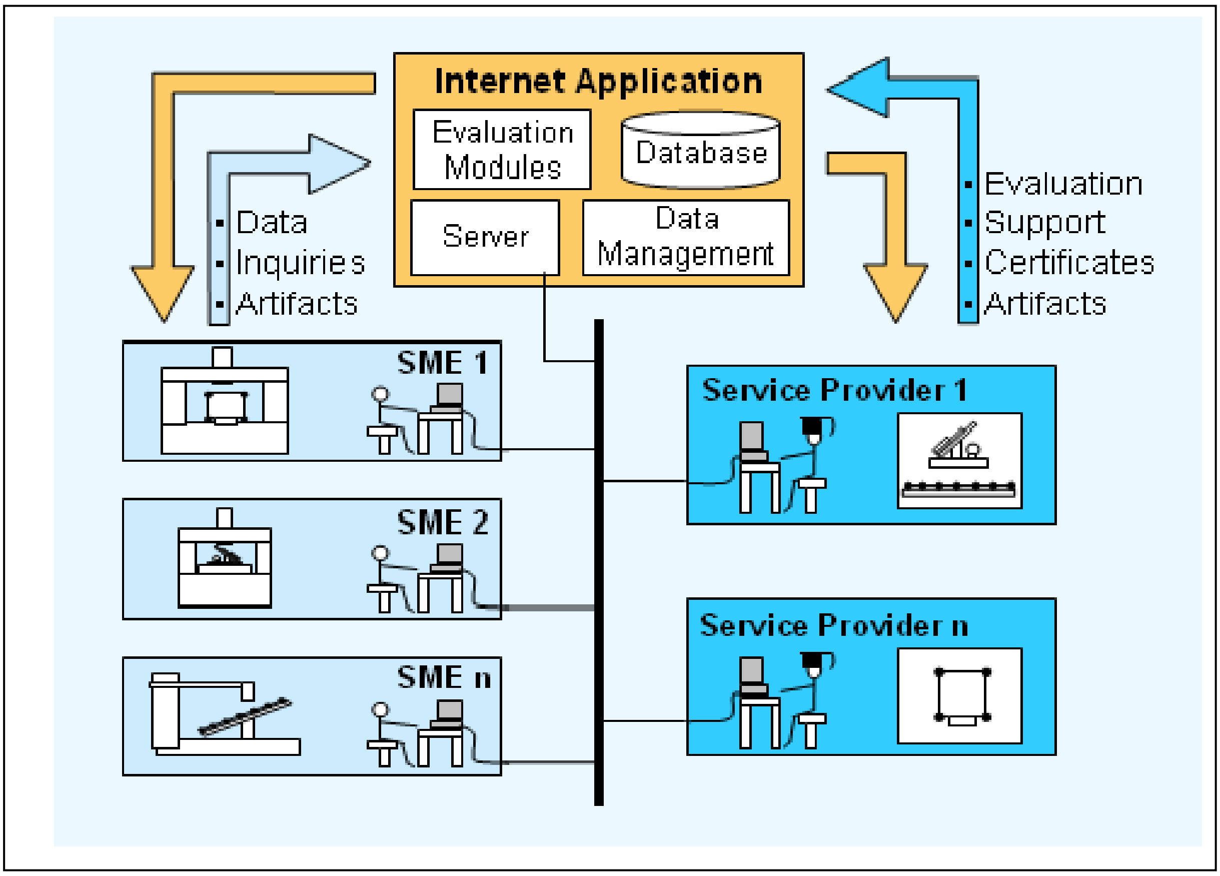


Figure 35. Internet metrology for testing & calibration + evaluation & certification at PTB Germany [www.amctm.org/index.asp] Workshop "Internet Measurement & Self-Calibration", Paper "Internet-based Applications for Metrology at PTB", Transparency 6

Recent tasks are **wireless inspection and calibration** of engineering processes and measurement means via Internet down to laboratories at universities, research institutes and industrial plants through online collaboration with legal calibration services, triggered by the demands of SME

+

direct comparisons of metrological hardware and software via Internet to overcome the so far uncontrolled deviations of different hardware and software realizations in applications for the same quality measurements, affordable for SME

+

international standardization in teaching and learning of metrological fundamentals through combination of virtual and real experiments and hands-on trainings (blended learning) at laboratories in universities, research institutes and industrial plants [10].

For a practical example see scopemeter [www.fluke.com/VirtualMeters/190c/Main190.exe]

5. EXPANDED FIELDS OF APPLICATION FOR INTERNET METROLOGY

Influenced by the increasing power of **micro computers** and the decreasing cost for processors and equipment the shift from centralised local data management to distributed global knowledge management is at dawn. The unification and standardisation of operation systems and application software under the influence of Microsoft is obvious. The capability, acceptance and economy for automation of **technical** and **non-technical** processes are increasing. Internet metrology will be increasingly used for measurement information acquisition in facilities & homes (Fig.36), health care & medical treatment (Fig.37), machine tools & plants (Fig.38) and cars & transport (Fig.39) [7], [8].

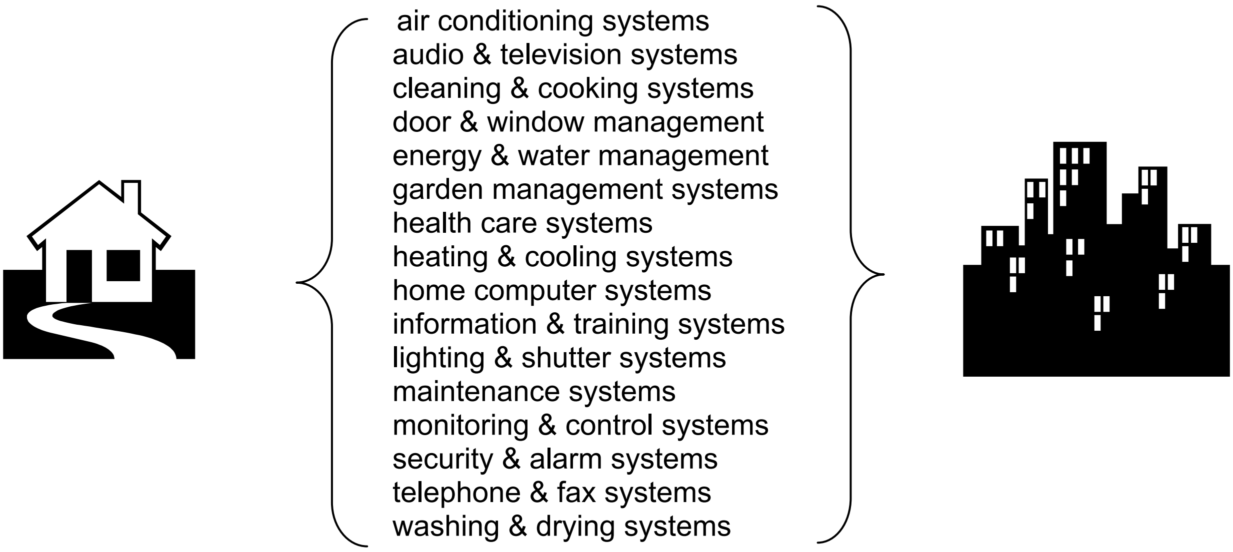


Figure 36. Measurement information acquisition in facilities & homes

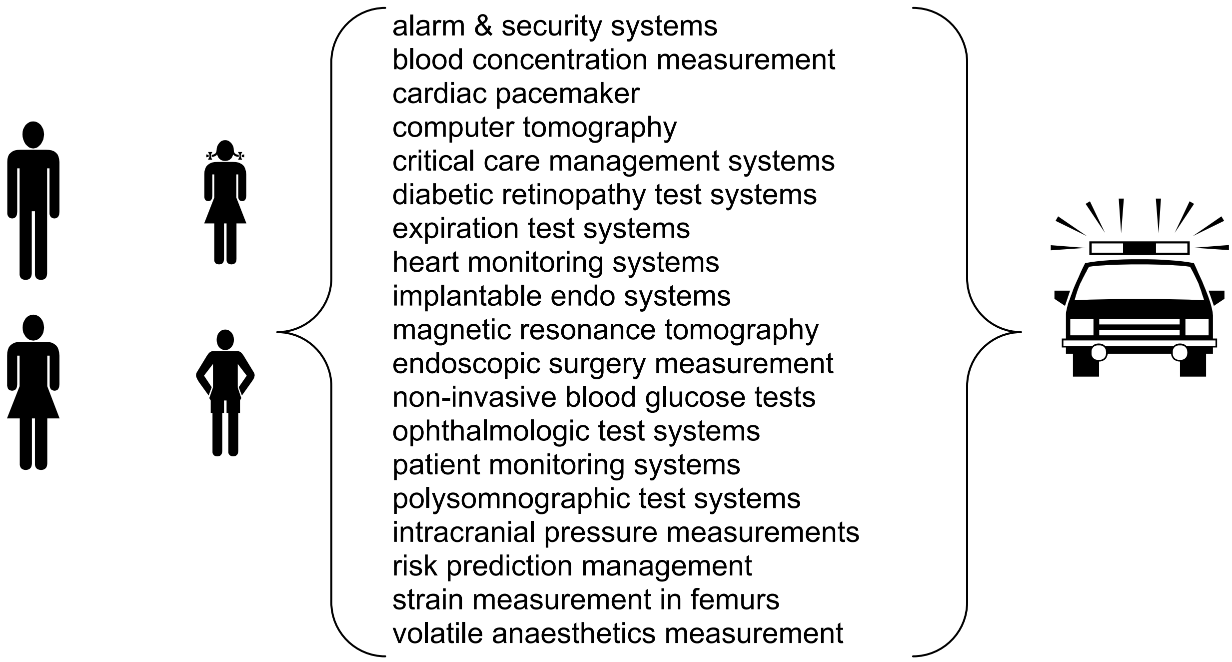
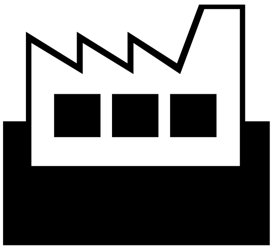


Figure 37. Measurement information acquisition for health care & medical treatment



assembling systems
autonomous transport systems
business management systems
conveyor systems
customer management systems
design & construction systems
development systems
energy & water management
machine tool control systems
maintenance systems
manufacturing systems
monitoring systems
process management systems
project management systems
quality management systems
recycling & waste systems
remote control systems
robot systems
storehouse systems
testing systems

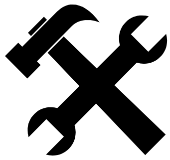
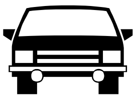


Figure 38. Measurement information acquisition in machine tools & plants



alarm & security systems
crash & surveillance systems
display & monitor systems
guide systems
maintenance systems
motor management systems
navigation systems
seat memory systems
sensor systems
X by wire systems

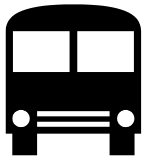


Figure 39. Measurement information acquisition in cars & transport

6. SUMMARY & CONCLUSIONS

Terms & Definitions in metrology are describing a body of knowledge which compel its practitioners to learn a great number of special concepts and terms. Some of the terms can be understood on the basis of general language, but it is typical for metrology that many words have another or a smaller range of meaning than in general language. The language of modern metrology is English. A precise and systematic terminology of metrology is fundamental for knowledge & collaboration management in metrology. It has been shown HOW Internet Metrology is the royals path to standardize terms and definitions in metrology.

Visualization & Virtualization are the central power of affordable collaboration, especially for SME. Visualization & virtualization help people to be well-informed, make collaborative designs, judge analytical data, make adjusted decisions, elaborate best solutions and prevent spoiling of valuable time, energy, material, work power and money by traditional trial and error procedures. It has been shown HOW Internet Metrology is the royals path for harmonization, unification and standardization of processes and products in metrology.

Knowledge & Collaboration Management in traditional metrology is in a continuing crisis. Knowledge and collaboration management was up to now limited by time, money, language, storage capacity, computing rate and transfer rate. The central power of new achievements are comfortable, real-time (just-in-time, on demand) and affordable collaboration. It has been shown HOW Internet Metrology is the royals path for collaboration, education and training in metrology.

The paper shows that Internet Metrology is a big chance especially for small and medium sized enterprises (SME) to shorten their gap in quality metrology in competition with large enterprises. Internet Metrology is an up-to-date HOW TO. Internet metrology is going far beyond the fundamental tasks of legal metrology but it will strengthen their power.

Forget Hardware & Software. Simplify Processes for Man:
- Comfortable & Functional & Affordable -

7. REFERENCES

see [Web Sites] and

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