DEAR FRIENDS DEAR COLLEAGUES,

IMEKO celebrates World Metrology Day in 2022 with this special newsletter issue. This year's topic is "Metrology in the Digital Era". Digitalization plays an essential role in many areas of IMEKO. Our Technical Committees talk about how the "Digital Era" applies to their area of expertise.

Press release worldmetrologyday.org:

“20 May 2022 "World Metrology Day” is an annual event during which more than 80 countries celebrate the impact of measurement on our daily lives. 20 May commemorates the anniversary of the signing of the Metre Convention in 1875. This treaty provides the basis for a worldwide coherent measurement system that underpins scientific discovery and innovation, industrial manufacturing and international trade, as well as the improvement of the quality of life and the protection of the global environment.

World Metrology Day recognizes and celebrates the contribution of all the people that work in intergovernmental and national metrology organizations and institutes throughout the year.

The theme for World Metrology Day 2022 is Metrology in the Digital Era. This theme was chosen because digital technology is revolutionizing our community and is one of the most exciting trends in society today."

MESSAGE FROM THE BIPM AND BIML DIRECTORS

Because of the importance of this message, we fully quote here:

"The adoption of digital technology is revolutionizing our community. It is improving processes and opening new opportunities. It is one of the most exciting trends in society today, typifying the rapid pace of change that we are experiencing every day.

One of the cornerstones of digital transformation is the open and transparent exchange of information. Whenever information is needed, it must be easy to find and easy to access in a format that is both interoperable and reusable. Data that meet these requirements are what is now known as being "FAIR".That is, they must be Findable, Accessible, Interoperable and Reusable. When these requirements are met, data can be recognized as being trustworthy and can underpin open data practices.

In order to maximize the efficiency with which information is used in the new digital world, it is essential that all sources of information should not only be readable by humans but also be available in formats that can be read by machines. When this is the case, it might also be acted upon by machines (i.e. be "machine actionable") and used as the basis for new applications of artificial intelligence.

The opportunities brought by digital transformation will be realized more quickly if the global quality infrastructure can be adapted to promote and use new digital technologies that generate and use data that is FAIR. Amongst the central components of the national and international quality infrastructure is metrology, the science of measurement, and its application, which is already starting to support the requirements of the new digital economy.

A leading example of the actions to support the digital transformation is the work of the CIPM to develop an SI Digital Framework. This Framework will be based on a core representation of the SI, including agreed formats for basic data elements, including values, units and uncertainties based on the SI Brochure. It will enable the implementation of new services by the NMIs, the BIPM and related organizations that make the best use of open data formats, software tools and services that build upon the SI core representation. Such services will enable data to be available for analysis and improve the quality of data, and improve data transparency. The outcome of the SI Digital Framework will be new digital applications developed and deployed in the broader metrology community and in research disciplines that rely on the SI.

The application of digital measurement frameworks to industry and consumers is integral to an inclusive and trusted digital transformation. The incorporation of digital principles and practices in documentary standards and technical regulations from the outset is an area that the OIML is examining. A digital certificate of conformity which adheres to the FAIR principles is part of this narrative. The digital transformation of metrology can bring many benefits to our community. For example, it can expedite time-to-market for measurement products and services and reduce delays associated with approval processes. In turn, this contributes to innovation, product agility, and sustainability.

For the BIPM and the OIML, the journey towards achieving the goal of digitalization will be twofold. We will transition our own activities and services, which will, in turn, provide the digital foundations for all users of measurement data. This is a journey that will be both progressive and fascinating and one which we look forward to sharing with our stakeholders."

By Martin Milton, Director of BIPM and Anthony Donnellan, Director of BIML

worldmetrologyday.org

THE SIGNIFICANCE OF THE DIGITAL ERA IN THE IMEKO TECHNICAL COMMITTEES

TECHNICAL COMMITTEE 3, MEASUREMENT OF FORCE MASS TORQUE AND GRAVITY

Although TC3 deals with the conventional mechanical quantities of force, mass, and torque, the measurement and traceability of these is being increasingly supported by the use of digital techniques. This support ranges from the application of digital twin technology to optimize the design of balances and force transducers to the generation of digital calibration certificates. It is expected that the impact of digital techniques in this area will only increase, with the further optimization of mechanical measurement methods using this evolving technology.

TECHNICAL COMMITTEE 4, MEASUREMENT OF ELECTRICAL QUANTITIES

The global concept of Industry 4.0 is one of the key aspects of digitalization and improvement of industrial production. For most industries to remain competitive in the global market, it is necessary that the concept of Industry 4.0 be incorporated into all stages of the industrial processes. This is possible by means of metrology, a science that connects and verifies theory and practice. Measurements are in all industrial environments where it is necessary to implement the concept of Industry 4.0 at basic levels:

- Processing work fundamental level of implementation of measurements in crucial stages of an industrial process;
- Laboratory/Legal Measurements the level of calibration of measuring instruments;
- Industrial activity level of verification of existing and new equipment that is installed and located in industrial plants (e.g. automotive industry or smart grids);
- Education, the level of training of the new generation of engineers for metrological work in the environment of Industry 4.0.

Metrology as a science of measurements is a key factor in the domains of science, technological development and industrial production. It allows accurate and precise data on all relevant physical parameters to be found in the system and, at the same time, provides verifiable feedback on the outcome of each industrial process. Although the current emphasis of the expansion of Industry 4.0 is on the process part (IoT, IIoT, AI, Big Data, Wi-Fi, 5G, 6G, Embedded Systems, Smart devices, Cloud Computing), measurements are the foundation that enables the work of all other parts of the industrial system. This is clearly a good sign that metrology needs a higher visibility promotion in order to remain relevant and at high priority at all levels of decision making. We are in a digital revolution where the previously mentioned modern concepts come on a stage. The digital transformation has begun, and measurement, metrology and measurement infrastructure shall be prepared for the new challenges. This should be the mission of IMEKO to answer the new challenges that arise in the Digital Era. Measurement of these quantities is a key factor of innovation in this field. IoT or smart devices produce enormous numbers of data that will be even greater with the reducing cost of the devices and their use in new areas. The knowledge of these systems through the measurement will improve their performance and will help to optimize and make more efficient data usability. Reliable measurements are essential for scientific research, trade and industry. Addressing society's challenges and the emergence of new technologies require increased accuracy and new measurement capabilities, especially electrical ones.

Today, almost everything can be considered an "industry". The broad concept of digitalization of industrial processes under I4.0 shows that every industry needs to be, more or less, updated to new, better standards, but under what conditions and costs? Metrology, as a traditional intermediary between theoretical/legal demands and practical/field implementation, is once again a crucial stepping stone from the "before I4.0" to the "with I4.0" industry. "How" is the big question in this that metrology needs to assist in finding the answer to, along with its usual tasks like monitoring in "reality check" purpose.

Excluding human decision making and intervention from an industrial process can lead to some ethical questions in the I4.0 era of automatization and Artificial Intelligence (AI). The biomedical field is one most obvious problematic areas, but also many other, less sensitive fields are affected as all industrial products affect human life if not directly (e.g. food and pharma), then indirectly (e.g. oil drilling and mining) or by mediated effect (education and certification).

Legal metrology is one of the three basic types of metrology, in addition to industrial and laboratory (scientific) measurements. Calibration and other legal measurements can be significantly improved by introducing the Industry 4.0 concept. Excluding or reducing the impact of the human factor on laboratory work, automation, parallelization, creation of connected databases, and improvement of measurement uncertainty are just some of the possibilities that would be realized with Industry 4.0. As the next step in this chain, there is a vast field of integrating I4.0 enabled metrology in an industrial environment. There is a challenge how to conform measurement equipment to some processes, but also vice versa.

Some processes need to be updated in order to improve or even remain possible in I4.0 digital world. Again, the human factor is one of the crucial implications, how they affect the industrial I4.0 and metrology, but also how they affect the people, both those included in the process and all outside the process (environmental impact, carbon footprint, etc.). Finally, education is the key to the future. How young engineers and technicians will be formed and educated to become proficient in the I4.0 era, but they must retain knowledge of all past/current older generation technologies that are used in industry, obtain knowledge on the new I4.0 technology and how to blend them in a single process. Also, they need to be able to predict and be ready to use and master any future technology that will be introduced during their career. This is a great challenge and stress to both the students and educators.

The role of metrology in the strategically important transition of industrial production to the concept of Industry 4.0 can be summarised in ten basic points: 1. Awareness-raising, 2. Communication, 3. Recording of conditions and needs, 4. Planning realistic improvement options, 5. Monitoring, 6. Control quality, 7. Design, 8. Testing, 9. Legislation, 10. Education of new staff. Each of these points requires a detailed analysis of all aspects of theory and practice, as well as the application of innovative methods. In recent years, the spread of digital systems and the pace of their development have accelerated even further. As a result, high precision measurements are more and more important nowadays in this digital infrastructure. Digital systems are present in the industry, education, research, health care and in almost every area of life. The computing, data storage and signal processing capabilities are growing exponentially: the number of sensors, the size of computer networks and as a result, the data available about the environment around us is rapidly increasing the need for cost effective and efficient measurement methods. The community of IMEKO plays an important role in the development of novel technologies and facilitating progress in the following important areas: reference architectures for measurement systems, analytical methods for deriving complex information from large quantities of data, developing high frequency measurements methods for telecommunications and the 5G-6G networks, developing more and more complex models for simulations and virtual measurement instruments.

The development of new measuring systems in the concept of Industry 4.0 includes research on the possibility of implementing new technologies to standard metrological practice in the industry, but also determining the degree of readiness of each industrial system for the transition to Industry 4.0. In order for this improvement to pay off economically, each system must have accurate information on the measurement uncertainty and reliability of

the equipment it owns, what needs to be changed, whether existing equipment can only be upgraded to new standards, or new equipment needs to be procured without unnecessary additional investment.

Only when we have clear goals, targets and available resources we can determine the optimal strategy for the metrology development in the I4.0 environment.

TECHNICAL COMMITTEE 6 DIGITALIZATION

Digital transformation encompasses revolutionary changes in technologies, processes, and economies and affects the industry, science and, respectively, all areas of the quality infrastructure. Examples are cloud computing, automation, remote services and digital twins. These developments challenge the established processes, tools and practice in metrology but also provide many new opportunities to improve the metrology landscape. For instance, digital technologies can help to make services in legal and industrial metrology more efficient by using cloud solutions, remote services and other digital tools.

Concrete developments resulting from the digital transformation today are the Internet of Things (IoT), Smart X (where "X" stands for, e.g., city, grid, sensor, service) and artificial intelligence (AI). Each of these developments comes with its own metrological questions and requirements, such as, for instance, the role calibration in the IoT, traceability for smart sensors or the metrological assessment of AI.

The digital transformation also affects the whole quality infrastructure: digital data and digital processes will need to be considered in the whole product lifecycle; shorter innovation intervals, software updates and self-learning systems require a highly efficient and effective QI, which itself uses digital technologies. Hence, the bodies and elements of the QI need to embrace the digital transformation. This cannot be achieved by the individual bodies alone but requires a joint approach. Therefore, a joint statement signed by CIPM, OIML, CODATA and IMEKO on the collaboration for a digital transformation in the quality infrastructure. More institutions will follow soon.

IMEKO itself is addressing the digital transformation on several levels. In 2020, the TC6 "Digitalization" was founded, which has all the above-mentioned challenges and opportunities in its scope. Many other TCs partly address digital transformation in their scope (e.g., TC8, TC10, TC17 and TC21) and collaborate with TC6. As a first step, three sessions about digital transformation were organized for the IMEKO World Congress 2021. In 2022 IMEKO is joining forces with CIPM, OIML, EUROLAB, EURAMET and GULFMET for the first IMEKO Conference on metrology and digital transformation in September 2022. These activities will help foster the digital revolution in metrology even more and bring together experts from all around the world.

TECHNICAL COMMITTEE 7 MEASUREMENT SCIENCE

The arrival of metrology in the Digital Era produces multiple scientific topics that directly concern the TC7 Measurement Science Technical Committee. Recent TC7 presentations dealt with the inclusion of AI methods into the measurement processes, and with the concept of virtual objects under measurement:

The inclusion of AI methods into the measurement process raised multiple epistemological questions. For example, "can a result issued from an AI featured measurement be a measurement result?" or "Can AI make "what is the meaning of the uncertainty introduced by the AI methods?". To anticipate a little, the previous question will soon raise a new one:

"what is the meaning of the uncertainty introduced by quantum computing in a measurement process?"

Considering software as a system under measurement also reminds us of an old question related to measurability: "is counting a measurement process?", updated as "is an estimation of property of a virtual object by way of a computational process a measurement process?". This question is crucial when considering the use of weakly defined measurement, also named soft measurement, as a way to estimate software properties or, more generally, virtual properties.

TECHNICAL COMMITTEE 8 TRACEABILITY IN METROLOGY

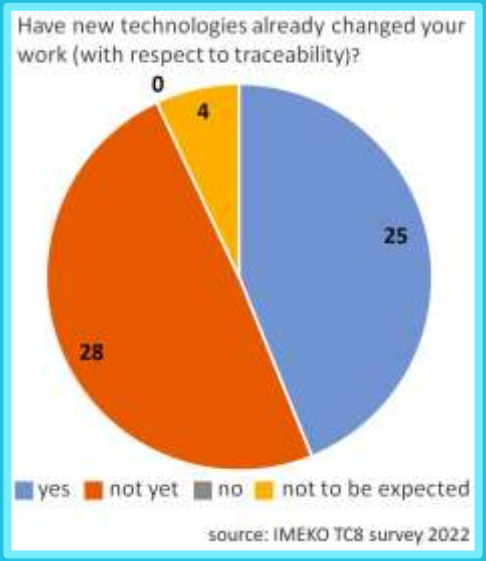
Although traceability is the backbone of metrology, the term sounds outdated. But a new survey amongst IMEKO colleagues from all over the world has shown that there are new topics which came into focus due to digitalization.

25 of the 57 responding IMEKO members have already experienced changes (with respect to traceability), and only 7% expect daily work not being affected in any way in the near future. All others need and could be supported on time.

IMEKO TC8 "Traceability in Metrology" took up the challenge to address these new issues. A sub-committee "traceability in digitalization "has been founded and shall discuss and highlight, amongst others, the following topics:

- Automated use of "horizontal traceability"-information provided by digital certificates
- Traceability of virtual devices highlighting the use and need for virtual standards, reference implementations and (golden) reference data sets
- Traceability of/in sensor networks – e. g. to clarify questions like: Does each sensor need to be traceable to classify a network as traceable as a whole?
- Traceability of self-learning and AI systems-When and how can a system being able to change settings on its own be considered/classified as traceable?

The work will be harmonized, and the results will be discussed with IMEKO TC 6 "Digitalization".



TECHNICAL COMMITTEE 10 MEASUREMENT FOR DIAGNOSTICS, OPTIMIZATION AND CONTROL

The topic "Metrology in the Digital Era" is fully relevant and actual for IMEKO TC10. The TC10 community does research in 21 scientific areas, and many of them are closely related or cover comprehensively the strongly connected metrology and digital world. Digitalization is already an integral part of Diagnostics, Optimization and Control. It interweaves the basic theories and covers the complete information chain of sensoring, signal processing, fault detection and prognosis, validation of the

product, moreover of the complete system of quality and conformity. Using this digital highway of information supports the cutting edge research and realization of various real-time solutions for condition monitoring and maintenance in the loop and embedded control of dynamical systems, enables non-destructive testing of mechanical systems, is a strong basis for sophisticated safety and risk assessment methods and supports the evaluation and management of systems uncertainties. The Digital Era is the same, a key enabler nut also a key exploiter of the research results of IMEKO TC10, artificial intelligence, machine learning and data science techniques incorporated into the complex world of Internet of Things (IoT) bring the TC10 topics' solutions on an adaptive, much higher level. Beyond the technical solutions, TC10 purposely targets the research on the related human aspect of these inventions to strive continuously improve the quality of life and the environment. TC10 incorporates Industry 4.0 and autonomous driving vehicle areas and various industrial branches like industry, transportation, mechatronics, electronics, acoustics, urban systems, living environment, civil engineering, technology of health systems, avionics, automotive, energy, machining, green environment, water treatment and biomedicine that strongly requires to do research also on the standardization challenges involving deeply their digital mapping as well. Finally, recognizing the intensive digitalization challenges, the IMEKO TC10 on Measurement for Diagnostics, Optimization and Control appointed many years ago a dedicated research topic, the so-called "Digital transformation", in order to support and encourage the management and process related exploration of these rapid changes. Moreover, digitalization is a bi-directional field: on the one hand, digitalization is an enabler and brings the related research fields to a higher level; on the other, it is especially important to develop cutting edge theories and solutions for the measurement of the digital world, e.g. measurement of information content (like Information Theory), digitalization maturity, human-digital integration etc. Consequently, the topic "Metrology in the Digital Era." is a key challenge and, as such, an actual research topic for the whole world and for the IMEKO community naturally.

TECHNICAL COMMITTEE 14 MEASUREMENT OF GEOMETRICAL QUANTITIES

The Technical Committee 14 of IMEKO deals with measurements of geometrical quantities. Our aim is to promote and develop both the theoretical knowledge and practical applications of product inspection methods, process control techniques and quality management in the field of dimensional metrology. The established techniques of dimensional metrology like coordinate measuring machines, optical sensors based on digital image processing or computer tomography render point clouds, large amounts of data, that have to be digitally processed to get information about the geometry of a workpiece.

Furthermore, there are many challenges that metrologists active in this field have to face in relation to digital transformation in metrology, which is boosted by rapid changes in the production industry (digital manufacturing, Industry 4.0, smart factories, etc.). Automation, computerization, reduction of necessary human interference and time optimization are the main postulates of the fourth industrial revolution. In response to this, metrology of geometrical quantities must get as close to manufacturing processes as possible and focus on techniques that make fast and cost-efficient measurements possible. This is why in our field we may observe some changes. In many applications, tactile methods are superseded by optical ones that are capable

of measurements of millions of points in few seconds. New in-process and in-line metrology systems integrated in the manufacturing processes or production lines are developed. Fast processing methods for big data and advances in data-fusion techniques may be used for improving multisensor devices. New hardware and software solutions increase the number of applications of systems that may be used for non-destructive testing of measured workpieces' internal structures. TC14 activities are in-line with mentioned advances. Our scope covers all methods, systems and devices that are used for the determination of geometrical quantities values in different fields of industry. Our members are actively working on research and development in precision engineering, nanomanufacturing, bioengineering and production (in automotive, aerospace, space, machine, and energy sectors, among others) fields.

There are many problems that arise due to digital transformation in metrology. Some of the most important that our committee will try to address in the coming years include:

- Development of novel measurement systems, with the main focus on optical measurements, in-process and in-line systems,
- Research on accuracy assessment and traceability assurance methods for measurement systems used in metrology in the Digital Era,
- Works on the preparation of digital twin models for metrological devices and measurement processes,
- Development of material standards insusceptible to ambient conditions changes, which may be used in demanding industrial conditions.

TECHNICAL COMMITTEE 20 MEASUREMENT OF ENERGY AND RELATED QUANTITIES

Currently, digitalization is making huge strides and bringing breakthroughs in every area of our daily life. Metrology and especially measurement technology in the energy sector is closely linked to digitalization. Metrology and digitalization are the two sides of the same coin-metrology without digitalization and digitalization without metrology is almost unimaginable and inevitable. With enormous progress being made in Cloud Computing, Big Data, Artificial Intelligence and advanced Machine learning tools, metrology is already playing a huge role in the modern digital world to improve system efficiencies in an integrated energy network. Whether it is an energy network such as combined heat and power systems, smart buildings, smart cities, electromobility, quality assurance of integrated systems etc, metrology of integrated systems (system metrology) takes centre stage in a digital world towards energy efficiency and sustainability.

TECHNICAL COMMITTEE 21 MATHEMATICAL TOOLS FOR MEASUREMENTS

Even if we are in the "Digital Era" there is still a lot to do to apply the basic principles of measurement science, namely having the uncertainty indicated everywhere when indicating any numerical result.

Metrology is certainly also using digital means as any of the other branches of science today. In the latter, though, metrology does not play a primary role. It does only in some branches, namely in a specifically dedicated branch of measurement science.

TECHNICAL COMMITTEE 22 VIBRATION MEASUREMENT

Like other TCs, the work of TC22 will be affected by the transition to machine-readable digital calibration certificates initiated. However, the implications of the digital era for TC22 go far beyond this. Digital output accelerometers and gyroscopes are used in the billions, far outnumbering the analogue output sensors supported by today's calibration infra-structure. Such digital devices are used in a wide range of applications (smartphones, gaming consoles, IOT, drones, airbags, self-driving cars) and are being increasingly relied upon for accurate measurements. Often the measurements of interest are not the output of a single sensor but a connected network of sensors or the aggregated data from several different types of sensors. Furthermore, high-level processing is often incorporated into the sensors, and artificial intelligence is often used to process the raw sensor data. The methods to support the accuracy of inexpensive large-volume digital-output sensors relying largely on redundancy and artificial intelligence must be developed by NMIs, and these methods will coexist with the current paradigm of small-volume high-accuracy analogue-output calibrated sensors

Additional details:

As NMIs move to address the above-summarised needs of the digital era for accelerometers and other sensors, some additional details become apparent:

- Interface protocols for digital sensors need to be harmonized and standardized to facilitate the integration of such sensors and their calibration.
- There is a need for metrology-grade reference standard digital acceleration sensors. NMIs and most secondary calibration laboratories currently depend on analogue-output standards, which impose the need to compare analogue against digital measuring channels.
- Timing effects imposed by data acquisition and processing in digital sensors can create challenges for sensor calibration, in particular with respect to sensor phase response.

TECHNICAL COMMITTEE 24 CHEMICAL MEASUREMENTS

Digitalization is an important process occurring in Chemical Metrology, further accelerated by the last two-year events. It affects our field in many areas, such as product development, technological processes innovation, and environmental measurements.

In chemical laboratories, digitalization allows long-term data exchange models. Moreover, the use of Digital Calibration Certificates (DCCs) will be widely applied in chemical and electrochemical measurements. Soon, it will be possible to extract calibration periodicities (based on drift) from DCCs. Moreover, new models based on Artificial Intelligence are being developed to predict the behaviour of measuring equipment and sensor networks. As a matter of fact, big data are one of the most important outcomes of digitalization. So, handling huge amounts of data using Machine Learning and Artificial Intelligence algorithms will be a crucial activity. The role of Chemical Metrology will be to provide its expertise in data quality assessment to analyze critically the results coming from these new tools.

Digitalization will have a huge impact on metrology, even if some companies still underestimate it. A high degree of digitalization and automation brings benefits and greater responsibility for those in charge of assessing data quality. For these reasons, it will require a wise and balanced implementation.

THE TECHNICAL COMMITTEE 6 ORGANIZES THE FIRST INTERNATIONAL IMEKO CONFERENCE ON METROLOGY AND DIGITAL TRANSFORMATION WITH FIVE SPECIAL SESSIONS

For further information, visit: https://www.m4dconf2022.ptb.de/home

JOINT STATEMENT OF INTENT ON DIGITAL TRANSFORMATION WITH IMEKO'S INVOLVEMENT

"The International Bureau of Weights and Measures (Bureau International des Poids et Mesures (BIPM)), BIPM, the International Organization of Legal Metrology (OIML), the International Measurement Confederation (IMEKO), the International Science Council (ISC) and its Committee on Data (CODATA) signed a Joint Statement of Intent on the digital transformation in the international scientific and quality infrastructure on 30 March 2022. The joint statement provides a platform for the signatory organizations to come together to indicate their support, in a way appropriate to their particular organization, for the development, implementation, and promotion of the SI Digital Framework as part of a wider digital transformation of the international scientific and quality infrastructure. Other international organizations are expected to sign the joint statement in the future.

The joint statement is part of an ongoing initiative by the International Committee for Weights and Measures (CIPM) and its Task Group on the Digital SI (CIPM-TG-DSI) to develop and establish a worldwide uniform and secure data exchange format based on the International System of Units (SI). Prof. J. Ullrich, Chair of the CIPM-TG-DSI, commented that the signing of the joint statement marks a ground-breaking step in transforming the highly successful international scientific and quality infrastructure, with the SI as an anchor of trust, into the era of digitalization."

Signing of the Joint Statement of Intent. Clockwise from top left: Wynand Louw, CIPM President (on behalf of the BIPM); Mathieu Denis, ISC Science Director and Acting CEO; Barend Mons, CODATA President; Roman Schwartz, CIML President (on behalf of the OIML); Frank Härtig, IMEKO President.

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