Newsletter

December 2025

ViDiT (Trustworthy virtual experiments and digital twins) is a European research project within the European Partnership on Metrology programme co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States. The project has 22 participants consisting of eight National Metrology Institutes, two research centres close to industry, five universities and six companies. The project is coordinated by Physikalisch-Technische Bundesanstalt (PTB).

Why ViDiT?

Virtual experiments and digital twins are key enabling technologies to achieve and realise European strategic policies devoted to sustainability and digitalisation within the complex framework of Industry 4.0 and the European Green Deal. Virtual experiments and digital twins are both simulation models that accurately replicate physical systems and characteristics in a virtual environment. Digital twins further include dynamic updates of the virtual model according to the observed state of its real counterpart. Hence, they consist of two parts, a Physical to Virtual connection that models the considered system and a Virtual to Physical connection that implements prevention and control strategies to achieve the target accuracy in the physical system.

The use of virtual experiments and digital twins in metrological applications requires uncertainty evaluation methods, as well as reliable validation procedures, to make them fit for purpose, e.g. as substitutes or extensions, to certified measurement devices. This project will develop these methods and procedures to ensure the reliability and trustworthiness of virtual experiments and digital twins in metrology. In addition, this will enable the traceability of modern measurement systems and it will boost and strengthen the European lead in this field. To facilitate the uptake of the developed methods by National Metrology Institutes and industrial stakeholders, three good practice guides will be written, and the applicability of the methods will be demonstrated in twelve case studies covering a variety of industrial metrology applications.

Good Practice Guides Spotlight

The ViDiT project has already produced a few Good Practice Guides (GPGs) and a user guide to disseminate the results of the project. Here are highlight excerpts from this material.

GPG D1 – Uncertainty Evaluation for Virtual Experiments (VEs)

The GPG provides practical guidance on uncertainty evaluation when combining real measurements with VEs. A VE is a digital model that replicate measurement processes.

Case Study: Coordinate Measuring Machines (CMMs)

This case study highlights the importance of selecting the right uncertainty evaluation method when using VEs for coordinate metrology. While simple measurands like radius are robust across methods, complex features such as roundness require advanced approaches to ensure accurate and reliable uncertainty estimates.

Key Highlights:

- **Simple measurands, simple methods:** For smooth measurands like circle radius, uncertainty evaluation is largely insensitive to the chosen method, and basic approaches work well.
- **Input data matters:** Use actual measured coordinates rather than nominal ones in virtual CMMs (vCMMs); small differences in input can significantly affect uncertainty results for some measurands.
- **Bias correction is essential:** Identify and correct biases in data analysis or adjust uncertainty estimates accordingly to maintain reliable coverage rates in the case of highly non-linear measurands.

The GPG will be made available after 30.4.2026 on the project website.

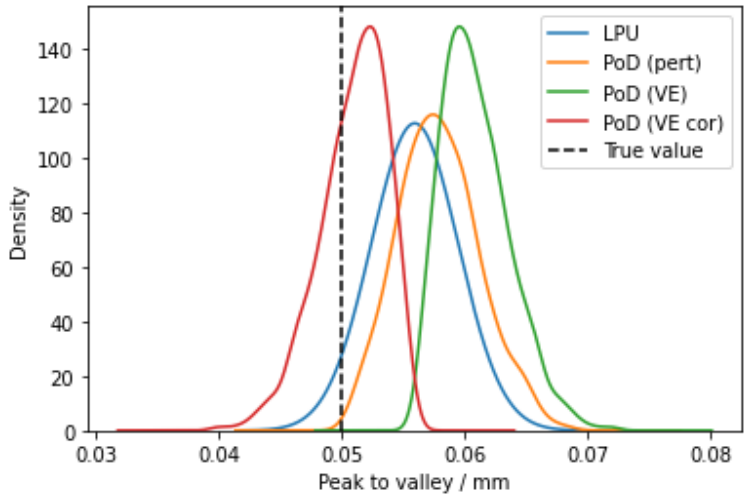

Figure 1: Figure showing that four different procedures of evaluating the measurement uncertainty using a vCMM can result in considerable different distributions characterizing the uncertainty. Please refer to the GPG and associated publications for an explanation of the procedures. The simulated ground true value is also shown.

GPG D2 – Uncertainty Evaluation for Digital Twins (DTs)

The GPG focuses on uncertainty evaluation for DTs in advanced measurement applications. The guide compares different evaluation methods, offers practical implementation advice, and supports informed decision-making for future developments.

Case Study: 3D Robotic Measurements

This part of the guide focuses on assessing measurement uncertainty in robotic metrology systems. Using a DT approach; uncertainty sources robot kinematics, sensor precision, and sensor-to-robot referencing are modelled and propagated via **Monte Carlo simulation** in compliance with JCGM 101:2008.

Key steps include:

- **Sensor Characterization**: Automated evaluation using calibrated gauge blocks to capture systematic errors and precision across the full range.
- **Robot & Sensor Calibration**: Kinematic and extrinsic calibration using a traceable 4-ball artefact for robust uncertainty modelling.
- **Digital Twin Integration**: Real-time uncertainty propagation embedded in the measurement workflow, enabling traceable, context-specific uncertainty for each point in the 3D scan.

Why it matters: This methodology ensures reliable dimensional inspection in industrial environments, supporting automation and compliance with international standards.

The full GPG will be made available at the project website once finalised.

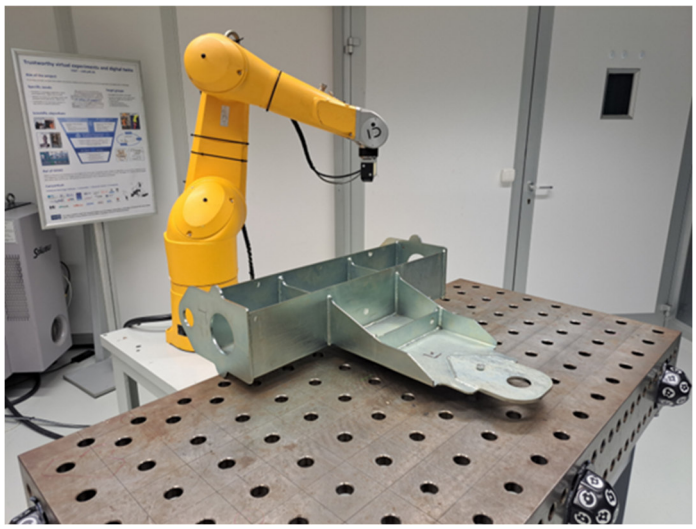

Figure 2: 3D robotic measurement system.

User guide D4 – User's Guide for the Software Repository

This is a user guide to assist in utilizing software tools created for VEs and DTs created by the ViDiT project.

Topic: Uncertainty Evaluation for Optical Machine-Vision Measurement

This Python-based tool provides a configurable DT demonstrator for optical vision systems. Users can simulate inspection scenarios, adjust robot, calibration, and sensor parameters, and compute combined uncertainty.

Highlights:

- **Interactive GUI** for parameter selection and uncertainty calculation.
- **Well-documented examples and templates** (Python notebooks) for easy adaptation.
- **Traceable approach** to evaluate how system variables influence measurement reliability.

At the end of the project, the full open source software repository will be made available at PTB's Gitlab server https://gitlab1.ptb.de/vidit-group/vidit and can be downloaded as a whole, including all required datasets, from the following Zenodo community: https://zenodo.org/communities/vidit/

Publications and Conference Presentations

The following peer-reviewed papers have been published during the last five months of the project:

- Kok, Gertjan & Dijk, Marcel (VSL). (2025). "*Measurement Uncertainty Evaluation: Differences Between Virtual Experiments and the Standardized Approach"*, Metrology, DOI: 10.3390/metrology5040059
- Giacomo Maculotti, Lorenzo Giorio, Gianfranco Genta, Maurizio Galetto (POLITO). (2025). "*Digital Metrology for Nanoindentation: Synthetic Data Generator for Error Identification"*, Micromachines, DOI: 10.3390/mi16121394

Furthermore, results from the ViDiT project have been presented at several conferences and seminars this year, including:

- Finn Hughes (PTB): "*Bayesian estimation for virtual experiments in metrology featuring semi-parametric modelling using Gaussian processes*", MATHMET 2025 Conference
- Sonja Schmelter (PTB): "*Virtual experiments and digital twins in metrology – challenges and first results of the ViDiT project*", MATHMET 2025 Conference
- Nursen Bayazit (PTB): "*Surrogate Modeling for Flow Field Reconstruction in Pipe Systems Using Computational Fluid Dynamic Simulation and Measurement Data*", MATHMET 2025 Conference
- Marcel van Dijk, Walter Knulst, Devrim Nalbantoglu, Gertjan Kok (VSL): *"Metrological Validation of a Digital Model for a CMM including Digital Bias Correction",* IMEKO TC-6 International Conference on Metrology and Digital Transformation – M4DConf 2025 Benevento, Italy, September 3-5, 2025
- Manuel Stavridis (PTB): "*Uncertainty evaluation using virtual experiments with the example of the tilted-wave interferometer"*, VirtMet2025 Workshop, online, Dec. 2025
- Gertjan Kok and Marcel van Dijk (VSL): "*A closer look on uncertainty evaluations using Virtual Experiments and VCMMs"*, VirtMet2025 Workshop, online, Dec. 2025

- Matias Alberto Aguirre (INTI): "*Development of a Digital Counterpart for the Internal Arc Testing*", VirtMet2025 Workshop, online, Dec. 2025
- Guillermo Schneider (INTI): "*Automated Anomaly Detection in Quantum Voltage Standards Using Feature-Based Time Series Classification*", VirtMet2025 Workshop, online, Dec. 2025
- Brahim Ahmed Chekh Oumar (TEKNIKER): "*Digital twin of robotic 3D scanning system: providing metrological traceability*", VirtMet2025 Workshop, online, Dec. 2025

Previous publications and conference presentations of the ViDiT project ich can be found at the project website.

Webinars Based on Work in the ViDiT Project

Results of the ViDiT project have been disseminated in two webinars:

- "Zastosowanie modeli Digital Twin w metrologii współrzędnościowej do oceny niepewności pomiaru, automatycznego wyboru najlepszej strategii pomiarowej i określenia optymalnych parametrów pomiarowych", https://lmw.admin.pk.edu.pl/2025/08/21/digital-twin/, 25.09.2025
- "*Digital Metrological Twins for 3D Robotic Measurement. A use case from the VIDIT Project.*", https://events.teams.microsoft.com/event/dffe7818-2204-4bbb-a3ca-dce148516af4@62f653bf-9c21-465b-bdbf-1b18ba164624, 18.11.2025

Our objectives

The overall objective of this project is to develop methods and tools that will ensure the reliability and trustworthiness of virtual experiments and digital twins in metrology in order to support digital transformation within Industry 4.0 and the European Green Deal.

The specific objectives of the project are:

1. To develop methods for evaluating the uncertainty associated with real measurements for three different applications by using the results from corresponding virtual experiments in line with the current state-of-the-art for uncertainty evaluation.
2. To develop methods for uncertainty quantification for digital twins representing complex measurement processes and mechanisms for four different applications, in each case including the effect of dynamic influences on the digital model such as thermal drift or vibrations.
3. To develop approaches for the validation of virtual experiments and digital twins for all applications of objectives 1 and 2, using statistical procedures for the assessment of differences between calibrated standards and corresponding data from their virtual counterpart.
4. To demonstrate the practical applicability of the developed methods, using twelve different case studies covering all the metrological applications of objectives 1 and 2.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations and end users.

Some facts:

Project start date and duration:	May 2023, 36 months	
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Project website: https://www.vidit.ptb.de/home		
Internal Funded Partners: 1. PTB, Germany 2. FFII, Spain 3. GUM, Poland 4. LNE, France 5. VSL, Netherlands 6. VTT, Finland	External Funded Partners: 1. ENS Paris-Saclay, France 2. IDEKO, Spain 3. INTI, Argentina 4. PK, Poland 5. POLITO, Italy 6. TEKNIKER, Spain 7. UNIPD, Italy 8. UPM, Spain 9. USPN, France	Unfunded Partners: 1. DUI, Netherlands 2. EMERSON | FLEXIM, Germany 3. GEOMNIA, France 4. KROHNE, Germany 5. Mahr, Germany 6. Endress+Hauser SICK, Germany 7. TUBITAK, Türkiye

Participants:

Funding:

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