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

Selected Research Topic number: **SRT-r05**
Version: 1.0

Title: Development of validated key comparison software

Abstract

Key comparisons in the field of metrology are a core component of the Mutual Recognition Arrangement and more than 1900 have been carried out since 1999. All national metrology institutes (NMIs) and designated institutes (DIs) participate in such comparisons, and many have acted as the pilot for a comparison. However, the process of calculating a key comparison reference value and the degrees of equivalence for participants can be difficult, and while tools and guidelines exist for the most straightforward comparisons, many real comparisons have complexities that mean such tools cannot be easily used. Proposals addressing this topic should focus on the development of validated generalised tools to support comparison pilots and comparison participants, along with training material to help the metrology community understand the mathematics, and practicalities of comparison analysis.

Keywords

CIPM Mutual Recognition Arrangement; key comparison; data analysis; uncertainty analysis; comparison analysis, covariance, software, Consultative Committees, technical committees.

Background to the Metrological Challenges

The Consultative Committees (CCs) of the International Committee for Weights and Measures (CIPM) organise key comparisons as part of the CIPM Mutual Recognition Arrangement (CIPM MRA) to demonstrate global equivalence in measurements and to provide evidence for metrology institutes to support their Calibration and Measurement Capability (CMC) claims. These are followed by key comparisons organised by Regional Metrology Organisations (RMOs) that must be linked to the CC comparisons. Each CC key comparison calculates a ‘key comparison reference value’ (KCRV) and a unilateral “degree of equivalence” that compare participants’ reported values with the KCRV. While many guides and papers exist on how such KCRVs can be calculated these are either written around the most straightforward comparisons or for complex but specific cases. Further challenges arise when results are inconsistent, and decisions must be made about how to handle inconsistencies. RMO comparisons must be linked in a robust way to the CC comparison KCRV through one or more “link laboratories” and supplementary comparisons also require a ‘comparison reference value’ (CRV).

Over the years, most technical committees have encountered a multitude of challenges related to the analysis of comparison data. These include, but are not limited to, (i) the need for software to allow different approaches to outlier handling and allow comparison models to be rapidly and helpfully compared, (ii) software to effectively handle correlations between measurements, (iii) unstable or aging artefacts and reference materials, (iv) comparisons involving multiple artefacts whose properties are determined over a measurement range or for a variety of parameters, (v) the need to efficiently provide visualisation and interpretation of the analysis of large amounts of data, (vi) the need to adapt a comparison during its lifetime whilst ensuring the results can be evaluated in a consistent and quality assured manner and (vii) the time and resources needed to conduct comparisons and evaluate the results.

There is a barrier to smaller or less experienced NMIs/DIs piloting comparisons because the complexity of the analysis phase makes the process labour intensive and too expensive. Such complexity limits the pool of possible pilots, increasing piloting responsibilities and costs for others. This issue could be addressed by clear step-by-step guidance, software tools and training. For CC and CMC reviewers it is difficult to check the analysis quality in a comparison when a new type of analysis is conducted for each comparison. Agreed

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processes and data quality checking software focusing on statistical indicators would provide greater confidence in the results. CC groups working on comparison analysis with inconsistent data sets would benefit from software that provides options, written in a modular fashion. These generalisations could be addressed by making the routine parts of comparison analysis easier and training more people in the concepts, creating space to think beyond existing methods. Technical protocols, for example, which consider those aspects necessary to determine all uncertainty contributions of the respective comparisons will provide additional support to participants to deliver more consistent measurements.

For these reasons, information about the practices, recently used tools and methods should be collected from all EURAMET TCs and then analysed to obtain a clear picture of the challenges. A subset of challenges/requirements should be prioritised for implementation that will have the largest benefit for those CCs with more complex comparison structures and where a common solution would benefit multiple CCs. The software developed should therefore be written in a way that either addresses the needs of other CCs or could readily be adapted to meet those needs. The software should allow for different forms of KCRV calculation, and for different approaches to handling outliers and questionable data. However, the software alone could risk becoming a “black box” used unthinkingly, hence it should be supplemented by sufficient training and guidance, along with careful consideration of the theoretical basis on choices of analysis procedures. Consideration should also be given to supporting both human-readable and machine-readable reports, and proposers should consider the use of the European Metrology Network (EMN) Mathmet’s Quality Assurance Tools [1]

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 proposal shall focus on the development of comparison analysis tools and their implementation to support Consultative Committees (CCs), Technical Committees (TCs) and metrology institutes.

The specific objectives are

1. To gather specific needs regarding software for comparison analysis from across all EURAMET TCs, their corresponding CCs, and EMNs who wish to contribute, plus the requirements from other important stakeholders (BIPM, JCRB, JCGM, other RMOs). To create a subset of common requirements that will form a base for the development of software tools, guidance documents, and training within the project and to identify a list of those that are desired beyond the project.
2. To evaluate current methods and develop new methods for the validation of reference value and degree-of-equivalence calculation methods addressing (i) the selection and verification of the comparison data analysis models and (ii) testing of the numerical precision of software implementing the models. The methods should be applicable to existing methods for validation of reference values and degrees-of-equivalence with integrated flexibility to meet future needs. The implementation of new tools such as machine learning should be considered.
3. To develop and validate easy-to-use software modules that will calculate reference values and unilateral degrees of equivalence for comparisons reflecting the specific needs outlined in objective 1. The resulting software to be developed for an agreed subset of the most commonly required methods in EURAMET, and flexible to meet emerging needs. Digitalisation aspects should be considered such as machine-readable and machine-interpretable reports of analysis outputs.
4. To provide training materials including user guidelines, practical demonstrations, examples and videos to support comparison pilots, participants, and comparison working groups in the use and possible future development of validated methods and software for comparison analysis, and the reliable handling of inconsistent data. The training materials, guidelines, and software tools should undergo rigorous testing and evaluation in multiple worst-case scenarios in order to assure their proper functionality prior to general release.
5. To facilitate the take up and long-term operation of the capabilities, technology and measurement infrastructure for analysis of the results of comparisons developed in the project, by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), and end users (e.g CIPM CCs and EURAMET TCs). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, e.g. via EURAMET TCs and EMN Mathmet, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,
- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

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; or (ii) other relevant European Partnerships.

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

The development of the research potential should be to a level that would enable participation in other TPs.

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 0.7 M€ and has defined an upper limit of 0.9 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % 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,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- 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 metrology community and the CIPM Consultative Committees and EURAMET TCs.

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.

Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

These references have been provided by EURAMET.

[1] *European Metrology Network for Mathematics and Statistics Strategic Research Agenda* https://www.euramet.org/european-metrology-networks/mathmet/strategy/strategic-research-agenda