



Physikalisch-Technische Bundesanstalt
National Metrology Institute

Into the Future
with Metrology

The Challenges of Digital Transformation



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connected – flexible – efficient – intelligent – transparent – disruptive

We are in the middle of a digital revolution. In households, trade and industry, new opportunities are being created everywhere by digital data traffic. The “Internet of Things” is driving this development at breakneck speed: machines exchange information directly with each other via digital interfaces. Entire production processes are already fully networked or have digital twins in a cloud. The catchphrase is “Industry 4.0”. Measuring devices are also in part inseparably linked with digital technology and automated data processing.

This transformation is a major challenge to the sophisticated system of quality infrastructure, consisting of metrology, accreditation, conformity assessment, norms & standards and market surveillance. In order to be able to continue to guarantee the safety of (and confidence in) measured values, PTB has compiled all the necessary tools under the umbrella of a comprehensive digitalization strategy – from digital calibration certificates and virtual measuring instruments to intelligent research data management and digitally supported testing and approval processes. Thus, the German economy’s commitment to providing quality shall continue to apply in a digitalized world.

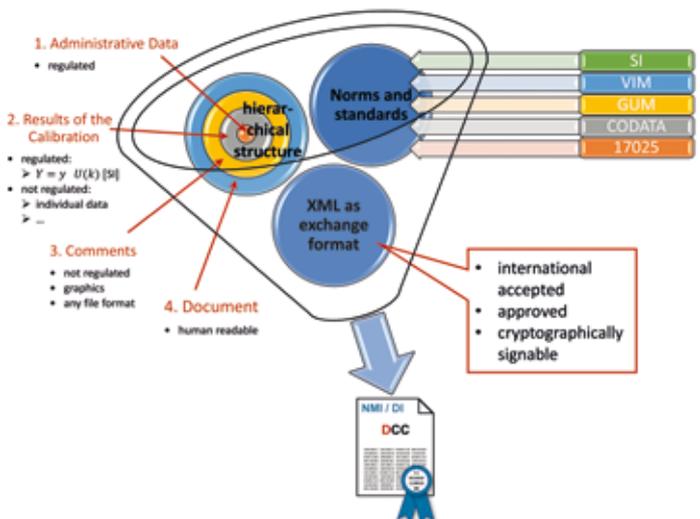
Core Objective 1: Also in a digitalized world will PTB be committed to ensuring uniformity in metrology

The quality infrastructure (QI) in Germany is an essential guarantor of economic success. QI is based on the interaction of metrology, standardization, accreditation, conformity assessment and market surveillance. PTB plays a very important role in this. One of its core legal tasks is to ensure the uniformity of metrology according to the Units and Time Act. PTB is thus a guarantor for ensuring measurement trueness, measurement stability and testability and strongly supports international harmonization in these areas. In order to be able to achieve these goals now also in a digitalized world, PTB is developing applications such as digital calibration certificates, is researching the comparability of real and virtual measurements in the “Metrology for Virtual Measuring Instruments” (VirtMet) Competence Center and is working on objective evaluation methods for machine learning and artificial intelligence.

Digital calibration certificates

In industrial metrology, PTB supports the calibration sector with the appropriate infrastructure in developing machine-readable digital certificates for the mutual recognition of their validity. An example of this is the digital calibration certificate which contains the calibration information in a structure that is comprehensible for computers and can be secured with a digital seal. By doing so, this information can be read out directly from digital systems and can automatically be used further on. In addition to using this procedure for digital calibration certificates, it can also be used for any other metrological documents, such as machine-readable certificates of conformity

or digital test reports. Via suitable software interfaces, the information contained in these documents can be used worldwide.



Basic approach for a digital calibration certificate

The “Metrology for Virtual Measuring Instruments” Competence Center

Within the scope of digitalization, the importance of mathematical and physical simulations and computer-based experiments is increasing rapidly. If such simulations are used to imitate real measuring devices and measurements, these can be designated as a “virtual measuring instrument”. Here, the task of metrology is to ensure confidence in simulation results if these are to be used in the same way as real measurements. For this reason, PTB has established the “Metrology for Virtual Measuring Instruments” (VirtMet) Competence Center. Here, it carries out interdisciplinary research and pools expertise in order to develop concrete virtual measurement procedures and

to work on overarching questions, for example: How can the comparability of virtual and real measurements be established? Which standards are needed for interfaces, metadata and data formats? And how can virtual experiments for complex measurement systems be handled with machine learning methods?

Machine learning and artificial intelligence

Digital change continuously allows new products and processes to emerge that push proven quality-assurance measures to their limits. This is particularly evident in the case of complex products which dynamically change their state after they have been placed on the market. To be reliable, a product would need to be tested several times during its life cycle, sometimes continuously. As of today, there are still no practicable solutions for this.

An example of this is applications of machine learning (as a type of artificial intelligence – AI) in medical devices. Although numerous innovative medical products are currently being developed with a high share of software, only a fraction of them make the leap into the healthcare market. A major reason for this is the lack of structured processes as well as the lack of a quality infrastructure for an objective, verifiable and reproducible validation of AI technologies.

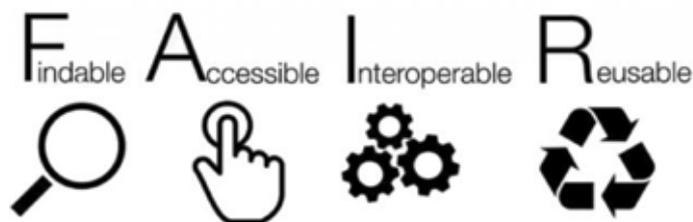
For the use of machine learning, PTB is working on defining objective evaluation methods to assess the quality of algorithms; together with medical experts, PTB is developing procedures for the provision of reference data; and it collaborates on norms and standards for quantifiable and verifiable data quality criteria.

For example, researchers at PTB are training an artificial neural network in such a way that it is able to assess the quality of individual mammography images. A virtual mammography developed by PTB which has led to a huge database of images, each with precisely known characteristics, is particularly helpful. In this context, PTB is also involved in the development and establishment of a digital quality platform with which AI-based solutions can be validated. This platform is to provide comprehensible criteria for the determination of data quality and to ensure that the evaluation by a computer is objective and cannot be manipulated.

Core Objective 2: PTB participates in the sustainable usability of research results and data

Data-driven research and business can only be implemented if reliable data are accessible and sustainably usable. Accordingly, research funding institutions increasingly demand that research results are properly documented, archived for the long term and, if possible, made publicly available free of charge. These requirements for data management are summarized by

the acronym “FAIR Data”: Data should be findable, accessible, interoperable and reusable.



Basic elements of research data management

Research data management

One objective of PTB is to establish data-based research and development with assured quality and reproducibility. For this reason, PTB is engaged, among other things, in a comprehensive concept for research data management. Within the framework of individual consultations, researchers at PTB receive, upon request, information on all tasks connected with research data management: creation of data management plans, documentation of the work steps, storage and publication of data, selection of file formats and metadata formats.

National research data infrastructure

In order to promote the sustainable usability of research results not only within its own institution but also between research partners and industry, PTB is strongly involved in the “National Research Data Infrastructure” (NFDI) project. The focus is on quality, reliability and unambiguous machine interpretability of all research results, including consideration of numerical data with units of measurement and uncertainties.

Core Objective 3: PTB develops holistic concepts for the handling of measuring instruments and measurement data

New measurement instruments often contain distributed, partially virtualized components and use services from the cloud. However, in regulated areas, the hurdles in terms of approval and conformity assessment are high when measuring devices contain such modern communication and information technologies. Manufacturers increasingly see this as an obstacle to innovation and fear long-term competitive disadvantages. Therefore, in a digitally networked economy and industry, holistic concepts for the handling of measurement data and digitally linking measuring instruments are necessary. This also considers the fact that these concepts must meet the requirements of legal and industrial metrology. Up to now, these two areas have been largely separated in their metrological treatment, as they are subject to different legal and organizational framework conditions. In the course of the digital transformation, however, these strict categories are becoming increasingly blurred.

PTB can provide support here by developing legally compliant reference architectures. The focus is on digital interfaces and interoperability across application areas. In particular, architectures for the legally compliant separation of the measuring instrument software into a legally relevant and a free part enable manufacturers to develop innovative products, regular software updates and individual adaptations for customers without having to go through the approval process again.

The “Metrology Cloud”

PTB has initiated a pilot project to build up a comprehensive digital infrastructure which is to merge pre-existing but not yet connected architectures and databases: the “Metrology Cloud”. By means of this digital quality infrastructure, PTB aims to successfully upgrade legal metrology digitally: The Metrology Cloud is intended to enable the coupling of pre-existing data infrastructures and to provide differentiated and secure access for all interested parties (conformity assessment bodies, market surveillance, manufacturers and users in legal metrology). It thus provides the basis for new concepts for the coordination, concentration, simplification, harmonization and quality assurance of metrological services. The aim is to start with a reliable core of this digital infrastructure at PTB and to gradually expand the “Metrology Cloud” to a “European Metrology Cloud”.

The use of a “Metrology Cloud” as a central access point to the data is a prerequisite for the efficient use of modern big-data analysis methods, such as those already used outside the legally regulated area of metrology. For example, the concepts developed there for predictive maintenance are based on the fact that continuously available data makes it possible to make predictions on future developments. The aim is to proactively maintain machines and systems and to predict malfunctions

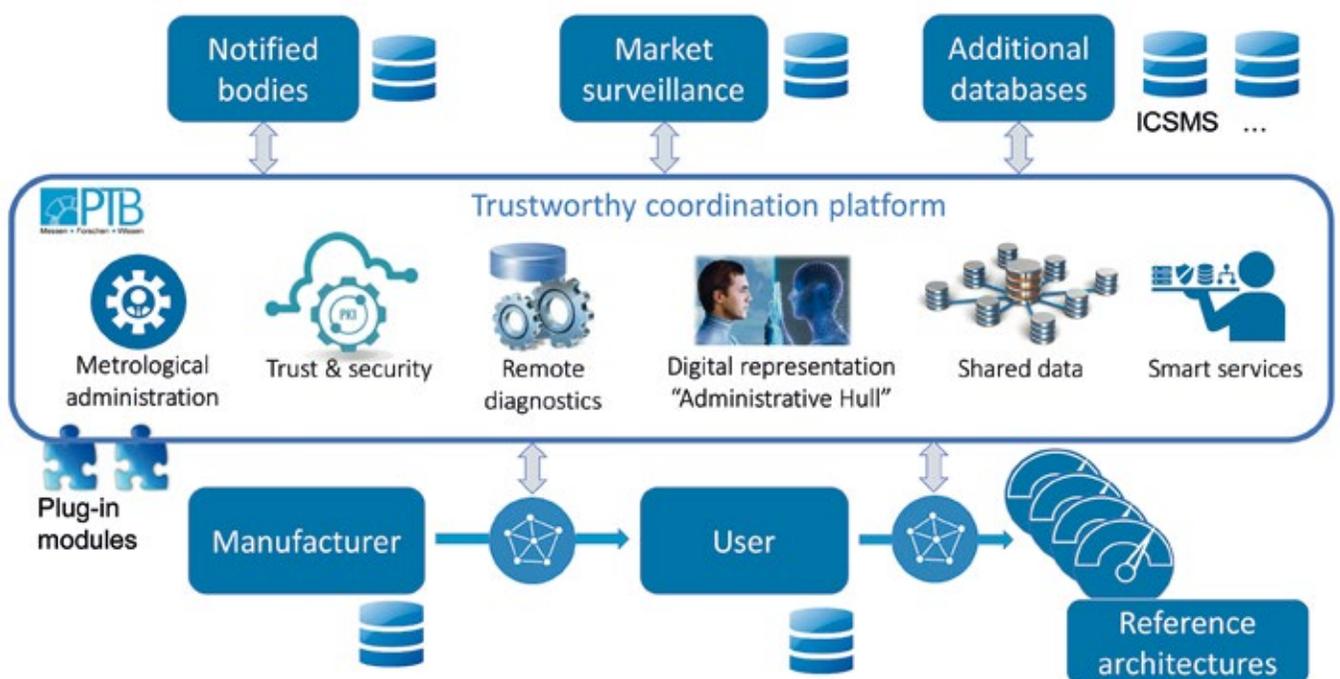
before they have an impact or break down. In principle, this concept could also be used to make the measurement, calibration and verification system more efficient.

Communication of metrological data on the “Internet of Things”

The Internet of Things involves the digital communication of data and of the algorithms that are based on it. The same principle is used in Industry 4.0 for networked production. For this purpose, measured data from sensors are used in many places as a bridge between the real world and the virtual world. When developing the digital Calibration Certificate (DCC), PTB is therefore also paying special attention to its applicability in Industry 4.0 and in similar contexts. In addition, PTB, together with a European consortium, is developing data models and recommendations to transfer metrological data on the Internet of Things. This includes, in particular, the development of a “D-SI” data model for SI-based, machine-interpretable communication of measurement data and measuring instrument data. PTB’s goal is to establish the SI as a link between different systems in such a way that the units are always automatically converted to the SI base units for the machine.

„Metrology by design”

A suitable data model for the communication of measurement data, a connection to the “Metrology Cloud” as well as the efficient use of digital information about the measuring device should ideally already be considered during the development; in other words: “Metrology by design”. PTB intends to establish this approach by involving measuring instrument manufacturers and users at an early stage.



Basic building blocks of the “Metrology Cloud” as a decentralized platform for digitalization processes in legal metrology

Safe data “Made in Germany”

The topic of “data as an economic good” is of great importance to industrial companies in the value-added chain and will become even more important in the future as a result of the advancing digital transformation. The quality of the data obtained, including from sensors and actuators, and the reliability of the statements and conclusions derived from it are of central importance, especially for industry. The reliable determination and assurance of data quality is thus the prerequisite for the successful use of data as an economic good.

For this reason, PTB is working in the BMWi lighthouse project GEMIMEG-II with a national consortium from industry and research with the aim of developing a secure, consistent, legally compliant and legally compatible end-to-end availability of information for the implementation of reliable, networked measurement systems.



Core Objective 4: PTB supports the efficient and safe use of digital technologies

PTB develops and uses digital technologies both for its own workflows and for quality infrastructure processes. In doing so, it considers the concepts of “security and privacy by design” to be indispensable for securing trust. This means that in the development of hardware and software, data protection is taken into account from the very beginning on the one hand, and on the other hand attention is paid to reducing weak points and sensitivity to attacks as much as possible. The individual components of this digital transformation are intended to be combined in such a way in the medium term that they result in a uniform overall picture. One of these components is an electronic file, or “e-file” for short (German: *E-Akte*), a central electronic document management system in which all PTB documents are conveniently stored and retrieved and which supports spatially flexible, joint work. Before using e-files throughout PTB, some departments tested it in practice in a pilot phase to check the system thoroughly and optimize it for PTB purposes. The challenges in introducing e-files at PTB are that, among other things,

- large amounts of data are stored in non-office formats;
- sensitive manufacturer data must be protected against unauthorized access;
- within the scope of research collaborations, partners must be granted access to joint documents.

Another digital building block is the customer portal called “e-services” (official German name: *E-Services*). This portal is intended to provide efficient and secure orientation to customers of PTB. With this service, web-based processing of ordering data – which is closely linked to PTB’s e-file system – is to be set up. The customer portal will be the central digital contact point for customers from the field of conformity assessment and calibrations and will ensure the easy upload of information and the management of orders. Upon completion, this will also include the provision of digital certificates with security features, as already described in the example of the digital calibration certificate under Core Objective 1. The pilot phase is expected to start at the beginning of 2021.

Core Objective 5: PTB promotes the active participation of all employees in digitalization

A digital transformation can only succeed if no one is left behind and if digital innovation is stimulated. For this purpose, PTB is developing, among other things, formats for the active support of digital pioneers within its own ranks and offers a wide range of training and learning opportunities for all employees. These include, for example:

- a variety of seminars, training courses and learning opportunities;
- promotion of opportunities to participate and become involved;
- regular “Digital Workplace” theme days as a forum for information and exchange.

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The texts of these Info Sheet and further information can be found in the internet: www.ptb.de > Research & Development > Into the Future with Metrology > The Challenges of Digital Transformation



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