

# Workshop on Metrological Traceability

28 August 2024

Organized by the CIPM Forum on Metrology and Digitalization in partnership with IMEKO Technical Committees TC6 (Digitalization), TC8 (Traceability in Metrology), and TC21 (Mathematical Tools for Measurements)

## Metrological traceability

Metrologically traceable measurements are essential when important societal decisions are based on physical data. The rigor of traceable measurements is crucial for making robust, reliable, and trustworthy decisions. But what exactly is traceable measurement, and how should it be represented in digital form? This question now concerns many people working on the digital transformation of measurement infrastructures. Should the digitalization of traceability aim to capture the processes that people follow today, or should it look beyond these day-to-day routines and consider the essence of traceability and how to achieve it with machines?

The workshop consists of two sessions, each followed by an open panel discussion. The first session examines traceability within the context of today's measurement infrastructure. Starting from the traceability principles established in the late 20th century, panellists will explore how these concepts can be modelled and represented in digital form, leading to significant benefits for those at the ends of traceability chains. The second session will focus on new and emerging measurement system technologies. Panellists will discuss a range of systems, including intrinsic standards, sensor networks, virtual measuring systems, and virtual data spaces. Do these technologies challenge the traditional concept of traceability, or can the most important foundational principle of international quality infrastructures be applied to these systems too?

## Workshop format

Sessions have four panellists and a chair. The panellists will each give a 20-minute presentation. After these talks, a 30-minute discussion will be led by the session chair, in which audience participation is encouraged.

## Online participation, time and date

The workshop will be held at the IMEKO World Congress venue, on Wednesday 28 August between 8 AM and 12 Noon (0600 UTC to 1000 UTC).

Online participation will be available using the Webex platform.

There is no charge for online participation and registration is not required. Interaction during the discussion sessions will be possible using the chat facility on the platform.

A recording of the complete workshop will be made available after the conference.

Please find the dial-in data at the end of the document

## Session 1: From foundational principles to digital traceability chains

**Title:** Metrological Timelines for visualizing and digitalizing metrological traceability

**Speaker:** C. Ehrlich (NIST)

**Abstract:** Metrological traceability is a seemingly straightforward concept used to help provide confidence in measurement results, which includes measured values and measurement uncertainties. However, there are several aspects of traceability that are not so immediately obvious, such as the system of precautions that must be taken to ensure that mistakes haven't been made, and these must be taken into account in a rigorous documented statement of traceability. Metrological timelines can be developed to assist in visualizing the steps necessary to demonstrate traceability, and with the advent of modern digitalization tools it is worth exploring how the development of these timelines can be more readily modelled and implemented into documents like digital calibration certificates. This talk is intended to stimulate discussion of such possibility.

**Title:** Connecting a digital traceability chain together

**Speaker:** Blair Hall (MSL)

**Abstract:** Value is created when an important decision is made based on results at the end of a traceable measurement chain. Measurement accuracy must meet the need for a trustworthy decision process. So, information about measurement errors is carefully assessed along the whole traceability chain, a practice well-understood today. However, the exchange of digital data now introduces challenges as well as opportunities to enhance value. Digital systems require strict logical instructions. So, care is needed in choosing what information will be shared and how digital systems should be instructed to use it. This talk examines how the links of a traceability chain can be connected by recognising the importance of the unique measurement errors that occur at each stage of the process and shows how such information can be represented in digital form.

**Title:** The concept of provenance in the context of metrological traceability

**Speaker:** Ryan White (NRC)

**Abstract:** Data provenance plays a crucial role in ensuring data quality by capturing essential information about the processes, entities, and agents associated with the data of interest. It serves as a historical record, enabling data consumers to establish trust in the provided data's quality. In the field of metrology, data provenance is part of the requirements for reporting measurement results in a traceable measurement chain. By clearly separating data provenance as contextual metadata associated with a measurement result, metrology can benefit from existing metadata standards and focus on modelling metrology-specific details. This talk explores the application of a domain-agnostic conceptual model of provenance and considers the necessary metrology-specific details to describe the provenance of a measurement result within a traceable measurement chain.

**Title:** VNA Tools - a metrology software supporting the digital traceability chain

**Speaker:** Marko Zeier (METAS)

**Abstract:** VNA Tools is free software that supports the traceability chain from the primary realization of the measurand all the way to the end user. This is achieved through detailed modelling of the measurement process and full consideration of correlations through special data formats. The level of detail, which is transferred to the end user, can be adjusted based on need and acceptable data volume. At the end user level, the software manifests itself also in different alternate forms, e.g. integrated in a commercial measuring device. This way it supports the seamless further processing of

the data according to the users need. The uncertainty budget is updated at every step in the traceability chain. VNA Tools creates thus value beyond the (digital) calibration certificate and supports the digital dissemination of metrological principles.

## Session 2: Traceability for emerging measurement technologies

**Title:** Traceability challenges for intrinsic, deployable standards

**Speaker:** Barabara Goldstein (NIST)

**Abstract:** The redefinition of the SI combined with advances in photonics integration and miniaturization are enabling a new generation of measurement devices that deliver traceable measurements through commercial, deployable quantum-based sensors and standards. These broadly enabling technologies not only truncate or even eliminate the calibration chain, they challenge us to rethink our traditional notions of traceability and measurement assurance. What role does an NMI play in ensuring traceability if it's delivered by a third-party product? What does it mean for NMIs to trust each other's measurements – if those measurements happen in the field? These and other questions will be explored in this talk.

**Title:** Traceability in data spaces - from individual measurements to a digital product passport

**Speaker:** Sascha Eichstädt (PTB)

**Abstract:** Data spaces are digital realms of data and information shared between stakeholders and peer groups. They underpin several developments in sectors ranging from automotive industry, social sciences to governmental networks. Digital traceability of information in data spaces is needed to validate statements about metadata and data quality and features. In many cases this also directly translates to metrological traceability of measurements to the SI. The concept and development of digital product passports bring these traceability aspects together to form a tool for a digital quality infrastructure.

**Title:** Metrology for virtual measuring instruments

**Speaker:** Sonja Schmelter (PTB)

**Abstract:** In the course of digitalization, the importance of modelling and simulating real-world processes in a computer is rapidly increasing. Simulations are now in everyday use in many areas. For example, simulations are used to gain a better understanding of the real experiment, to plan new experiments or to analyse existing experiments. Simulations are now also increasingly being used as an essential component of a real measurement, usually as part of an inverse problem. When such simulations are used to imitate real measuring equipment and measurements, this can be described as a "virtual measuring device" or "virtual measurement". However, to ensure confidence in the results of such a virtual measurement, traceability and methods for evaluating uncertainty are needed. In this talk, we will discuss how to ensure reliability and trustworthiness of virtual experiments and digital twins to make them fit, e.g. as substitutes or extensions, to certified measuring devices.

**Title:** Reliable Methods for Real-World Sensor Networks

**Speaker:** Shahin Tabandeh (VTT)

**Abstract:** This research aims to develop reliable methods for assessing data quality and measurement uncertainty in diverse real-world sensor networks. The proposed methods will address uncertainty propagation, correlation treatment, and uncertainty-aware sensor fusion, ensuring comprehensive data quality metrics that include various influencing factors. The study will also explore uncertainty-aware intelligent alerting systems in sensor networks and discuss the automation of these methods for large-scale networks.

## Session 1

**Chair:** Alistair Forbes (NPL)

Alistair is a Fellow in the Data Science Department at the National Physical Laboratory, UK, and Visiting Professor in the Computing and Engineering Faculty, University of Huddersfield, UK, and in the Mathematics and the Computing and Information Science Departments, University of Strathclyde, UK. His research interests are in mathematical and statistical modelling, numerical analysis and scientific software engineering applied to metrology. Recently he has been involved in aspects of digitalisation in metrology, such as scientific computation with dimensioned variables, and was a member of the Expert Group advising the CIPM Task Group on the Digital SI. He is the chairman of IMEKO TC21: Mathematical Tools in Metrology.

## Presenters



**Charles Ehrlich** is Program Leader, International Legal Metrology Program, Office of Weights and Measures, Physical Measurement Laboratory, National Institute of Standards and Technology (NIST). He has been U.S. Representative (CIML Member) to the International Organization of Legal Metrology (OIML) for 25 years, first Vice President of the CIML for 6 years; Chairman, Joint Committee for Guides in Metrology (JCGM) Working Group 2 (VIM Committee), Member of JCGM Working Group 1 (GUM Committee) Active historically in the National Conference of Standards Laboratories International (NCSLI) in multiple areas, including metrological traceability and intrinsic standards.



**Blair Hall** is a Distinguished Scientist at the Measurement Standards Laboratory of New Zealand (MSL). Blair chairs the Asia-Pacific Metrology Programme's focus group on digital transformation (DXFG). He is a member of the NCSLI Measurement Information Infrastructure committee, the IMEKO Technical Committees on Digitalization (TC6), and Mathematical Tools for Measurement (TC21), and he currently represents MSL at the CIPM Forum for Digitalisation and Metrology.



**Ryan White** is a research officer and lead for Digital Metrology at the National Research Council Canada (NRC). He serves as the NRC delegate at the CIPM Forum on Metrology and Digitalization and chairs the forum's working group on Metrology Semantics. He is also a member of NCSLI Committee 141 on Measurement Information Infrastructure and Automation.



**Marko Zeier** is Head of the RF & MW laboratory at METAS, the Federal Institute of Metrology, Switzerland. Marko is a member of the VDI/VDE GMA-FA 1.20 and the European Metrology Network MATHMET. His laboratory is known for state-of-the-art realization and dissemination of SI traceability of high frequency impedance (S-parameters) in which VNA Tools plays a crucial role.

## Session 2

**Chair:** James Fedchak (NIST)

James is the Associate Director for Measurement Services in NIST's Physical Measurement Laboratory, where he represents NIST's calibration services and has pursued an effort to both modernize and digitally transform NIST's calibration services. He is a member of the IMEKO Technical Committee on Digitalization (TC6) and Traceability in Metrology (TC8) and represents NIST on the Inter-American Metrology System (SIM) Technical Committee Working Group Metrology for Digital Transformation – M4DT (MWG14). He was one of the NIST representatives at the Forum on Metrology and Digitalization (FORUM-MD; March 2024).

### Presenters



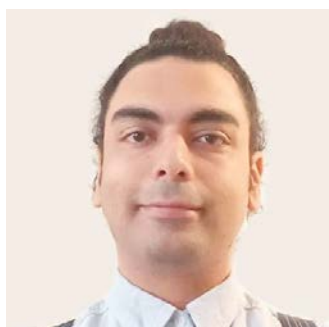
**Barbara Goldstein** serves as Associate Director of the NIST Physical Measurement Laboratory. She leads the “NIST on a Chip” program which is developing a suite of quantum sensors and standards to deliver traceable, embeddable measurements directly to point-of-use. She is a leader in international quantum standardization, convening and leading multiple efforts including IEC Standards Evaluation Group on Quantum Technologies (SEG 14) Working Group 2 (Research); IMEKO TC25 - Quantum Measurement and Quantum Information; and a new international collaboration referred to as “NMI-Q” to foster collaboration among the world’s metrology institutes to advance the quantum economy.



**Sascha Eichstädt** is Head of the “Metrology for digital transformation” department at the Physikalisch-Technische Bundesanstalt (PTB). He was earlier the working group leader of “Coordination Digitalization” in the Presidential Staff of PTB, and chaired the EURAMET working group “Metrology for digital transformation” from 2020-2022. Sascha currently chairs the OIML Digitalisation Task Group and the IMEKO Technical Committee TC6 on Digitalisation.



**Sonja Schmelter** is head of the working group “Modelling and Simulation” at PTB. She is also on the “Metrology for virtual measuring instruments” (VirtMet) steering committee of the PTB Competence Center and is the coordinator of “Trustworthy virtual experiments and digital twins” (ViDiT), a project funded by the European Partnership on Metrology.



**Shahin Tabandeh** coordinates the EPM 22DIT02 FunSNM project on sensor network metrology at VTT MIKES. He is a member of the BIPM Consultative Committee for Thermometry (CCT) and its Working Groups for Environment (CCT-WG-Env) and Humidity (CCT-WG-Hu), and the Digitalization Task Group (CCT-TG-Dig). Additionally, he serves as the EURAMET TC-T contact person and is an active member of the TC-T strategy working group, TC-T Humidity sub-committee, and TC-T Digitalization Task Group.

## **IMEKO 2024 World Congress, Video Dial-In data**

Join Webex meeting on Wednesday 28 August between 8 AM and 12 Noon (0600 UTC to 1000 UTC)

- Join by meeting number

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