EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s09**
Version: 1.0

Title: Large-scale dimensional measurements for geodesy

Abstract

Geodetic reference frames form the backbone of all georeferencing services, as well as for most critical Earth observations, such as sea level height, and volcano or earthquake monitoring. These require a 1 mm accuracy of the reference frame, which is still a challenging target. The reference frames are derived from global space-geodetic observations for which the traceability chain is very complex. Two of the weakest points can be tackled by modern large-scale dimensional metrology: the high-accuracy references for the Earth-bound verification of Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), or Global Navigation Satellite Systems (GNSS), and the geometric tie of co-located space-geodetic observations. This calls for innovative field instrumentation for extended outdoor measurements as well as an advance in measurement and analysis strategies.

Keywords

International Terrestrial Reference Frame (ITRF), large-scale dimensional metrology, length metrology, geodesy, surveying, local ties, georeferencing, index of refraction, GPS traceability.

Background to the Metrological Challenges

Geodetic data is used everywhere in modern life, from satellite navigation over automated machine guidance to modern digital services like car sharing. But also most critical observations in earth science or hazard monitoring are performed within the reference frame established by geodesy. Consequences of changes in the global sea level, tectonic activities including earthquakes and volcanoes can be mitigated if predicted early and accurately enough. This requires a robust and accurate frame of reference, enabling data comparison over decades. This need is exemplified in the United Nations General Assembly (GA) resolution, '*A Global Geodetic Reference Frame for Sustainable Development*' in support of the improvement and maintenance of the International Terrestrial Reference Frame (ITRF) as the foundation reference frame. Traceability to the SI definition of the metre of the ITRF scale is complex. Congruence between the "ITRF metre" and the "SI metre" is on a level of a few millimetres at best. Sea level changes or typical tectonic displacements at hazardous locations such as nuclear waste repositories, however, are in the order of one millimetre per year. For a fast and reliable detection by geodetic monitoring, the ITRF should enable a non-ambiguous detection of drifts with velocities below 0.1 mm/year over decades. Fostering SI-traceability in this system is hence regarded a major priority for the field of length metrology in its current strategic research agenda.

Two elements in the SI-traceability chain are critical and accessible to large-scale dimensional metrology: 1] extending ground references of low uncertainty necessary to overcome unknown systematic deviations in primary space geodetic measurements, and 2] mapping of individual frames of reference into a common one in order to merge various space geodetic observations. In terms of measurement technology, the targeted level of uncertainty for these references calls for SI-traceable primary standards for length measurements over several kilometres, and measurement capabilities suitable for surveillance networks on site. The targeted uncertainties below 1 mm over extended distances require inherent capabilities to account for the index of refraction, as well as relative measurement uncertainties well below 1×10^{-6}.

Currently, about 120 local tie vector datasets that supply the relative position of co-located geodetic instruments are available and used in ITRF processing. They are mostly obtained by a combination of topometric ground measurements and GNSS. For large sites, the number of topographic stations is directly imposed by the distance measurement accuracy. Consequently, improving the distance accuracy will revolutionise the survey work approach and lead to improved final results and increased efficiency. Another fundamental challenge is the determination of reference point positions for SLR and VLBI instruments. Today's most accurate methods are tedious to carry out and faster methods need to be developed. In addition to atmospheric corrections and traceability of the geometric reference points of space geodesy techniques, internal systems stabilities needs to be studied and calibrated. Further to this, a need to use physical surveying networks and traditional surveying techniques at core sites deteriorates the accuracy instead of making the tie directly between the reference points of each technique. This requires development of new methodologies.

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.

The JRP shall focus on improving the complex traceability chain in geodetic length metrology

The specific objectives are

1. To develop and validate field-capable primary or transfer standards to disseminate the unit metre over reference baselines over distances of at least 5 km with a measurement uncertainty below 1 mm (k = 2).
2. To develop and validate 3D capable novel measurement devices with a measurement range of operation of 200 m and accuracies of better than 200 µm outdoors, capable of compensating fast variations of the index of refraction at a relative uncertainty level better than 1 µm /m.
3. To develop technologies, methods and uncertainty assessment for the Earth-bound SI-traceable verification of space-geodetic measurement technologies like GNSS or SLR over distances of at least 5 km with uncertainties of 1 mm or better and their implementation in a European reference standard.
4. To reduce uncertainty of the so-called local tie between co-located space-geodetic techniques at Global Geodetic Observing System (GGOS) core sites by one order of magnitude to 1 mm over 200 m in real time continuous tracking. This requires a coordinated effort of novel dimensional measurement systems, methodology and analysis strategies and their demonstration in pilot studies at at least 2 European GGOS core sites.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the European geodetic measurement infrastructure by provision of European-wide access to the developed high-level references, collaboration with the established existing measurement supply chain (accredited laboratories, instrumentation manufacturers), and dissemination to standards developing organisations (ISO, IAG working groups) and end users (geodesy, surveying, high energy physics, and Earth sciences).

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 outside Europe 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.

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

In particular, proposers should outline the achievements of the ImeraPlus project T3.J3.1 Long Distance, EMRP project SIB60 Surveying as well as IND53 LUMINAR, and EMPIR project 17IND03 LaVa, and how their proposal will build on these.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

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 JRP 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,
- Transfer knowledge to the geodesy, surveying, high energy physics, and Earth sciences sectors.

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 EMPIR 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

Time-scale

The project should be of up to 3 years duration.