Newsletter

September 2023

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 21 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.

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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 June 1st, 2023, the ViDiT kick-off meeting took place at Politecnico di Torino in Turin, Italy (Figure 1). The consortium discussed the work planned for the next three years.


Figure 1: The ViDiT kick-off meeting at Politecnico di Torino in Turin, Italy, on June 1st, 2023.

The work packages (WPs) and selected applications of the project are shown in Figure 2. The objectives of WP1 and WP2 are to develop uncertainty evaluation methods for virtual experiments and digital twins, respectively. In WP1, these methods will be applied to the following three metrological applications: coordinate measuring machine (CMM), tilted wave interferometer (TWI), and flow meter measurement. In WP2, the following four complex measurement use cases will be considered: 3D robotic measurement, nanoindentation, NanoCyl, and electrical measurements. Since all the considered digital twins include dynamic effects, the models have to be updated according to sensor data. WP3 develops validation approaches for all seven applications mentioned above. Here, statistical procedures will be used for the assessment of differences between calibrated standards and corresponding data from their virtual counterpart. Furthermore, surrogate models will be constructed for one virtual experiment (flow measurement) and one digital twin (3D robotic measurement). The surrogate models will be validated against traceable measurement data and improved as necessary. After having developed the methods for uncertainty evaluation and validation, they will be applied to twelve industrial case studies in WP4. This will demonstrate the practical applicability and transferability of the developed methods in real industrial environments.

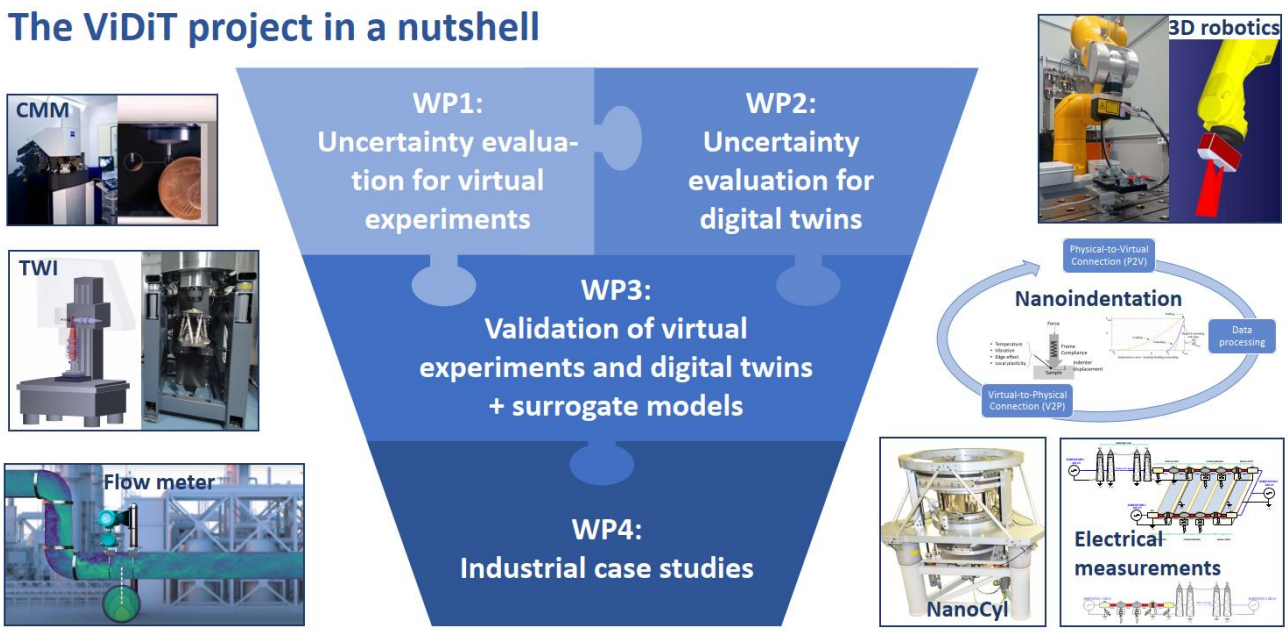


Figure 2. Illustration of the four technical work packages and the seven metrological applications of the ViDiT project.

On May 30-31, 2023, the joint workshop of ENBIS and MATHMET "Mathematical and Statistical Methods for Metrology" (http://www.msmm2023.polito.it/ ) took place in Torino, Italy. The ViDiT project has been presented with three talks and a poster:

- Gertjan Kok – VSL, NL: Challenges related with Virtual Experiments in Metrology
- Giacomo Maculotti – DIGEP, Politecnico di Torino, IT: Trustworthy virtual experiments and digital twins (ViDiT) – Uncertainty evaluation for Digital Twins
- Saint-Clair T. Toguem – LNE, FR: Monte Carlo simulations for uncertainty estimation of error separation techniques
- Sonja Schmelter – PTB, DE: ViDiT project "Trustworthy virtual experiments and digital twins"

## Impact on relevant standards

The consortium will promote the project's results and outcomes within the standardisation community, as well as providing input into the standardisation process. The project participants are involved in the JCGM WG1, which is in charge of the Guide to the expression of uncertainty in measurement (GUM) and its supplements. These documents serve as the de facto standard for evaluating uncertainty in metrology and are utilized globally at all stages of the measurement chain, from National Metrology Institutes to industry. Furthermore, the project's findings will be shared with working groups at DIN, ISO, and CEN. The relevant standards in preparation/revision will be identified for ISO, and work on these standards will be suggested to the appropriate working groups or committees. The participants will also present the project's outcomes to the International Academy for Production Engineering (CIRP), EURAMET, IMEKO and other networks, where they are active. All these activities will ensure the uptake of the project's results by the metrological community.

## Longer-term economic, social, and environmental impacts

The outcomes of this project will include the provision of methods for the GUM-compliant uncertainty evaluation of virtual experiments and digital twins, as well as procedures for their validation. Furthermore, the newly developed approaches will be applied to a variety of industrially relevant test cases. These methods, procedures and case studies will enable the industry and users of virtual experiments and digital twins to e.g., optimise meter design or to improve the efficiency of welding processes. This will provide the basis for gaining traceability in several metrological applications, where virtual experiments or digital twins are employed (e.g., asphere and freeform metrology, nanoscale mechanical characterisation, the quality control of welded parts). This will lead to a reduction in the production time as well as to parts being manufactured with better surface quality. Industrial stakeholders will be involved in defining case studies to ensure the transferability of the developed methods and procedures for uncertainty evaluation and validation in industrial setups. The good practice guides that will be written in this project will be disseminated to industrial stakeholders to further support the uptake of the developed methods in these and other fields of application. Additionally, representatives of industry (both manufacturers and users) will be invited to a workshop on uncertainty evaluation for virtual experiments and digital twins, which will be organised and held by the project participants.

The outcomes of this project will provide a common understanding among European National Metrology Institutes on how to make virtual experiments and digital twins fit for use in metrological applications. The methods for assessing the uncertainty will be summarised and published in good practice guides so that they can be easily adapted by the metrological and scientific communities. Research papers will also be published in high impact peer reviewed journals, and as part of the knowledge transfer, a workshop on uncertainty evaluation for virtual experiments and digital twins, will be organised and held, to which representatives of academia and National Metrology Institutes will be invited. Results will be disseminated to the European Metrology Networks AdvanceManu and MATHMET as well as to the International Academy for Production Engineering (CIRP), which will make them accessible to a wider audience including stakeholders from all these networks. The collaboration of European National Metrology Institutes in this project will increase their visibility and authority in drafting common regulations and guidelines.

## Stakeholder Committee

A Stakeholder Committee has been established for the ViDiT project, up to now consisting of eight members from different industrial sectors. The Stakeholder Committee will provide the consortium with information to help them steer the project and they will receive the project's results firsthand. The aim of the Stakeholder Committee is to clarify the needs of the various interested parties, to feed these into the project and to ensure that the project remains focused on practical, applicable, and essential research.

## Some facts:

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| Project start date and duration: | May 2023, 36 months | |
| Coordinator: Sonja Schmelter, PTB | Tel: +49 30 3481 7766 | E-mail: sonja.schmelter@ptb.de |
| Project website: https://www.vidit.ptb.de/home | | |
| Internal Funded Partners:<br>1. PTB, Germany<br>2. FFII, Spain<br>3. GUM, Poland<br>4. LNE, France<br>5. VSL, Netherlands<br>6. VTT, Finland | External Funded Partners:<br>1. ENS Paris-Saclay, France<br>2. IDEKO, Spain<br>3. INTI, Argentina<br>4. PK, Poland<br>5. POLITO, Italy<br>6. TEKNIKER, Spain<br>7. UNIPD, Italy<br>8. UPM, Spain | Unfunded Partners:<br>1. DUI, Netherlands<br>2. FLEXIM, Germany<br>3. GEOMNIA, France<br>4. KROHNE, Germany<br>5. Mahr, Germany<br>6. SICK, Germany<br>7. TUBITAK, Türkiye |

## 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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