Newsletter

July 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, six 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.

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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.

Highlights/Progress

On 25 & 26th of June 2025, the ViDiT project had a progress meeting at VSL in Delft (Figures 1-2).

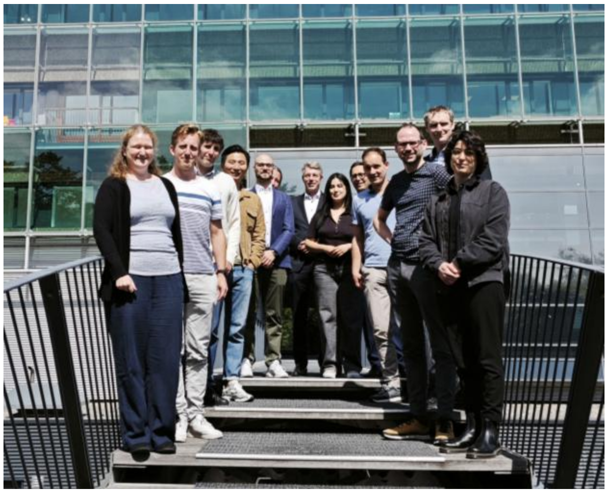

Figure 1: The ViDiT progress meeting was held at VSL in Delft.

VSL is the national metrology institute of the Netherlands which employs approximately 100 people. In the role of national metrology institute, VSL manages and develops the national primary measurement standards for the Netherlands, providing traceability to measurement results of companies, laboratories and other institutions. Additionally, VSL is very active in scientific research to make sure that its measurement standards are up-to-date with the latest scientific developments.

The consortium discussed the work done during the first 27 months of the project and planned for its continuation until the end of the project in approximately nine months. There were 17 persons attending the meeting on-site and 17 persons attending the meeting online.

Figure 2: Project partners at meeting and laboratory tour at VSL.

Highlights from the project meeting

LNE's reference rotary table

As part of the national effort to strengthen angular metrology capabilities, the French Bureau National de Métrologie (BNM) and the Laboratoire National d'Essais (LNE) launched the development of a high-precision rotary table intended to serve as the national angular reference standard (Figure 3).

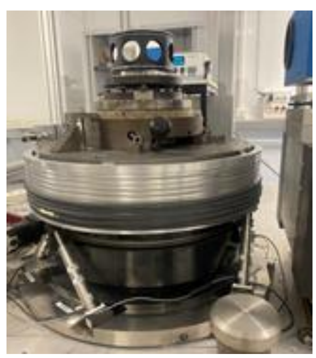

Figure 3: The reference rotary table from LNE.

The system targets an expanded uncertainty of less than ±0.1 arcseconds. The system addresses two main objectives: a) Provide a continuous angular reference for calibrating angle standards such as polygons and optical encoders, with reinforced traceability to the SI unit of angle. b) Achieve a controlled and highly accurate rotational motion, enabling the precise evaluation of angular measurement instruments and serving as a calibration basis for industrial applications. In the ViDiT project, LNE, ENS and USPN collaborated to develop the digital twin modelling of the rotary table and explore the data driven error source identification to further enhance the accuracy and uncertainty level of the rotary table.

Digital twin modelling of the rotary table

Despite the high accuracy of the reference rotary table, its performance can still be optimized through traceable and real-time correction of angular position measurements using multisensor data, while accounting for geometrical errors and thermal influences within a dynamic uncertainty evaluation framework. The digital twin model of the rotary table is shown in Figure 4, where the key issue is tackeled through virtual angle measurement, uncertainty assessment and system control.

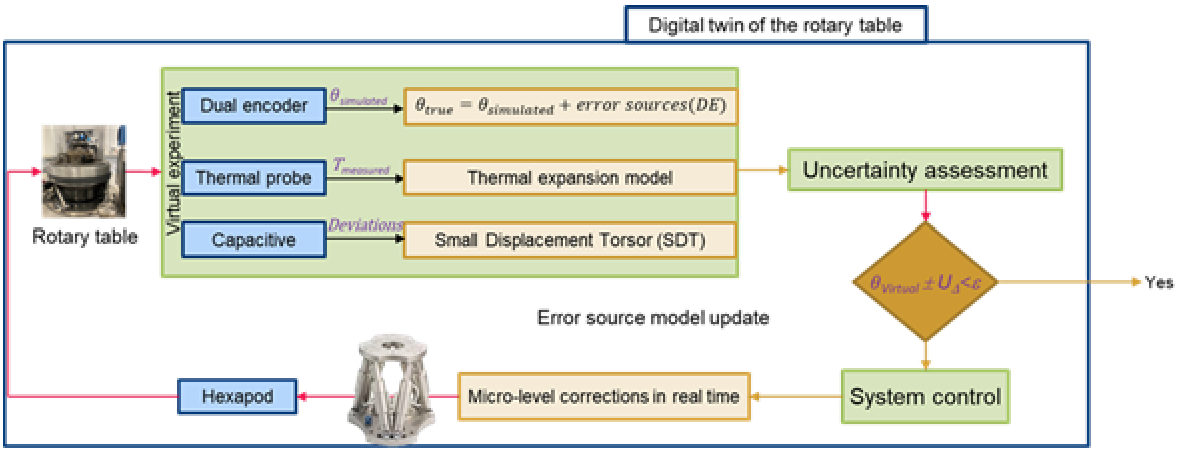

Figure 4: The digital twin model of the rotary table.

Data-driven error source identification for the rotary table

The virtual entity of the rotary table's digital twin enables the generation of sufficient virtual measurement data. In the next step, USPN will develop a machine learning model to directly predict error source parameters from angular measurement data. As shown in Figure 5 the model can either identify abnormal error sources or accurately estimate specific error parameters, thereby supporting the re-calibration of the digital twin model.

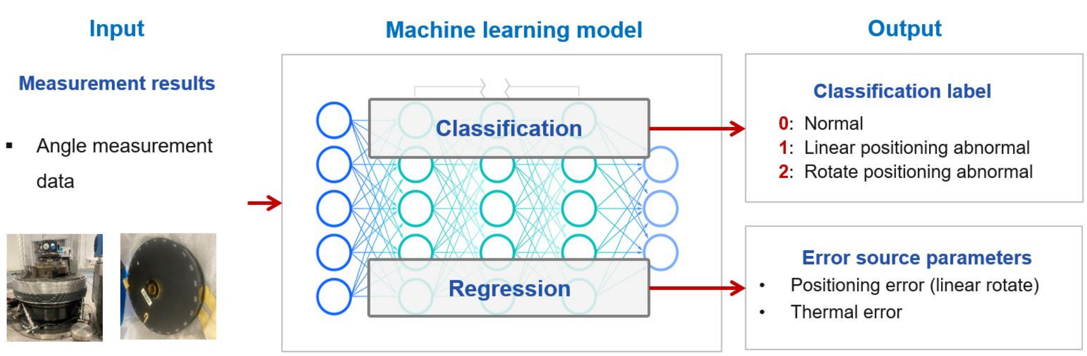

Figure 5: Machine learning based error source identification for the rotary table.

Publications and conference presentations

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

- van Dijk, M., & Kok, G. (2025). Comparison of uncertainty evaluation methods for virtual experiments with an application to a virtual CMM. Measurement: Sensors, 38. https://doi.org/10.1016/j.measen.2024.101785

- Hughes, F., Marschall, M., Wübbeler, G., Kok, G., van Dijk, M., & Elster, C. (2025). JCGM 101-compliant uncertainty evaluation using virtual experiments. Measurement: Sensors, 38, 1–5. https://doi.org/10.1016/j.measen.2024.101731

- Hughes, F., Marschall, M., Stavridis, M., & Elster, C. (2025). Using Virtual Experiments to improve Data Analysis. Measurement Science and Technology, 36, 4. https://doi.org/10.1088/1361-6501/adbeec

- Bayazit, N., Marschall, M., Straka, M., Schmelter, S. (2025). A novel framework for the uncertainty evaluation of virtual flow meters. Measurement Science and Technology, 36, 7. https://doi.org/10.1088/1361-6501/adea0e

- Bennoune, R., Chen, G., Toguem Tagne, S.-C., Vissiere, A., Damak, M., Mehdi-Souzani, C., Anwer, N., Mayer, R., Nouira, H. (2025). Advanced ultra-high precision system (NanoCyl) for accurate cylindricity measurements. CIRP Journal of Manufacturing Science and Technology, 59, 118-126. https://doi.org/10.1016/j.cirpj.2025.03.005.

- Aguirre, M. A., Bierzychudek, M. E., Coppa, D. N., Laiz, H. M. (2025). Virtual experiment of temperature rise test in high-voltage switchgear. Measurement: Sensors, 38, 101494. https://doi.org/10.1016/j.measen.2024.101494

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

- Fortmeier, I., Scholz, G., Stavridis, M., Marschall, M. (2025). Current activities towards traceable form measurements of aspheres with a tilted-wave interferometer. 126. Jahrestagung der Deutschen Gesellschaft für angewandte Optik (DGaO).

- Stavridis, M., Marschall, M., Hughes, F., Fortmeier, I., & Elster, C. (2025). Methods of uncertainty evaluation using virtual experiments with the example of the tilted-wave interferometer. Sensor and Measurement Science International (SMSI).

- Khamlichi, A., Arcones, E., Vera, C. A., & Rovira, J. (2025). DESARROLLO DE UN GEMELO DIGITAL PARA LA ESTIMACIÓN DEL. 1–7. XX ERIAC VIGÉSIMO ENCUENTRO REGIONAL IBERO-AMERICANO DE CIGRE. Ciudad del Este, Paraguay 25 a 29 de mayo de 2025

- Bayazit, N. (2025). Uncertainty evaluation methods applied to a virtual ultrasonic flow meter. International Metrology Congress (CIM), Lyon, France.

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

Some facts:

<table>
<tr><td>Project start date and duration:</td><td colspan="2">May 2023, 36 months</td></tr>
<tr><td colspan="3">Coordinator: Sonja Schmelter, PTB Tel: +49 30 3481 7766 E-mail: vidit@ptb.de
Project website: https://www.vidit.ptb.de/home</td></tr>
<tr><td>Internal Funded Partners:
1. PTB, Germany
2. FFII, Spain
3. GUM, Poland
4. LNE, France
5. VSL, Netherlands
6. VTT, Finland</td><td>External Funded Partners:
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5. Mahr, Germany
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Participants:

Funding:

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

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