**EMPIR Call 2015 – Health, SI, Normative and Research Potential**

Selected Research Topic number: **SRT-s10**
Version: 1.0

# Title: Dimensional metrology for geodesy and surveying

## Abstract

Geodetic measurements include space geodetic observations, such as Global Navigation Satellite Systems (GNSS), satellite laser ranging (SLR) systems and traditional ground-based techniques. Such measurements are used to support policymaking for sustainable development, climate change monitoring and natural disaster management, and have a wide range of applications for transport, agriculture and construction. Improvements of the accuracy and the traceability of geodetic measurements are required to support the realisation of the International Terrestrial Reference Frame (ITRF), which is currently based on SLR measurements. In addition, the surveying of large facilities requires approximation formulae for the dispersion of the air refractive-index. Finally, more accurate geodetic measurements will promote the dissemination of the unit of length for measurements of up to several kilometres.

## Keywords

Geodesy, surveying, long distance, local tie measurements, air refractive-index, satellite laser ranging systems, International Terrestrial Reference Frame

## Background to the Metrological Challenges

Improving the accuracy and traceability of geodetic measurements, in particular SLR measurements is important for new realisations of the ITRF, which is updated every few years. The ITRF is commonly used by global studies in earth sciences and until now, has been realised through SLR measurements alone. SLR observes satellite orbits, in particular tracking their distance to the geocenter. ITRF coordinates are required to be relative to the geocenter at the 1 mm and 0.1 mm/yr level. However, this accuracy is currently not available. Without precise information on the origin of the reference frame, satellite orbits, and especially the SRL measurements will be biased, which can lead to misinterpretation of global changes, e.g. sea level rises, which are annually just a few mm.

When the accuracy of geodetic measurements increases, the differences between geometric local tie measurements using different techniques become more and more important. Improving ties between different techniques at co-location sites is crucial as the ability to calculate coordinates relies on the accuracy of the measurements. The current requirement is ±1 mm uncertainty in 3-D for the relative positions of the reference points. However, this is not yet achievable as many ties are old, not regularly controlled and incapable of detecting temporal variations.

Finally, in high energy physics, new, gigantic colliders of up 100 kilometres circumference are currently planned. Such large facilities will require extended geodetic surveillance networks with traceable measurements and uncertainties at the millimetre level or below. In particular, underground measurements will require reliable, optical refractivity-compensated telemeters as GNSS-based measurements cannot be performed underground. The use of optical refractivity-compensation requires a model of the dispersion of the air refractive-index, which directly determines the accuracy of the optical measurements. The metrological and surveying community has currently derived approximation formulae for the dispersion of the air refractive-index, based in part on high-accuracy experimental data. However, the experimental verification with the highest accuracy was only focussed on typical metrological conditions. Therefore the validity of the approximation formulae over a wider range of typical outdoor conditions down to the $10^{-8}$ level of uncertainty is required.

## 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 the accuracy and traceability of long distance measurements in the kilometre to hundreds of kilometres range.

The specific objectives are

1. To develop methods to compare SLR systems with traceable instruments in the several kilometres range and to improve the accuracy of SLR systems in order to achieve uncertainty levels in the millimetre range.
2. To increase the accuracy of geometric local tie measurements used in multi-technique geodetic fundamental stations or super stations, in order to improve the correlation between the multiple techniques used for the ITRF.
3. To expand current knowledge of the dispersion of the air refractive-index over a large range of temperature/pressure/humidity conditions in order to increase the accuracy of the formulas on which the air index compensation technique is based in novel telemeters. A target uncertainty better than $10^{-8}$ is required.
4. To improve the traceability of long distance measurements between European metrological reference baselines and large facilities requiring sub-mm accuracy.
5. To facilitate the uptake of the technology and measurement infrastructure developed by the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (ISO, CEN) 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 EMRP project SIB60 Surveying and how their proposal will build on those.

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 21 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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 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 science communities.

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.