



## TC for Metrology in Length: Highlights and Challenges

Harald Bosse, PTB, TC-L chair

Madrid and Tres Cantos, Spain  
15 – 18 May 2017



Length

- Introduction
- JRP example: DriveTrain (ENG 58, call 2013)
- TC-L activities
- Macroscale 2017 within meeting week of TC-L and CCL-WG-MRA



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**MACROSCALE**

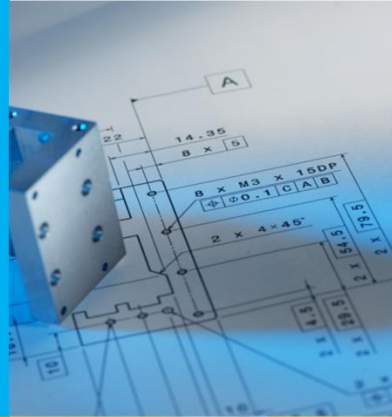
*Recent Developments in Traceable Dimensional Measurements*

# TC-L: Dimensional metrology

## - Areas of Impact



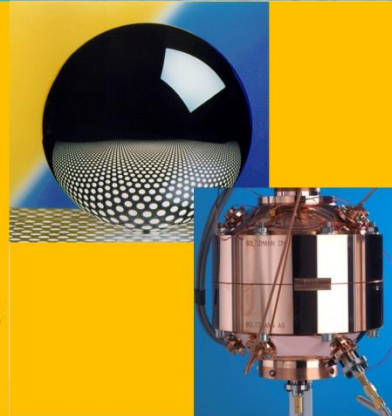
Traceability in dimensional measurements underpins all manufacturing, engineering and assembly industry worldwide, ensuring compatibility & interchangeability of parts.



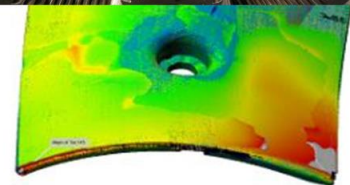
### Topics described in 4 TC-L Roadmaps

- Micro- and nanometrology
- Advanced manufacturing metrology
- Long range & large volume metrology
- Enabling fundamental science

Precision engineering and dimensional metrology are key to 3 **SI re-definitions** based on fundamental constants: form & dimension of **Avogadro** spheres and **Boltzmann** resonators, **Planck** balance interferometry



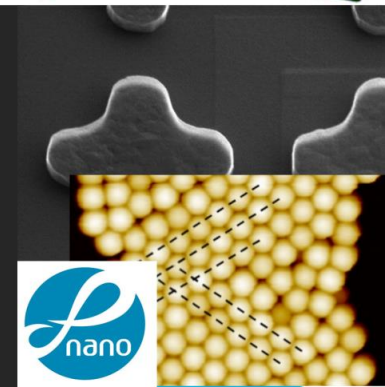
For new **science** (particle accelerators), **energy generation** (wind, civil nuclear), better accuracy & *in situ* calibration are speeding up manufacturing and enabling better efficiency, longer lifetimes. Solving gearbox problems is key to wind energy.



In aerospace, improving accuracy in aircraft assembly is reducing weight, reducing fuel burn (lower **environmental impact**, better **energy efficiency**). Key needs are accuracy and traceability for parts up to 40 m size.



Surface form and texture are critical to many nano-scale devices, particularly for *in-vivo* applications for **health**. Traceability infrastructure for 3D surface texture and simple dimensions on nano particles





# Open TC-L workshop on JRP results from EMRP calls in 2012

=> Overview: see TC-L presentation from 2016



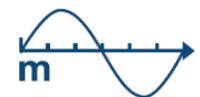
| Agenda   | Agenda  |
|--|---|
| Wednesday, Oct. 19, morning session  | Wednesday, Oct. 19, afternoon session   |
| 08:30 <b>Registration</b><br>VSL, Delft  | 13:15 <b>Lunch break</b>  |
| 09:00 <b>Welcome by host</b><br>Rob Bergmans, VSL, NL  | 14:00 <b>Crystalline surfaces, self assembled structures, and nano-origami as length standard in (nano)metrology</b> , <a href="#">CRYSTAL</a> , JRP SIB61<br>Ingo Busch, PTB, DE |
| 09:05 <b>Introduction to workshop</b><br>Harald Bosse, TC-L chairperson, PTB, DE   | 14:35 <b>Automated in-line Metrology for Nanoscale Production</b> , <a href="#">aim4np</a> , FP7: NMP.2012.1.4-3<br>Richard Koops, VSL, NL  |
| 09:15 <b>Metrology for long distance surveying</b> , <a href="#">Surveying</a> , JRP SIB60<br>Florian Pollinger, PTB, DE   | 15:10 <b>Angle metrology</b> , <a href="#">Angles</a> , JRP SIB58<br>Tanfer Yandayan, UME, TR   |
| 09:50 <b>Large volume metrology in industry</b> , <a href="#">LUMINAR</a> , JRP IND53<br>Andrew Lewis, NPL, UK   | 15:45 <b>Discussion and future planning: preparation for EMPIR Calls 2017</b><br>Jens Flügge, TC-L Convenor WG EMPIR  |
| 10:25 <b>Traceable in-process dimensional measurement</b> , <a href="#">TIM</a> , JRP IND62<br>Klaus Wendt, PTB, DE  | 16:15 <b>End of open TC-L workshop</b>  |
| 11:00 <b>Coffee break</b>  | 16:15 <b>Optional: Visits of selected VSL laboratories</b>  |
| 11:30 <b>Metrology for movement and positioning in six degrees of freedom</b> , <a href="#">6DoF</a> , JRP IND58<br>Jens Flügge, PTB, DE   |   |
| 12:05 <b>Multi-sensor metrology for microparts in innovative industrial products</b> , <a href="#">Microparts</a> , JRP IND59<br>Ulrich Neuschaefer-Rube, Christian Rothleitner, PTB, DE |   |
| 12:45 <b>Traceability for computationally-intensive metrology</b> , <a href="#">TraCIM</a> , JRP NEW06<br>Klaus Wendt, PTB, DE   |   |



**EURAMET  
TC-LENGTH**

**EMRP / EMPIR  
Open WORKSHOP**

**VSL, Delft, Netherlands  
October 19, 2016**



**Length**

# JRP Drivetrain (ENG 56, Call 2013)



Traceable measurement  
of drivetrain components  
for renewable energy systems



//Partner



EU: renewable energy target of at least 27%  
of final energy consumption by 2030

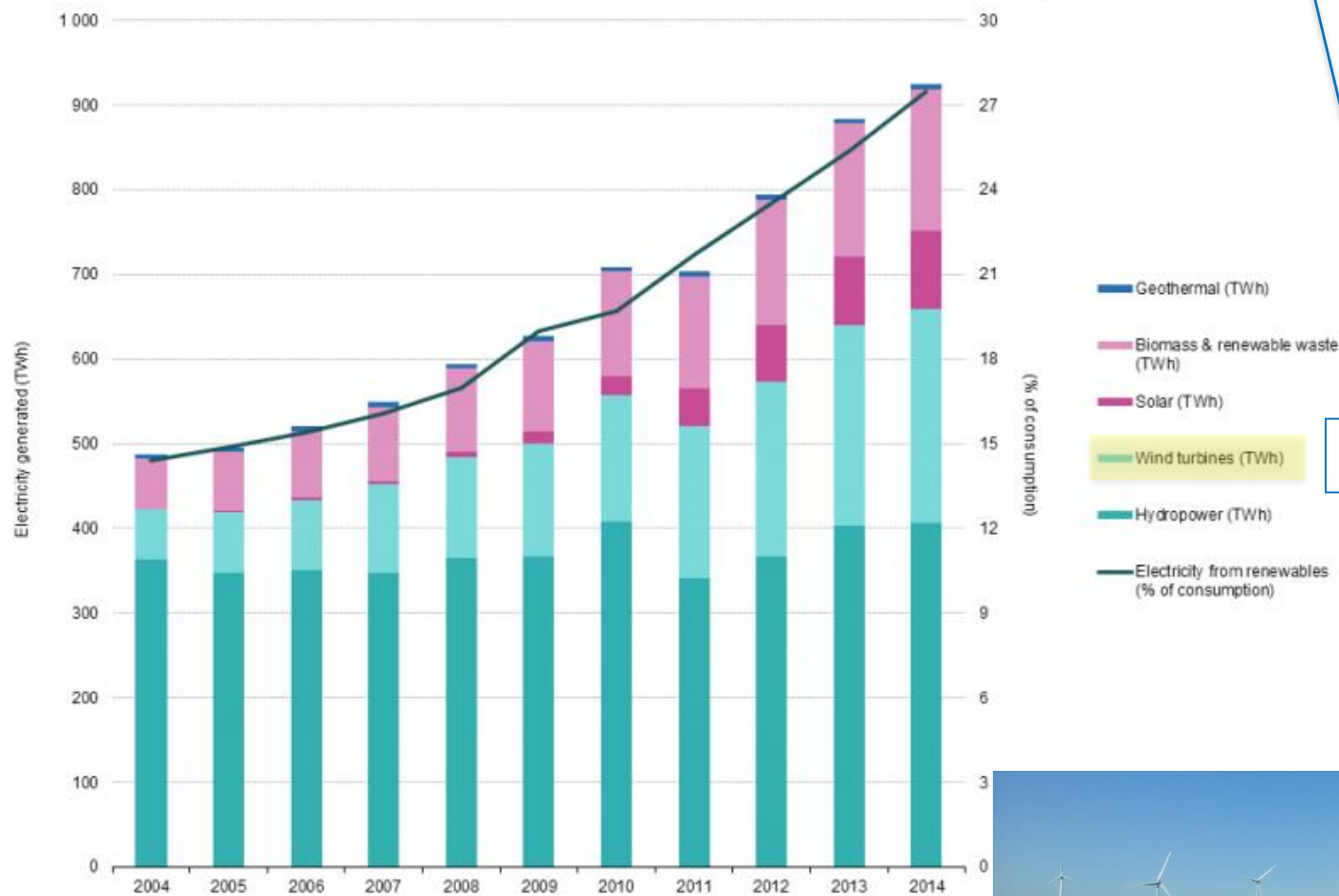


**EMRP**  
European Metrology Research Programme  
■ Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

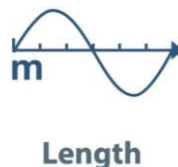


## Electric power generated from renewable energy sources EU-28, 2004–14

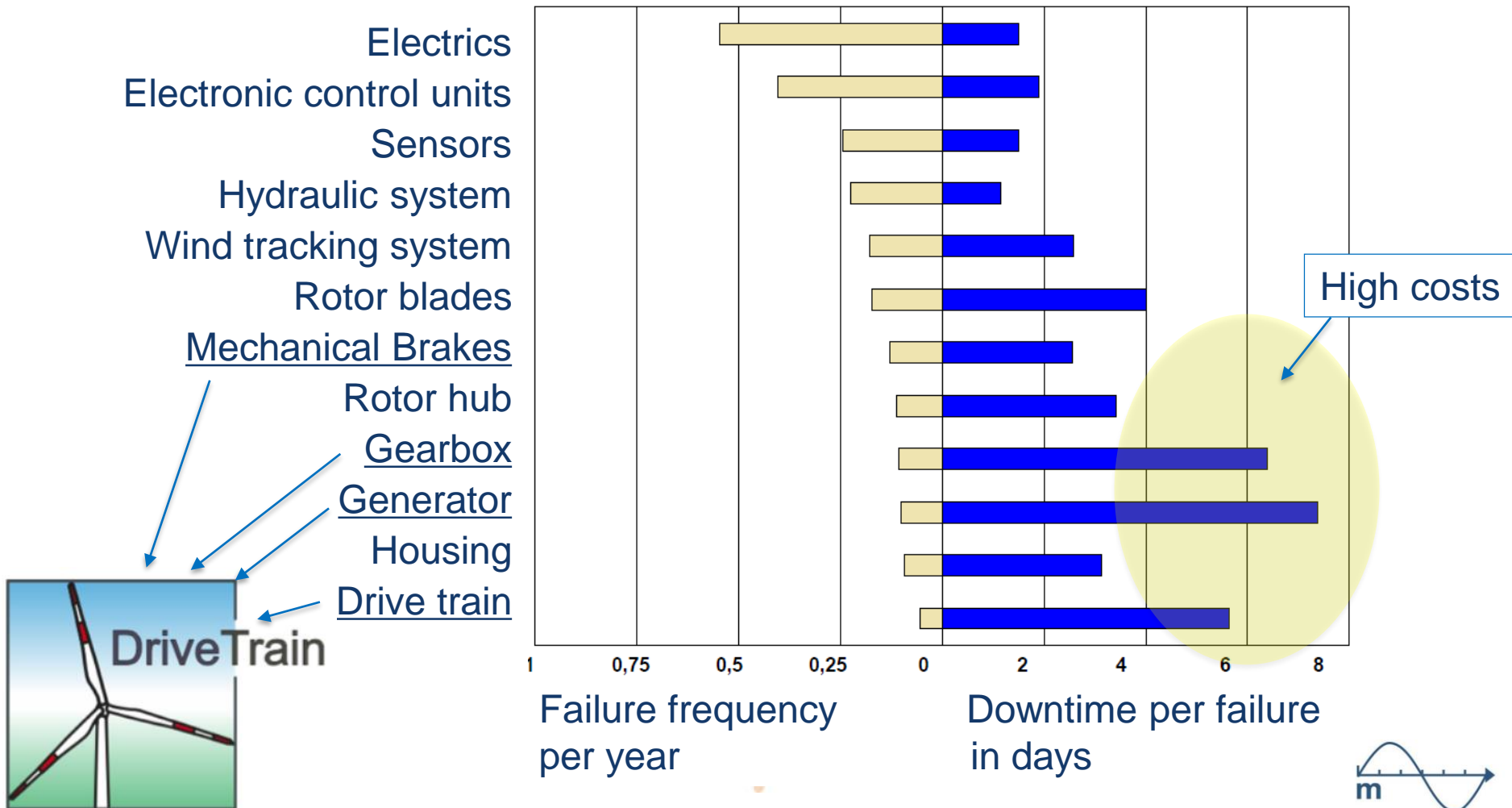


2015:  
DK: 42 %  
DE: 13 %  
UK: 11 %  
IT: 5.4 %  
FR: 4.6 %

=> 9%

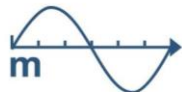


# Wind Power Systems: Analysis of system failures



Source:

Wissenschaftliches Mess- und Evaluierungsprogramm (WMEP) zum Breitentest "250 MW-Wind", 2007



# JRP DriveTrain (ENG 56, Call 2013)



Examples of developed standards:

## Bearing ring standard (340 kg):

- 800 mm outer diameter
- 600 mm inner diameter
- Form deviation:  $< 3,5 \mu\text{m}$
- kinematic support
- 12 temperature sensors



## Involute profile standard

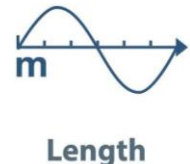
=> scanning CMM:

- 290 mm outer diameter
- 40 mm base circle
- Defined waviness:  
wavelength: 8,0 mm    2,5 mm    0,8 mm  
amplitude:    5,0  $\mu\text{m}$     3,0  $\mu\text{m}$     1,0  $\mu\text{m}$



Additional tasks:

- Thermomechanical modelling, virtual measuring process (=> MU), ...



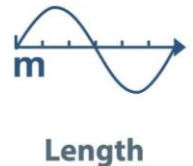
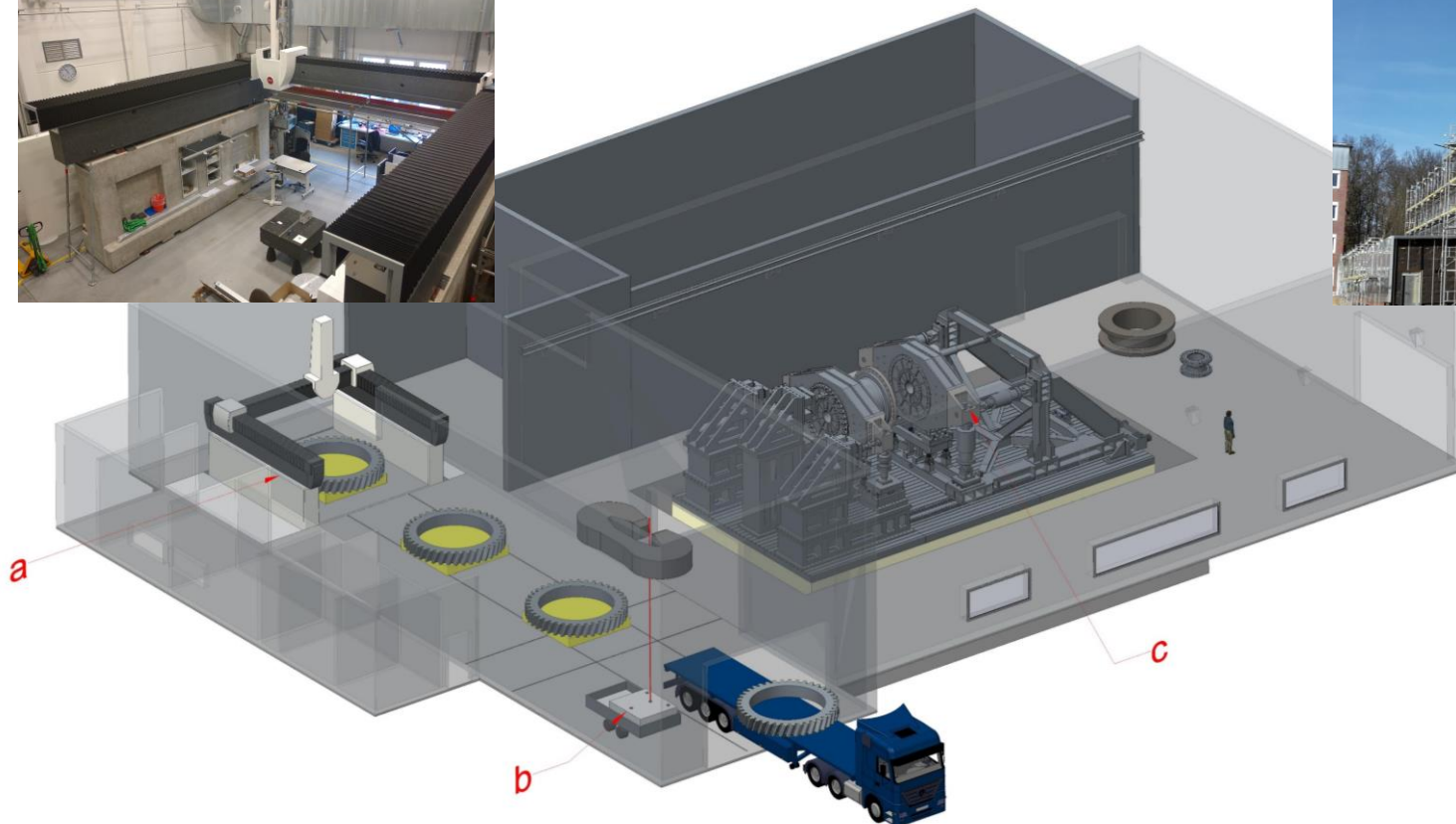


# PTB Competence Center WIND

funded by BMWI project (9.5 M€) and PTB (5.5 M€)



- Large CMM (5 m x 4 m x 2 m): to be installed in Oct. 2017 (PTB, Div. 5)
- Calibration facility for large torques (5 MNm => 20 MNm) (PTB, Div. 1)
- Calibration facility for wind velocity (3D vector) (PTB, Div. 1)



- Several ideas put forward for KCDB 2.0 discussion are similar approach in EURAMET TC-L & CCL-WG-MRA
- Restricted comparison portfolio based on key techniques, Executive Reports, ... <http://www.bipm.org/wg/AllowedDocuments.jsp?wg=CCL-WG>

| Principal Techniques                               | CCL-K1      | CCL-K2     | CCL-K3 |      | CCL-K4   | CCL-K5 |      | CCL-K6 | CCL-K7    | CCL-K8    |
|--|-------------|------------|--------|------|----------|--------|------|--------|-----------|-----------|
|  | gauge block | length bar | poly   | gau. | diameter | ball   | step | 2D CMM | linescale | surf tex. |
| <b>Realizing the Metre definition</b>              |             |            |        |      |          |        |      |        |           |           |
| Interferometry                                     | 2           | 2          |        |      | 2        | 2      | 2    | 2      | 2         | 1         |
| Wavelengths in air                                 | 2           | 2          |        |      | 2        | 2      | 2    | 2      | 2         | 1         |
| <b>Gauge Issues</b>                                |             |            |        |      |          |        |      |        |           |           |
| Temperature of Gauge                               | 1           | 2          |        |      | 2        | 2      | 2    | 2      | 2         | 1         |
| Mounting & Aligning                                | 1           | 2          | 2      |      | 2        | 2      | 2    | 2      | 2         | 1         |
| <b>Wavefront Probing</b>                           |             |            |        |      |          |        |      |        |           |           |
| Reflection Phase Effects                           | 2           | 1          |        |      |          |        |      |        |           |           |
| Wringing   | 2           | 1          |        |      |          |        |      |        |           |           |
| <b>Mechanical Probing</b>                          |             |            |        |      |          |        |      |        |           |           |
| Stylus contacting at surface, 1-D                  |             |            |        |      | 2        | 1      | 2    | 1      |           | 2         |
| Bi-directional probing for size                    |             |            |        |      | 2        |        | 2    |        |           |           |
| Probing for 3-D center coordinates                 |             |            |        |      |          | 2      |      | 2      |           |           |
| <b>Image Probing</b>                               |             |            |        |      |          |        |      |        |           |           |
| Sensing Line Centres                               |             |            |        |      |          |        |      |        | 2         |           |
| <b>Angle Metrology</b>                             |             |            |        |      |          |        |      |        |           |           |
| Measuring small angles (autocoll.)                 |             |            | 1      | 2    |          |        |      |        |           |           |
| Large Angle Gen: Circle Dividers                   |             |            | 2      | 1    |          |        |      | 1      |           |           |
| Small Angle Gen: SineBar, CircDiv.                 |             |            |        | 2    |          |        |      |        |           |           |
| <b>Formal mathematical processing of data sets</b> |             |            |        |      |          |        |      |        |           |           |
| ISO parameter extraction                           |             |            |        |      |          |        |      |        |           | 2         |
| <b>Form Metrology</b>                              |             |            |        |      |          |        |      |        |           |           |
| Flatness   |             |            |        |      |          |        |      |        |           | 1         |
| Roundness  |             |            |        |      | 1        |        |      |        |           |           |
| Thread, Gear Profile                               |             |            |        |      |          |        |      |        |           |           |
| 3-D Surface  |             |            |        |      |          |        |      |        |           | 1         |



Length

# Macroscale 2017 conference



**MACROScale** *Recent Developments in Traceable Dimensional Measurements*

- **October 17<sup>th</sup> - 19<sup>th</sup>, 2017, VTT-MIKES, Espoo, Finland**
- Co-organized by  
- In cooperation with EURAMET **TC-L** and the **Consultative Committee for Length (CCL)**
- Forum for reports on current trends and developments in the field of traceable dimensional measurements
- Around 100 participants from all continents expected
- Selected papers will be published in special issue of:

Measurement  
Science and Technology

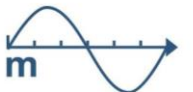


- Macroscale 2017 follows Macroscale 2011 & 2014 and former SPIE conference series “*Recent Developments in Traceable Dimensional Measurements*”
- Supported by:  **HELMHOLTZ  
FONDS e.V.**



Length

- Congratulations to EURAMET from TC-L



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