Publishable Summary for 18RPT01 ProbeTrace
Traceability for contact probe and stylus instrument measurements

Overview

The overall aim of this project was to develop traceable and cost-effective measurement capabilities for the calibration of form and surface roughness standards. Surface texture and form of products are important features to be examined and numerically characterised as parameters for engineering and scientific purposes. Such features of surfaces have great impacts on wear resistance, bearing, sliding and lubricating properties, fatigue and corrosion resistance, functionality, etc. Form and surface measurement devices with contact probes and stylus are used to characterise such surfaces. This project improved the scientific knowledge, instruments, methods and research capability in metrology for contact measurement probes and stylus instruments and enabled calibration labs to develop new capabilities for self-provision of traceability to the SI unit of length, the metre. Calibrations of reference stylus instruments using novel displacement generators (DG) were performed with expended uncertainties between 1 - 70 nm in all calibration setups except one. Two novel algorithms and dedicated open source software were developed for calibration of stylus devices using sphere standards. The software allowed calibration of not only the devices of certain manufacturers, but of all roughness measurement devices using spheres. Calibrations of form measurement device's probes using novel DG were performed with expanded uncertainties between 10 - 200 nm in all calibration setups. Calibration of the DGs using state of the art set ups realised by laser interferometers was performed to obtain direct metrological traceability to SI metre with the uncertainties of 5 nm and experimental investigations of DGs using precise angular measurement systems. A VBasic software for random noise reduction in surface roughness and form profiles, and a Python software for random noise reduction in roundness profiles were developed. Measurement profiles with random noise obtained from roughness and form measurement devices in calibration laboratories can be cleared of noise, and uncertainty of the measurements can be reduced with these softwares.

Need

Surface texture is of great importance in specifying the function of a surface. A significant proportion of component failure starts at the surface due to either an isolated manufacturing discontinuity or gradual deterioration of the surface quality influencing the proper functioning of the products. Therefore, in the manufacturing industry, surface properties need the periodical check to be within certain predetermined tolerances of roughness and form. The surfaces outside of these limits will result in failures in the performance of the products, influencing the productivity of European manufacturing industries. An accurate measurement of surface roughness and form is vital to quality control of the machining of a workpiece.

Form errors of machined parts are measured in a production line mostly by using coordinate measuring machines (CMMs) which are the key devices for factory of the future (industry 4.0). Reindustrialisation with the demand for higher precision has led to a new generation of CMMs working in scanning mode (which can measure dimension and form simultaneously). Since the contact measurement probes are used in scanning mode with CMMs, the dynamic performance of the probes must be evaluated.

Use of probes for form measurements in scanning mode with a fast scanning speed might be problematic due to required high data acquisition rates, therefore the dynamic performance of the probe including the electronics of the instrument should be well calibrated. For the surface roughness devices, there was a need for new traceable standards due to a recent increase in the required measurement ranges (e.g. 1000 µm).

Although there are documentation and methods for calibration of contact stylus instruments (ISO 12179; ISO 25178-701:2010 and DKD-R 4-2), there was no documentation for alternative routes or detailed investigations for calibration of reference stylus instruments used for calibration of reference standards of secondary level labs.

This project investigated portable traceable displacement generators and their use to establish new direct routes to SI unit metre definition, considering the emerging demands of industry in terms of dynamic properties, precision and larger measurement ranges in regard to contact probes used in form and surface roughness measurements. Knowledge transfer from experienced NMIs to those less experienced was necessary to ensure the development of new cost-effective capabilities that will enable emerging NMIs to achieve direct traceability to the SI unit, the metre.

Objectives

The overall goal of this project was to develop traceable and cost-effective measurement capabilities for the calibration of form and surface roughness standards with uncertainties in the range 10 nm –100 nm. The specific objectives of the project were:

1. To calibrate reference stylus instruments for surface roughness measurements using novel portable displacement generators with uncertainties in the range 10 nm–100 nm and to evaluate the efficacy of displacement generators vs existing methods (e.g. depth setting standards) for calibration of stylus devices. Further, to develop novel software for the calibration of stylus devices using sphere standards.
2. To calibrate reference probes for form measurements in static and dynamic mode using novel portable displacement generators with uncertainties in the range 10 nm –100 nm and to evaluate the current state of the art for calibration of flick standards.
3. To investigate the traceable calibration of transducers to be used as portable displacement generators under static (+/-1000 µm) and dynamic (+/-100 µm) measurement conditions, including investigations into the set-up of the generators to be used as 'portable'. Further, to prepare two best practice guides on their use in the calibration of stylus instruments and form measurement probes.
4. To develop noise reduction software, including the use of numerical methods for random noise bias reduction, that can be used to pre-process roughness and form profiles data to reduce the overall uncertainties down to a level of 10 nm in roughness and roundness measurements.
5. For each project partner, to develop an individual strategy for the long-term operation of the capacity developed, including regulatory support, research collaborations, quality schemes and accreditation. In addition, for partners to develop a strategy for offering calibration services from the established facilities to their own country and neighbouring countries. The individual strategies to be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Progress beyond the state of the art

Artefacts having only specific nominal values (e.g. depth setting standards) are used for calibration of surface roughness devices. Only few advanced NMIs had facilities for the required precision level e.g. (10-100) nm uncertainty up to 1 mm range. Other NMIs calibrated their reference devices using artefacts calibrated by advanced NMIs. The project provided new routes and novel methods for achieving direct traceability to the SI unit, the metre, instead of using depth setting standards. NMIs were able to calibrate their reference devices utilising displacement generators to achieve traceability with a standard uncertainty better than 21 nm. Continuous sampling provided better knowledge for error mapping of the reference stylus instruments as well as reaching larger calibration ranges e.g. +/-1000 µm. In the case where sphere standards are required to be used, this project developed openly accessible software to enable the calibration of any manufacturer's device without the need for proprietary software.

Form measuring probes are calibrated in static mode mostly using gauge blocks and then in dynamic mode using flick standards. Precise primary calibration of flick standards was performed by only a few NMIs. Besides, there was no documentation for primary calibration of flick standards. The project enabled calibration of contact measuring probes in static and dynamic mode using accessible and portable equipment having direct traceability to the metre with a standard uncertainty better than 10 nm. The performance of the contact measuring probes that were used for primary calibration of reference artefacts was evaluated in detail. The results were used to prepare best practice guides and will contribute to the establishment of new written standards for primary calibration of flick standards.

Displacement transducers are able to measure/generate very small displacement steps. They can be calibrated by laser displacement interferometers to provide direct traceability to the metre. However, this calibration is complex and difficult. The aim was to use a displacement transducer as a stand-alone device after its calibration by laser interferometers. The project went beyond the state of the art by detailed investigation on how to use the displacement transducers as portable displacement generators and by preparing best practice guides on this topic.

During surface roughness and form measurement of precise parts, noise influences the accuracy of the measurement and may offset the results. Currently, form and surface roughness devices are located on heavy mass tables or static and active vibration isolation tables for noise reduction. Producers of such devices develop their own software and apply their own statistical tools; however, these are only used for their own specific devices. Within the project, noise reduction softwares including the use of numerical methods for random noise bias reduction were developed to be used to pre-process roughness and form profile data. Overall uncertainties are expected to be reduced down to levels of 10 nm in roughness and roundness measurements. One of the softwares was designed to process the profile data of any commercial form and surface measurement device.

Results

Calibration of reference stylus instruments using novel portable displacement generators vs existing methods

CEM has revised the classical stylus instrument measurement methods based on material standards. CEM has participated in a EURAMET supplementary and key comparisons in order to test these improvements at highest level. Once the comparisons results will be available the update of Calibration and Measurement Capabilities at BIPM KCDB will be done, so the improvement of step height calibration service is expected.

INRIM calibrated the stylus instrument using DG and both with a calibrated sphere and with gauge blocks. The calibration results obtained using DG have been compared with the ones obtained using calibrated sphere and gauge blocks in the range up to 50 µm. The calibration factors obtained with the two methods are in agreement within the respective uncertainties. IPQ performed the calibration of its stylus device using a vertical DG in both static and dynamic conditions up to a range of 0-500 µm. The stylus device was also calibrated using the available material standards (gauge blocks and depth standard) in static and dynamic conditions. The comparison of the measured roughness parameters Ra and Rt, obtained from a sample surface, after each stylus calibration, was performed and good results were achieved. GUM calibrated its stylus instrument using Thorlabs DG in both static and dynamic conditions up to 75 µm range. The results were compared with standard calibration route, using depth setting standards. During the measurements, it was found that the weight of plate placed on top of the DG to serve as a flat measured surface has notable influence on the results of measurement. The comparisons showed that both calibration paths provide viable and comparable results. BIM calibrated its stylus instrument using a DG. The results were compared with a calibrated groove depth standard with 2,35 µm depth. The standard deviations obtained from groove measurements and simulated groove profile produced by DG are the same (5 nm in range 2,35 µm) which is due to the fact that the movement of the DG is automated. DMDM calibrated its stylus instrument using PI brand DG in the range up to 50 µm and compared it with calibration using groove depth standard in the range up to 7.894 µm. The standard deviations obtained from groove measurements and simulated groove profile produced by DG were similar. TUBITAK calibrated its reference stylus instrument using DG and using groove depth standard for the range 0-1000 µm. The maximum difference of the two results was less than 90 nm. These differences were always sufficiently smaller than the calculated uncertainties of differences. Therefore, it can be clearly stated that the calibrations of the stylus instrument using DG and using groove depth standard are compatible.

Two algorithms and a software were developed by NIS for calibration of stylus devices using sphere standards using Matlab. First algorithm is based on simplex method for finding fitting parameters of a polynomial. Second algorithm is based on a developed Genetic Algorithms adaptive algorithm for finding fitting parameters. This second algorithm was compared to the first algorithm. The software allowed calibration of not only the devices of certain manufacturers (mainly Taylor-Hobson), but of all roughness measurement devices using spheres, that is the first in the world.

The objective was successfully achieved.

Calibration of reference probes for form measurements in static and dynamic mode using novel portable displacement generators vs existing methods

FSB arranged a vertical and horizontal setup for probe calibration with a DG in the measurement range of ±3 µm. Prior to the actual calibration, a static noise level testing has been conducted, with particular attention to the impact of temperature variations on calibration. To reduce this influence, the device is protected by a thermal cage made of plexiglass. The research on the misalignment was conducted. Comparison of results obtained from the horizontal setup with those from the FSB's standard calibration method indicates a significant improvement in terms of measurement uncertainty from 0.040 µm to 0.016 µm. TUBITAK calibrated its form device probe using DG in static and dynamic mode. D parameter (ISO 5436) which is used in roughness metrology, was prefered to evaluate DG's movement. CEM built a specific setup for the use of a DG in its Mitutoyo roundness machine. A platform was attached to the device to allow the turntable to rotate while the probe is in contact with the piezo transducer. For the static calibration a 20 µm displacement was generated with the DG. The resulting amplification factor shows a little discrepancy with values obtained using the flick standard. This deviation will need to be studied in future work. The approach employed for the dynamic calibration was to produce a single-frequency sinusoidal wave that was measured by the form device. Frequency analysis was used to extract the harmonic content and this procedure was repeated varying frequencies and amplitudes. An iterative method for the fine-tuning of the frequency of the piezo was proposed in order to reduce the harmonic content distortion caused by closing errors. BIM successfully tested manually a Thorlabs Piezo controller, a new program in LabView was created in order to control the Piezo controller automatically and a rectangular signal was simulated as step height standard. The results were compared. The automatisation of the movement of the DG allows the generated profile to be symmetrical in whole measurement plane. GUM calibrated its form measurement device using a DG in both static and dynamic conditions. Thorough investigations were conducted to address alignment issues that could potentially introduce uncertainty in the measurement setups. Throughout the calibration process, various uncertainty sources were analysed, including Abbe error and alignment errors, among others. These investigations were aimed at achieving the desired level of precision within the range of (10-100) nanometers. Limitations of the method were also examined, including dependencies on power supply stability, driver quality, and software control for piezo actuator precision. Despite these limitations, the overall results offered significant advantages over traditional gauge block procedures, including improved repeatability and reduced user-dependent operations. IPQ calibrated its form machine using a DG and using a hemisphere. The calibration of flick standard was implemented following participation in the interlaboratory comparison of a flick standard using a form machine. DMDM studied on a design using PI DG in vertical position. Calibration setup was investigated. The movement of the DG was performed by a PI commercial software PiMikroMove.

An inter-comparison on measurements of a flick standard to define the current state of the art for the involved project partners: CEM (pilot), GUM, IPQ, TUBITAK and SASO-NMCC, was performed successfully. The flick standard was calibrated by each NMI according to their own available approach in dynamic operational mode. The maximum deviation had always been much less than the uncertainty. Eight results out of 44 showed En > 1.

The objective was successfully achieved.

Traceable calibration of transducers to be used as portable displacement generators

TUBITAK used a SIOS differential interferometer (DI) to calibrate DG. Different ranges along the entire range (+/-12 mm) of the DG were scanned. Detailed experimental investigation was performed against the pitch and yaw values of the DG measured by a precise autocollimator. For the linear error investigations, the maximum error was determined as 3 nm for the range of +/-1 mm that is used for calibration purposes in both vertical and horizontal orientation. Calibrations of INRIM's DGs were performed and investigated for minimising the influence from hysteresis and interferometer mirror weight. INRIM used a specially made differential interferometric set-up (double pass) for these tests. Measurement steps of λ/4 were used to minimise the error due to optical non-linearity. INRIM used this set-up to calibrate its three DGs. TUBITAK and INRIM used high precision autocollimators for testing of the unwanted rotation errors (pitch and yaw) of the actuators. With these autocollimators, it is possible to achieve an uncertainty of 0.1" (0.5 µrad) for the possible angular rotation errors of 20" (100 µrad). DMDM tested its PI brand DG with a Renishaw interferometer at a range of up to 50 µm and also tested its interferometric setup through participation in the interlaboratory comparison in the range up to 500 µm. The comparison results were used to minimise different effects on the interferometric DG calibration uncertainty. GUM performed the interferometric calibration of its Thorlabs DG using a HP interferometer in the range up to 750 µm. The effects were investigated for minimising the influence of hysteresis and interferometer mirror weight. The interferometric setup for DG calibration was also tested during the interlaboratory comparison with other project members, with good results. During the measurements, the influence of weight of optical element placed on the DG surface on measured results was observed and studied, as well as pitch and yaw measurements. Uncertainty budget including these factors was prepared. CEM performed the calibration of the DG in static and dynamic conditions utilising its setup that consists of a low CTE frame made of INVAR to hold the actuator and a Renishaw RLE10 laser encoder. For the static calibration, the piezo was commanded to discrete positions with a pitch of 500 nm in a range of 20 µm. The uncertainty of the measurements was calculated to be less than 10 nm for the whole range. The main contribution was caused by the Abbe error, as there is a limitation in the alignment of the laser beam with respect to the movement axis. For the dynamic calibration, different sinusoidal waves of 10 seconds of duration were generated with amplitudes ranging from 10 nm to 100 µm, and with frequencies of 0.5 Hz, 1 Hz and 2 Hz, that correspond to a simulated profile of 5 UPR, 10 UPR and 20 UPR in the roundness measurement setup. These simulated waves were measured by the laser encoder and a Fourier analysis was performed to extract the amplitude of the harmonic of interest. INRIM improved the developed soft-tool for generation of more complex movements by the DG in order to check the dynamic performance of the probes that will be used for multiwavelength and flick standards. A homemade code to generate a signal which is the sum of 10 frequency components without reverberation was written. The tactile stylus probe was placed in contact with the z-stage actuator and a comparison between the driving signal, the position monitor of the z-stage and the probe signal was performed. Non negligible differences in terms of bandwidth and noise are visible in the spectrum analysis of the recorded signals. Moreover, W and R parameters shows amplitude changes up to 20 % of the peak parameters (Rz, Rv) as calculated from the three different signals. IPQ acquired an Aerotech DG and calibrated DG using a HP Interferometer. With the special collaboration of INRIM, IPQ developed a software to perform calibration.

To assess the performance of DGs, an inter-laboratory comparison piloted by IPQ for calibration of DGs, was realised using a transfer standard (single-axis, Z piezo nanopositioning stage). The comparison, which included six laboratories, was not finalised due to customs clearance difficulties arising from some of the non-EU NMIs. Although one of the six laboratories was unable to complete its task, a final comparison report was prepared, using acquired data.

Recommendations were given for the calibration of portable DGs in the good practice guides for calibration of stylus instruments and form measurement probes using DGs. Investigations showed that linearity, hysteresis between outgoing & ingoing paths, repeatability, and stability are essential for the DGs' usage. The performance of DGs needs to be checked for unwanted rotations, such as pitch and yaw motions, over the entire range, in different orientations (vertical/horizontal), and at different speeds. The precautions for calibration of DGs may be considered as: (i) minimising the Abbe offset between the axis of the actuators and the interferometer (later for the probe / stylus axis), gauge temperature, ambient parameters (temperature influences may be reduced using low CTE materials and smart set-ups), (ii) avoiding mechanical constraints on DGs during assembling and arrangement of the cables, including the influence of weight of additional elements such as mirrors or optical flats placed on top of DG and finally, (iii) reducing interpolation errors of the interferometer varying mostly in the range of (1–5) nm with smart strategies.

The objective was successfully achieved.

Development of noise reduction software

TUBITAK developed a VBasic software (NBR) for random noise reduction in surface roughness and form profiles. FSB created a Python code (NR) for random noise reduction of roundness profiles. Both codes incorporate functions that support the Averaging method, Reduction of Fourier components, and Exclusion of Random components. In NR software using optimised routines, computation time was reduced to an acceptable level, for example 10 seconds. The NR module can be effortlessly imported into any Python project, making the NR functions accessible. In this way, NMIs and stakeholders can develop their own software for roundness analysis and utilise the pre-developed NR functions from this project. Both softwares were tested by project partners using both simulated and real measurement data. It was showed that random noise is eliminated by 95 %. It can be declared that noise reduction is not used in commercial devices and becomes important for measurements carried out in noisy industrial environments and when there is a need for very high precision form measurements with very low uncertainty values (e.g., form measurement of silicon sphere - new kg).

The objective was successfully achieved.

Impact

The webpage developed, www.probetrace.com, is regularly updated with news and information such as project reports, articles/papers published by the partners and details of project meetings.

The national dissemination of ProbeTrace activities in 2022 and 2023 continued with publications of articles in the IPQ newsletter. Two articles were presented in ESPAÇOQ no. 191 and no. 198.

IPQ disseminated information on the project by giving poster or oral presentations at: 23rd National Physics Conference FISICA2022 (https://fisica2022.sci-meet.net/) Faculty of Sciences of the University of Porto, Portugal, September 2022; IMEKO TC11 & TC24 Joint Hybrid Conference, October 17-19, 2022, Dubrovnik, Croatia; 8th SPMET National Meeting (http://www.spmet.pt/encontro8.html) in November 2022; 21st International Metrology Congress, Lion, France, March 2023 and the Workshop for traceability of contact probe and stylus instrument measurements in Belgrade (Serbia) in May 2023.

TUBITAK disseminated information on the project by giving poster at (Measurement Science Symposium and Exhibition in Turkey (https://zenodo.org/record/4467505#.YBK1ATEzapo) in November 2019; euspen's 23rd International Conference & Exhibition, Copenhagen, DK, June 2023 and 21th International Metrology Congress CIM 2023, Lyon, France, March 2023.

BIM has participated in the 30th International Scientific Symposium Metrology and Metrology Assurance 2020, held in Bulgaria and presented a paper on the project's purpose (http://metrology-bg.org/fulltextpapers/Proceedings_MMO_2020.pdf).

FSB has published an article in national trade magazine Svijet po mjeri (2020). An oral presentation was given at the 16th International conference CROLAB 2021, in Croatia in October 2021. FSB has published newsletter "Workshop on Novel methods for traceability in Form and Surface Roughness Measurements" posted on the website www.fsb.hr. FSB has disseminated project work related to the noise reduction of roundness data on international conference IMEKO TC11 & TC24 Joint Hybrid Conference, October 17-19, 2022, Dubrovnik, Croatia.

CEM introduced the ProbeTrace project on their institutional website, and also published a popular press article in the *e-medida* magazine in July 2023 "Trazabilidad en medidas de rugosidad y redondez: proyecto europeo ProbeTrace – Revista e-medida", presenting some of the work done during the project to large audience in Spain and other Spanish-speaking countries.

GUM introduced the ProbeTrace project on their institutional website.

Impact on industrial and other user communities

The participant NMIs have established new services for calibration of form and surface roughness standards using the traceability route established with the novel methods developed in the project. They started calibrating their reference form measuring devices and stylus instruments. Improvements for calibration of form and surface finish standards through investigations of contact measurement probes and stylus instruments enable NMIs to calibrate their own devices by themselves without having to use calibrated reference standards of advanced NMIs. This also provides traceable and more reliable measurements of form and surface finish parameters to various industries (such as automotive, aerospace and energy) in the participant countries as well as in Europe. In addition, newly developed guides will facilitate the application of the new methods for CMM, form and stylus instrument users and manufacturers. The project outcomes also offer solutions for the improvement of measurements taken in noisy industrial environments by applying developed noise reduction software tools.

Impact on the metrology and scientific communities

Newly developed methods, which provided alternatives to the conventional ones, are creating impact on calibration laboratories. The outputs of the project results were presented to emerging NMIs, accredited labs, end users and manufacturers in the joined capacity building workshops arranged together with EURAMET Capacity Building Officer and EMN for Advanced Manufacturing. Knowledge transfer from experienced NMIs to those less experienced on how to use these new types of standards proved to be very beneficial. On a broader scope, the project has strengthen the collaboration of European NMIs and has increased their competitiveness and consistency by producing a draft calibration guide for the use of portable DGs for calibration of stylus instruments and contact measurement probes. At the end of the project, the results showed that the project has provided valuable information to extend traceability of most probing-based form and surface texture measurements at the emerging NMIs.

Impact on relevant standards

A presentation about the project results and an input for testing of the dynamic performance of stylus instruments "Areal and profile surface texture" were given at ISO/TC 213/WG 16 N 1177 meeting. The consortium has also promoted the results of the project within other committees, e.g., EURAMET TC-L, COOMET TC Length and Angle, IMEKO TC 14 Geometrical Quantities. The process of drafting EURAMET guides for calibration of stylus instruments and form measuring probes was initiated in the last meeting of EURAMET TC-L using the information produced in the good practice guides. It is expected that, beyond the project, there will be a contribution to a further revision of ISO 12179 - Use of depth setting standards for calibration of contact stylus instruments. The project results were also presented to GULFMET and AFRIMET.

Longer-term economic, social and environmental impacts

Measurement of form and surface finish parameters relate to functionality of manufactured parts. Better achievements for the desired tolerances on automotive parts will provide better engine parts working more efficiently with improved fuel savings, longer lifetime, reduction in waste and production time, which altogether will have a positive impact on the environment.

Manufacturers in advanced countries of Europe (such as Germany and France) are establishing manufacturing plants in other countries of Europe and also in Asia, Middle East and Africa. In order to sustain similar quality of the manufactured parts, there is a need for development of metrology capabilities in the respective countries. The project has already started providing this (e.g., some EU NMIs asked to use output of the project) for surface roughness and form measurements, which will in turn result in improvements of manufacturing processes. This will increase economic growth in Europe and its neighbouring region(s) and enhance industry competitiveness and will therefore be instrumental for creating jobs particularly in the production of parts in a cost-effective way.

List of publications

Baršić, G., Šimunović, V. (2021) '18PRT01 Probe Trace Traceability for contact probe and stylus instrument measurements', *6th INTERNATIONAL CONFERENCE, LABORATORY COMPETENCE 2021*, p. 70-75. Available at https://zenodo.org/record/7092497

Saraiva, Fernanda et al (2023) 'A novel traceability route to the SI in roughness measurements at IPQ', *Acta IMEKO*, 12(3) p. 1-5. Available at https://doi.org/10.21014/actaimeko.v12i3.1456

Wildner, K., Trych-Wildner, A., Sosinowski, P. (2022) 'Feasibility Study of a Piezo Actuator as a Potential Standard in Calibration for Roundness Instruments', *Sensors*, 22 p. 9312. Available at https://doi.org/10.3390/s22239312

Šimunović, V., Baršić, G. (2024) 'Evaluating the spindle error of the roundness measurement device', *Measurement: Sensors*, 32 101038. Available at https://doi.org/10.1016/j.measen.2024.101038

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 September 2019, 48 months	
Coordinator: Dr. Murat Aksulu, TUBITAK Tel: +90 535 5876750 E-mail: murat.aksulu@tubitak.gov.tr Project website address: http://www.probetrace.org		
Internal Funded Partners: 1. TUBITAK, Türkiye 2. BIM, Bulgaria 3. CEM, Spain 4. DMDM, Serbia 5. FSB, Croatia 6. GUM, Poland 7. INRIM, Italy 8. IPQ, Portugal	External Funded Partners: 9. NIS, Egypt	Unfunded Partners: 10. SASO-NMCC, Saudi Arabia
RMG1: ME, Montenegro (Employing organisation); FSB, Croatia (Guestworking organisation) (RMG contract terminated before the start)		