# Title: Large Volume Metrology Applications

## Abstract

Large Volume Metrology (LVM) is key to many high value industries where Europe is globally competitive, and supports significant infrastructure. However further work is needed for robust 3D data analysis, a broader range of novel instruments for new applications, higher accuracy 3D volumetric refractive index correction, an extension of the Frequency Scanning technique to traceable targetless metrology of surfaces and the provision of a digital metrology infrastructure. Therefore, proposals in response to this SRT should address these issues and improve the metrology necessary to support the industrial adoption of large volume metrology.

## Keywords

Coordinate metrology, large volume, machine tools, reference data, laser tracker, photogrammetry, aerospace, automotive, robotics,

## Background to the Metrological Challenges

Large objects are manufactured and used in many high value industries such as the aerospace and automotive industries, in non-ideal environments. In order for these industries to operate correctly the position, dimensions and/or shape of key components have to be controlled within large volumes.

EMRP project IND53 LUMINAR addressed the needs expressed by a variety of users of LVM and developed a range of new dimensional measuring instruments, ways of compensating for thermal and refractive index distortions, measurement facilities and updated modelling software (all designed for in situ use). Large scale metrology continues to represent the research frontier, and thus new ways of considering the entire measurement process are still required.

3D optical surface scanners could be a future tool for dimensional measurements in production lines, but automotive companies have confirmed that current 3D optical scanner technology is not traceable and fails on uncooperative surfaces. The lack of mathematically rigorous processing of large datasets from LVM also leads to measurement results which are not robust nor traceable and do not have valid uncertainties. In addition, only very basic verified datasets are available (representing only simple features on single geometric objects) and there are no models or reference datasets for large networks of points, nor rigorous comparison of commercial software in this area. Models and reference data sets are also needed so that users can validate their software.

Improved Frequency Scanning Interferometry and novel and validated LVM methods are needed for the ever expanding range of end-user scenarios (for example, high accuracy (cheap) photogrammetry and absolute 3D coordinate measurements at long ranges) which are useable in harsh environments. Existing photogrammetry systems can handle hundreds of targets, but the accuracy of their measurements is limited to around 1 in $10^5$. For refractive index compensation, a typical system using air pressure and temperature probes will achieve an uncertainty of approximately $10^{-7}$ for the refractive index, but only for a single location at 0.1 Hz.

The demand for better geometrical performance in machining large parts is split between i) the requirement to compensate for machine geometrical errors and ii) the necessary testing of the machine and parts. Improved accuracy in, and ease of use of, automatic trans-machine handling of large parts is also needed for assembly operations. A significant amount of time is expended in moving parts between different machining cells, thus an improvement in the positioning capabilities of AGVs (Automatic Guided Vehicles) would reduce the time required for re-alignment after delivery.

## 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 traceable measurement and characterisation of large objects to underpin the industrial adoption of large volume metrology (LVM).

The specific objectives are

1. To improve the metrological capability of Frequency Scanning Interferometry based techniques beyond the state-of-the-art by developing i) methods to track multiple (>10) targets in real time, ii) dynamic capability (> 10 mm $s^{-1}$), iii) robust data processing for 3D point cloud and target positions, and iv) a traceable surface form scanner capable of measuring reflective finishes and complex surface geometries.
2. To develop novel and validated LVM methods for i) low cost photogrammetry-based techniques for the simultaneous coordinate metrology of multiple robotic and co-biotic systems, ii) very large volume, medium-accuracy, 3D, absolute positioning for tracking multiple items in factory environments, and iii) high accuracy ($\approx 10^{-7}$) refractive index determination of factory volumes.
3. To develop models to simulate self-organising production and assembly based on digital information from process-integrated measurement systems.
4. To produce equipment and validated methods for evaluating the performance and compensating for the errors of large machine tools (> 50 $m^3$). The cost and operability must be adequate to leave the equipment on board or on the shop floor. In addition, to develop equipment and validated methods, for tracking with adjustable accuracy the position of moving targets, intended for AGVs feeding subsequent machines with workpieces.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations e.g. ISO/TC 213, and end users e.g. the automotive and aerospace industry.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

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 IND53 LUMINAR and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

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 aerospace and automotive 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.