**EMPIR Call 2014 – Industry and Research Potential**

Selected Research Topic number: **SRT-i05**
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# Title: Metrology for additive manufacturing production assurance


## Abstract

Additive Manufacturing (AM) provides a way to manufacture highly complex, customisable and multifunction production metallic parts, enabling significant cost and in-use carbon savings. Currently there is a lack of traceable measurement of internal dimension, internal surface texture and part integrity which is critical to the successful uptake of the technology into a wider range of applications. The research described here aims to improve the accuracy and traceability of Non-Destructive methods (e.g. X-ray Computed Tomography (XCT)) enabling AM machine manufacturers to improve part quality and end users to accurately non-destructively quality assess their production parts. It will also influence future international standards identified as lacking by industry standards roadmaps.



## Keywords

Additive Manufacturing, dimensional metrology, Non-destructive measurements, XCT, test artefacts, laser sintering, electron beam melting, 3D printing, calibration methods and standards, raw material properties.


## Background to the Metrological Challenges

The development of additive manufacturing (AM), going from a prototype and pilot production technology into a mature manufacturing technology, results in a higher demand for methods and technologies for measuring, evaluating and validating both AM processes and AM parts, as well as the raw materials used in the processes. Recent roadmaps for AM, reflecting the opinion of over 100 industrially driven stakeholders [1-3], indicate urgent needs regarding improvement of process stability, product quality, better understanding of raw materials and standardisation. Key priority items for standardisation are identified as the creation of databases with material properties and geometrical accuracy [1].

Selective laser melting (SLM) of metal powders is a maturing additive manufacturing technique that enables the fabrication of highly complex monolithic metal parts. The freedom of design in SLM allows significant mass and cost reduction while maintaining or even improving product performance compared to parts that are produced by conventional (material removal) techniques. Major driving forces in the development of AM produced metal parts are applications in the medical sector as well as in the aviation and space industry. Estimates from Airbus Industries, for example, indicate that a 30 % reduction in weight is possible compared to current machines when an aircraft is produced entirely by AM while additionally being 60 % more cost effective [1], illustrating the potential for reducing the carbon footprint and preservation of material resources and energy.

AM has a particularly high potential for economically producing complex parts in low volumes and even single customised products, but this can only be realised in practice when products are manufactured the first time right. First time right production requires detailed knowledge of the raw materials and process details in order to control manufacturing within the design tolerances. Additionally, since the AM process works by building up the work piece layer by layer, it is inherently slow. Assessing the product quality only after production and finding out that the product is out of tolerance is unacceptable for economic viability.

Currently, AM production machines lack sufficient process control to ensure that the manufactured product stays within tolerance of the design specifications during fabrication. The geometrical accuracy of products can only be assessed by measuring critical to quality product parameters afterwards. Internal structures are usually completely inaccessible and require destructive preparation of the finished work piece before these structures can be measured and surface characteristics can be established. In order to improve the process stability and product quality, increased knowledge of process details is required that has to be based on reliable measurements of process parameters. Traceable in-process metrology therefore needs to be developed in order to improve the quality at the level of the manufacturing process.

Currently the only (partly) traceable way determine the internal dimensions of an AM made part is to destructively section the sample and to use conventional co-ordinate measuring (CMM) techniques. X-ray Computed Tomography (XCT) provides a unique way to non-destructively assess the internal features and structure of AM made parts and is increasingly being used by the AM industry for part assessment. However there is no traceability in the dimensional measurements it produces, with estimated measurement uncertainties up to 6 times greater than with CMM's [4]. Complex geometries and different materials have been shown to lead to artefacts and systematic measurement errors, which further limits the ability of XCT to make accurate measurements of AM parts.

## 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 proposal.

The JRP shall focus on the improvement of the accuracy and traceability of non-destructive measurements and validation of metallic parts realised by additive manufacturing (AM).

The specific objectives are

1. To develop and to validate non-destructive methods (e.g. XCT) to measure the internal and external dimensions of AM made parts and to provide traceable reference data to industry with tools for quality control of AM processes and AM products. The part size must be up to 10 cm and the measurement uncertainty must be smaller than 9 µm (three times the typical uncertainty of CMM measurements).
2. To develop methods to determine part integrity such as porosity, foreign object contamination, cracking, and the effect of post-processing. In addition, to develop methods and models for estimating the internal roughness.
3. To develop metallic artefacts with complex internal features and varying surface roughness and to perform round-robin tests to validate measurement methods.
4. To produce traceable reference data for raw metal powders to improve process modelling, taking into account that metal powders are reused in AM processes.
5. To provide inputs into AM standardisation activities (ASTM Committee F42 on Additive Manufacturing Technologies ASTM F42, ISO Technical Committee 261 on additive manufacturing).

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.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any 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 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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the Additive Manufacturing sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects”

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.

## Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] Additive Manufacturing, SASAM Standardisation Roadmap, 2014, available for download at http://www.sasam.eu/index.php/press/sasam-in-magazines-english/viewdownload/9/176

[2] Additive Manufacturing, Strategic Research Agenda, 2013, available for download at http://www.sasam.eu/index.php/press/sasam-in-magazines-english/viewdownload/9/175

[3] Wohlers Report 2013: Additive Manufacturing and 3D Printing State of the Industry, Annual Worldwide Progress Report, ISBN 0-9754429-9-6

[4] Inter-laboratory Comparison of Industrial Computed Tomography, CIA-CT Comparison, J. Angel, L. De Chiffre, 2013