European Partnership on Metrology
Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential

Selected Research Topic number: **SRT-s16**
Version: 1.0

Title: Establishing reliable and integrated gravity metrology for emerging applications

Abstract

Gravimetry is becoming increasingly vital in metrology, science, and society. The redefinition of SI units has raised the requirement for absolute gravity uncertainties in mass metrology to below 1×10^{-8}. The growing need for monitoring e.g. varying ice masses and water storage in climate change studies further underscores the importance of accurate long-term recorded gravity data. Gravity data are also crucial for geodetic infrastructure on the national and international level. Proposals addressing this topic should aim to characterise current instruments, design advanced equipment, and develop digital tools to enhance gravity determination, accuracy and reliability.

Keywords

Acceleration due to gravity, Kibble balance, kilogram, SI unit, gravimeter, geodesy, gravity network

Background to the Metrological Challenges

Gravimetry is the study of the local acceleration due to gravity, which varies both spatially and temporally. This variability necessitates individual measurements for specific locations and times. Traditionally, gravimetry has been used in geodesy to ascertain the Earth's shape. However, its applications are increasingly expanding into diverse fields such as geophysics, geology, hydrology, and climate change studies.

Presently, Kibble balances represent advancement in mass metrology by balancing mechanical and electromagnetic power to provide absolute measurements, independent of traditional mass standards and their calibration uncertainties. This capability makes Kibble balance suitable for weighing smaller masses with high precision benefiting industries such as manufacturing and pharmaceuticals. Kibble balance is encouraging the development of high-precision balances and actuators. However, achieving reliable realisation of the kilogram through Kibble balances requires measurement uncertainties of a few parts in 10^{-9}, which hinges on accurately determining the local gravity. Providing accurate uncertainty evaluations for absolute and relative gravity measurements to support the kilogram's reliable realisation will benefit various sectors in European society by offering reliable gravity data and regulated calibration procedures, ultimately enhancing research capabilities and measurement solutions.

Furthermore, the importance of gravity measurements in climate monitoring has been stressed in the BIPM's Strategy 2022-2032 document. At the 2022 BIPM Metrology Climate Action Workshop, enhancing gravimetric, geodetic, and ice velocity measurements was identified as a critical priority. Terrestrial water storage (TWS), which can be tracked through gravity measurements, is a vital climate variable that can indicate long-term changes in water availability due to droughts. The 2022 Global Climate Observing System (GCOS) Implementation Plan emphasises the importance of satellite-based observations, such as the Gravity Recovery and Climate Experiment (GRACE) and GRACE Follow-On, whilst supporting for a reference established through terrestrial gravity measurements. The integration of satellite and terrestrial data offers opportunities for independent verification and thus, achieving high spatial resolution for detected phenomena.

Moreover, the precise determination of gravity potential is crucial considering recent advancements in the accuracy of optical clocks. Long-term gravity monitoring also finds relevance in volcanology, as demonstrated by the Newton-g project, which highlighted the limitations of existing gravimeters. To support geodetic and geoscientific applications within the framework of the Global Geodetic Observing System (GGOS), the

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International Association of Geodesy (IAG) has initiated the establishment of the International Terrestrial Gravity Reference Frame (ITGRF). This new framework will rely on absolute gravity measurements and aims to replace the outdated International Gravity Standardisation Network (IGSN71). Additionally, reference and comparison stations that monitor residual temporal gravity variations will enhance the accuracy and reliability of gravity measurements, consequently supporting a wide range of scientific applications bridging the gap and improving the structure of gravimetric service for industrial and regulatory users.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

Proposals should focus on the establishment of integrated European gravity metrology for improved gravity determination, accuracy and reliability.

The specific objectives are

1. To develop research capabilities and measurement solutions for both established and innovative absolute gravimeters with the possibility to assess and compensate for various perturbing instrumental effects to reach combined relative measurement uncertainty down to 1×10^{-9} and to confirm this uncertainty by direct comparison of different absolute gravimeters.
2. To establish methods that ensure contributions of instantaneous local absolute acceleration due to gravity to the Kibble balances, with relative measurement uncertainty below 5×10^{-9}, considering combined absolute and relative measurements, and mathematical modelling.
3. To demonstrate the establishment of an integrated European metrology infrastructure, in context with the realisation of an International Terrestrial Gravity Reference Frame of the International Association of Geodesy that will be based on reference and comparison stations with relative measurement uncertainty of a few parts in 10^9. This includes the development of strategies and methods to facilitate calibration services for gravimeters in the operating institutions and in the neighbouring countries.
4. To develop a good practice guide for measurements and evaluation of uncertainties for absolute and relative gravity measurements contributing to the Key Comparison Reference Value (KCRV), Kibble balance and ITGRF. These good practice guide will enable harmonisation of the measurement procedures and uncertainty evaluation and will be exploited as well for knowledge transfer purposes.
5. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. EURAMET TC-M and TC-TF, relevant IAG working groups, and geodetic institutes) and end users (e.g. geophysics, geology, hydrology, and climate researchers, relevant industries and other stakeholders).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users. Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme, including H2020 Newton-g; or (ii) other relevant European Partnerships.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.1 M€ and has defined an upper limit of 2.6 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the geophysics and geodesy sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.