TC Length

Highlights and challenges

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Outline

- Highlights TC-L 2011/2
- Challenges in length metrology
  - Roadmap update
  - New triggers & targets

TC-L highlights:
TC-L meeting & Macroscale 2011 conference

- **TC-L 2011** meeting was organized at METAS, Wabern 3.-4. October 2011
- It was immediately followed by **Macroscale 2011 conference** with ~100 participants from all RMO areas, industry and universities

TC-L highlights: 2010 & 2011 EMRP calls

TC-L community was quite successful in 2010/2011 calls

- Funded projects have strong connections to Academia and industry
- In 7 length projects there are 17 university groups and 9 companies as partners
- These JRPs also had ~60 supporters from industry and academia
- In addition at least 6 JRPs with some dimensional metrology related research

First meeting of TC-L EMRP working group at PTB 2/2012

~open meeting with 40 participants

Funded length and length related JRPs

2010	IND05	MeProVisc	Dynamic Mechanical Properties and Long-term Deformation Behaviour of Viscous Materials
	IND10	**Form metrology**	**Optical and tactile metrology for absolute form characterization**
	IND11	**MADES**	**Metrology to Assess the Durability and Function of Engineered Surfaces**
	IND13	**Themal design and dimensional drift**	**Thermal design and time-dependent dimensional drift behaviour of sensors, materials and structures**
	IND14	Frequency	New generation of frequency standards for industry
	IND17	**Scatterometry**	**Metrology of small structures for the manufacturing of electronic and optical devices**
2011	HLT02	MetVes	Metrological characterisation of micro-vesicles from body fluids as non-invasive diagnostic biomarkers
	SIB08	**Subnano**	**Traceability of sub-nm length measurements**
	NEW01	TReND	Traceable characterisation of nanostructured devices
	NEW05	**MechProNO**	**Traceable measurement of mechanical properties of nano-objects**
	NEW06	**TraCIM**	**Traceability for computationally-intensive metrology**
	NEW08	MetNEMS	Metrology with/for NEMS
	NEW09	METCO	Metrology of electro-thermal coupling for new functional materials technology

EMRP call 2010; Metrology for industry: Form metrology

Optical and tactile metrology for absolute form characterization, Michael Schulz, PTB

Project Partners:

NMIs

Research inst. & Univ.

PTB, CMI, METAS, LNE, MKEH, SMD, VSL

Fraunhofer Institute for Production Technology, TNO, Technical University of Illmenau, Universität of Stuttgart

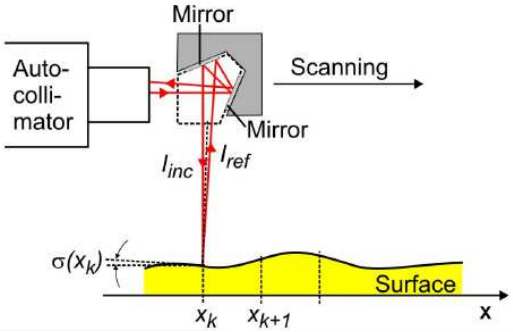
XPRESS Precision Engineering, IBS Precision Engineering

Companies

Form measurements:

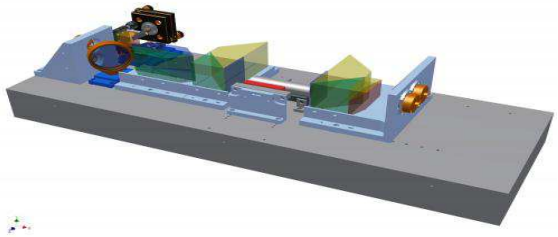
- on flat surfaces with uncertainties < 1 nm and
- on curved surfaces with uncertainties < 10 nm

using imaging (interferometric) and scanning (optical and tactile) methods, developing software for the handling of a large number of data points, investigating error influences for interferometric and tactile scanning methods by modelling and simulation.



EMRP call 2010; Metrology for industry: Thermal design and dimensional drift

Thermal design and time-dependent dimensional drift behavior of sensors, materials and structures, Jens Flügge (PTB)



Project Partners:

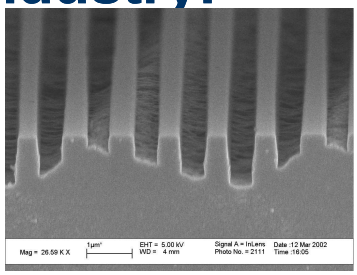
PTB , LNE, NPL, VSL, ENSMA, FhG, TU Ilmenau

- Development of test facilities, techniques and procedures for measurements of dimensional drift
- Investigation of long term drift properties of sensors, materials and structures;
- Measurement of thermal behaviour of materials and structures, modelling and optimisation of thermal design.

Collaborators

FOGALE nanotech, HEIDENHAIN, PHILIPS, Agilent Technologies, M+W GROUP, IBS, TNO, KLA-Tencor, RENISHAW, SIOS, ZEISS, ASML, esa

EMRP call 2010; Metrology for industry: Scatterometry



Metrology of Small Structures for the Manufacturing of Electronic and Optical Devices, Bernd Bodermann (PTB)

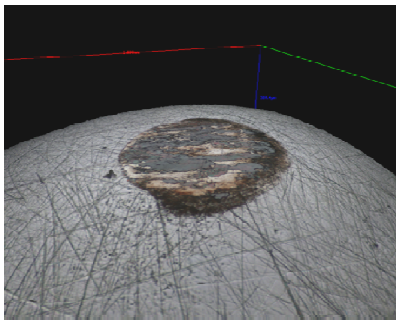
Project Partners:
PTB, CMI, DFM, MIKES, VSL, NPL, UEF, DUT, Nanocomp, JCMwave

- Scatterometry and CD-SEM for metrology of advanced functional structures in the sub micrometer-range: micro-structured surfaces, IC processing, diffractive optical elements
- Validation and optimisation for applications in industry
- Development of ”golden” reference standards for metrology in wafer processing

Collaborators

ASML, Fraunhofer IOF, NIL TECHNOLOGY, SIOS, HEIDENHAIN, Ignis, ZEISS, We make it visible., TUDelft, National Institute of Standards and Technology, NIST

EMRP call 2010; Metrology for industry: MADES



Metrology to Assess the Durability and Function of Engineered Surfaces, Mark Gee (NPL)

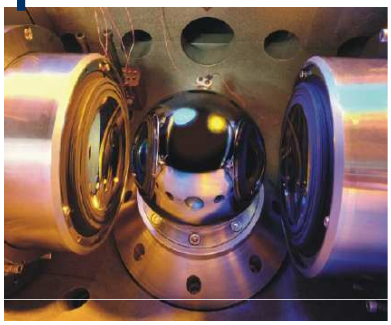
Project Partners:
NPL, BAM, CNAM, DTI, INRIM, MIKES, PTB, FAU, VTT, Alicona

Fundamental aspects of metrology for tribology:

- measurement of very small wear volumes
- long term measurement of low friction
- measurement of the temperature at wear interfaces
- measurement of changes in chemistry that occur at the contact interface between surfaces
- development of methods for the assessment of the durability of tribological surfaces

TecVac - IonBond - Teer Coatings
Phoenix Tribology - Tetra - Airbus
Rolls Royce - Aero Engine Controls
Sandvik - Glud - Marstrand
nCATS - E-Surf! - VITO VAMAS

EMRP call 2011; SI broader scope: Subnano



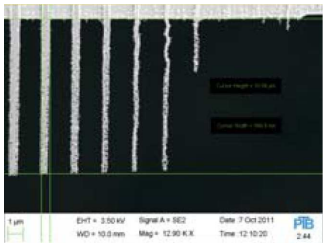
Traceability of sub-nm length measurements, Birk Andreas (PTB)

Project Partners:
PTB, CMI, MIKES, NPL, UME, VSL, INRIM, TUDelft, Università di Torino

The purpose of this JRP is to enable traceable measurements in the sub-nm range for optical interferometers as well as improved capacitive sensors.

- Modeling: wave front aberration for interferometers, capacitive sensors alignment & environment
- Measurement devices technology: wave front sensor, interferometers development, capacitive sensor studies, x-ray interferometer
- Cross validation

EMRP call 2011; New Technologies: MechProNo



Traceable measurement of mechanical properties of nano-objects, Ludger Koenders (PTB)

Project Partners:

PTB, BAM, CMI, MIKES, NPL, TU Dresden, Uni Helsinki

- Traceable force and displacement calibration of nanomechanical test systems (force range 10 mN to 10 pN, displacement resolution 0.1 nm)
- Provision of reference materials
- Development of validated modeling techniques
- Validated procedures to characterize size, shape and mechanical properties of nano-objects
- Intercomparison to evaluate the effectiveness of using reference materials

EMRP call 2011; New Technologies: TraCIM

Traceability for computationally intensive metrology, Alistair Forbes (NPL)

Project Partners:

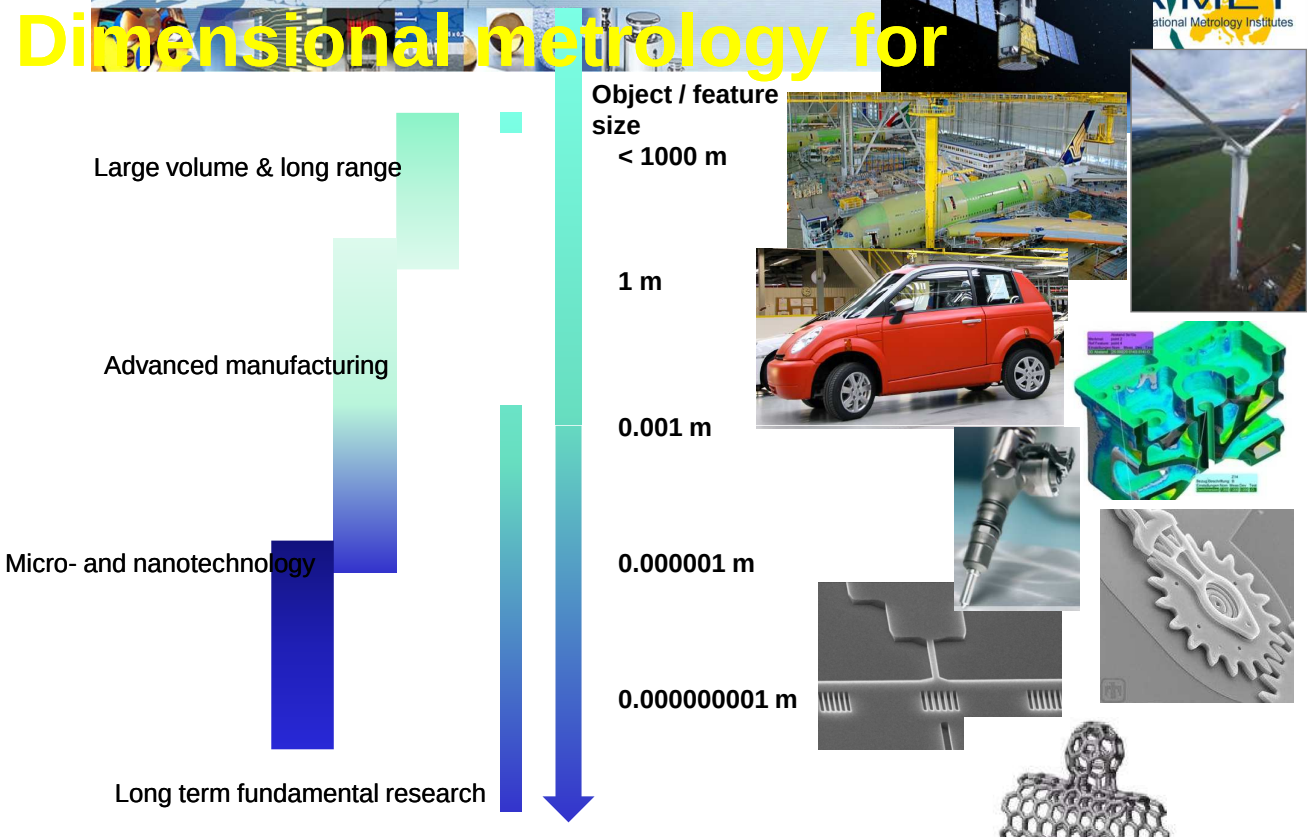
NPL, CMI, INRIM, PTB, UM, VSL, Uni Huddersfield, Uni Zwickau Hexagon, Mitutoyo, Werth, Zeiss

- Developing a coherent framework for establishing traceability in computationally-intensive metrology, like e.g. 3D coordinate metrology
- Encoding formal statements of computational aims in clear, unambiguous terms
- Reference data (or numerical artefacts, numerical standards, softgauges) associated with computational aims, Data Generators
- Criteria to assess the performance of software
- Enabling ICT to perform the software validation or ‘numerical calibration’

Challenges of length metrology

- TC-L WG EMRP 2/2012
  - Decided to maintain the topics of EMRP roadmaps, but to update content
  - Draft versions of the updated roadmaps ready last week

Dimensional metrology for



Large volume & long range metrology

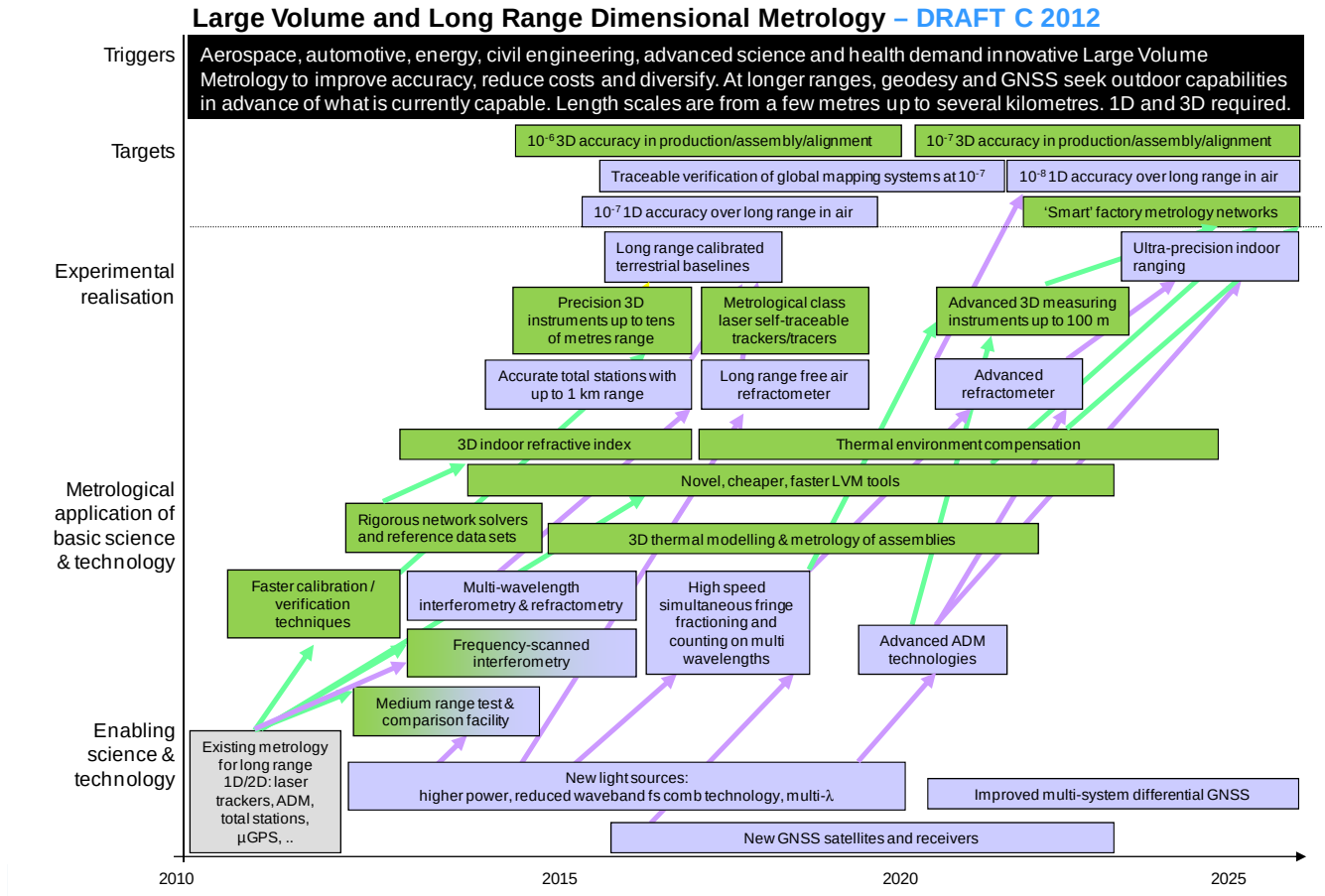
New triggers:

- Next generation **'super jumbo' aircraft** are now routinely manufactured: needs to improve automation and assembly accuracy
- Increasing need of **renewable energy sources (wind, future fusion, re-consideration of nuclear fission new build)**. =>**large scale civil engineering**.
- **Galileo** satellites have been launched => validated **improvement in accuracy**
- European industry focusing to **lower-volume, high-value, customised manufacturing** – the concept of the 'smart factory' which uses omnipresent metrology.

Large volume & long range metrology

New targets:

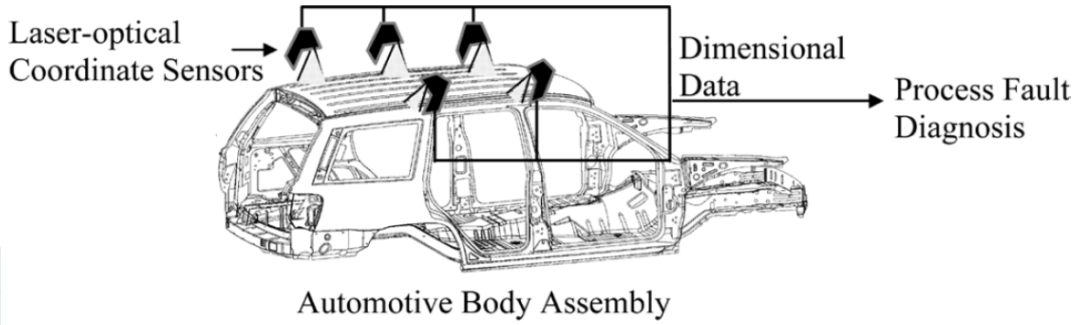
- **3D refractive index** covering the typical working volume of a factory, eventually to 10^{-6} or 10^{-7} accuracy level, to enable omnipresent optical metrology systems.
- Techniques for **thermal compensation of large structures** which cannot be assembled in controlled environments.
- Novel measuring systems based on innovative technologies, taking **accurate metrology directly to the shop-floor**, whilst lowering costs, to extend the uptake by smaller companies (SMEs).



Advance manufacturing

New triggers:

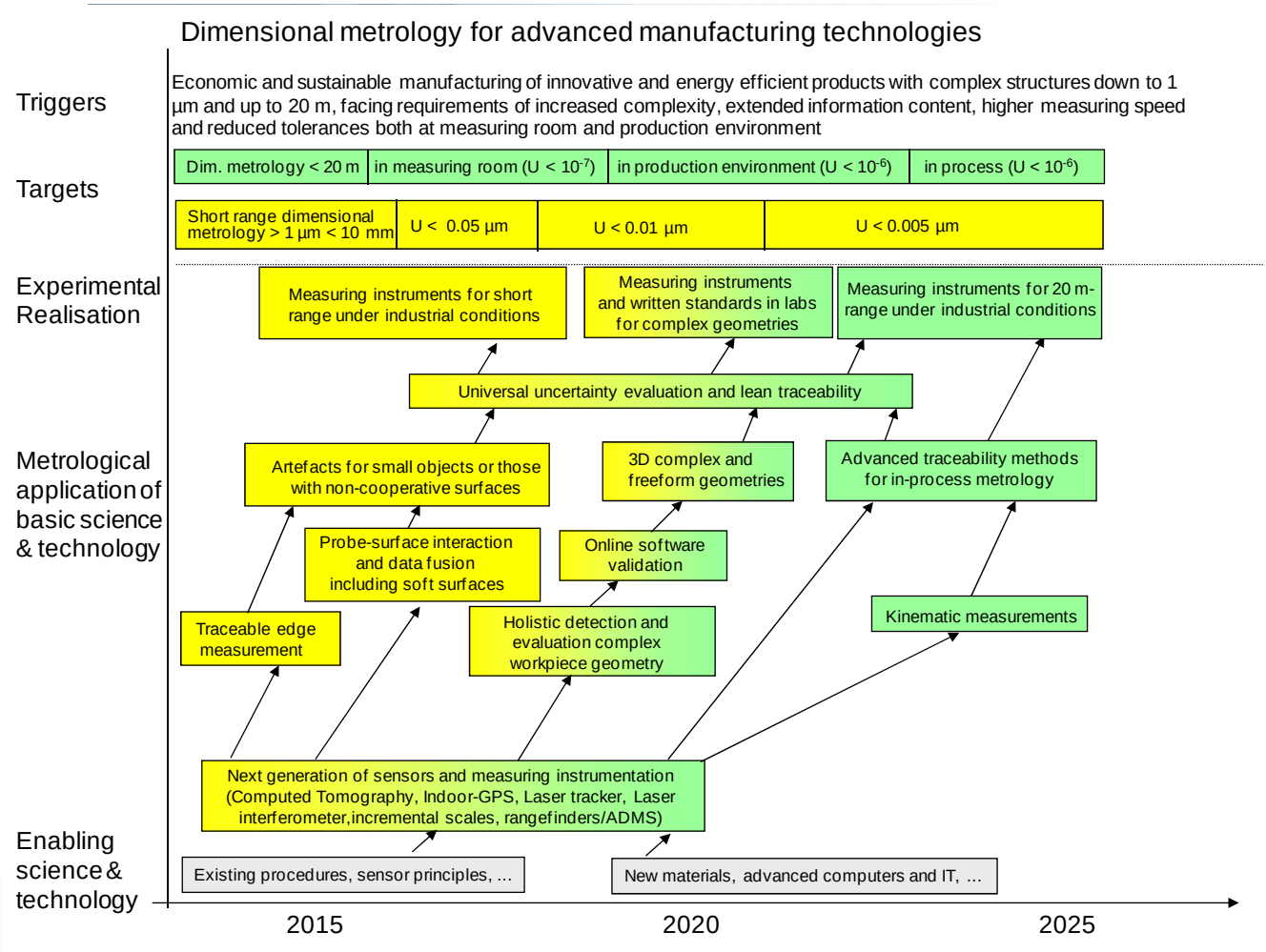
- European industry focusing to **lower-volume, high-value, customized manufacturing** – the concept of the 'smart factory' which uses omnipresent metrology.
- **In process coordinate measurement** is becoming an important tendency of high accurate and cost efficient production.
- **Lean calibration concept** is spreading in car and aviation industry, requires new inline concepts

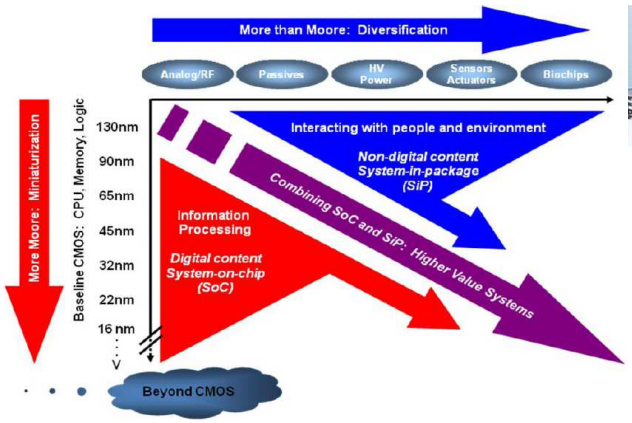


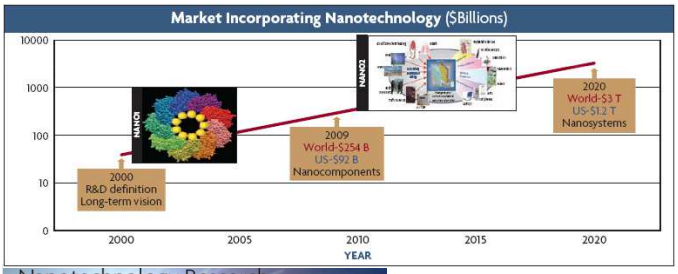
Advance manufacturing

New targets:

- traceable **inline metrology tools in production** environment
- **traceable lean calibration methods** for industry
  - transfer standards, artefacts
  - probe sample interaction with various sensors
  - software validation
  - etc.







Micro- and nanotechnology

New triggers:

Semiconductor Industry.:

- ITRS2011
  - **Every year 5-10%** higher accuracy demand
  - Nanoelectronics: size is critical

Nanotechnology:

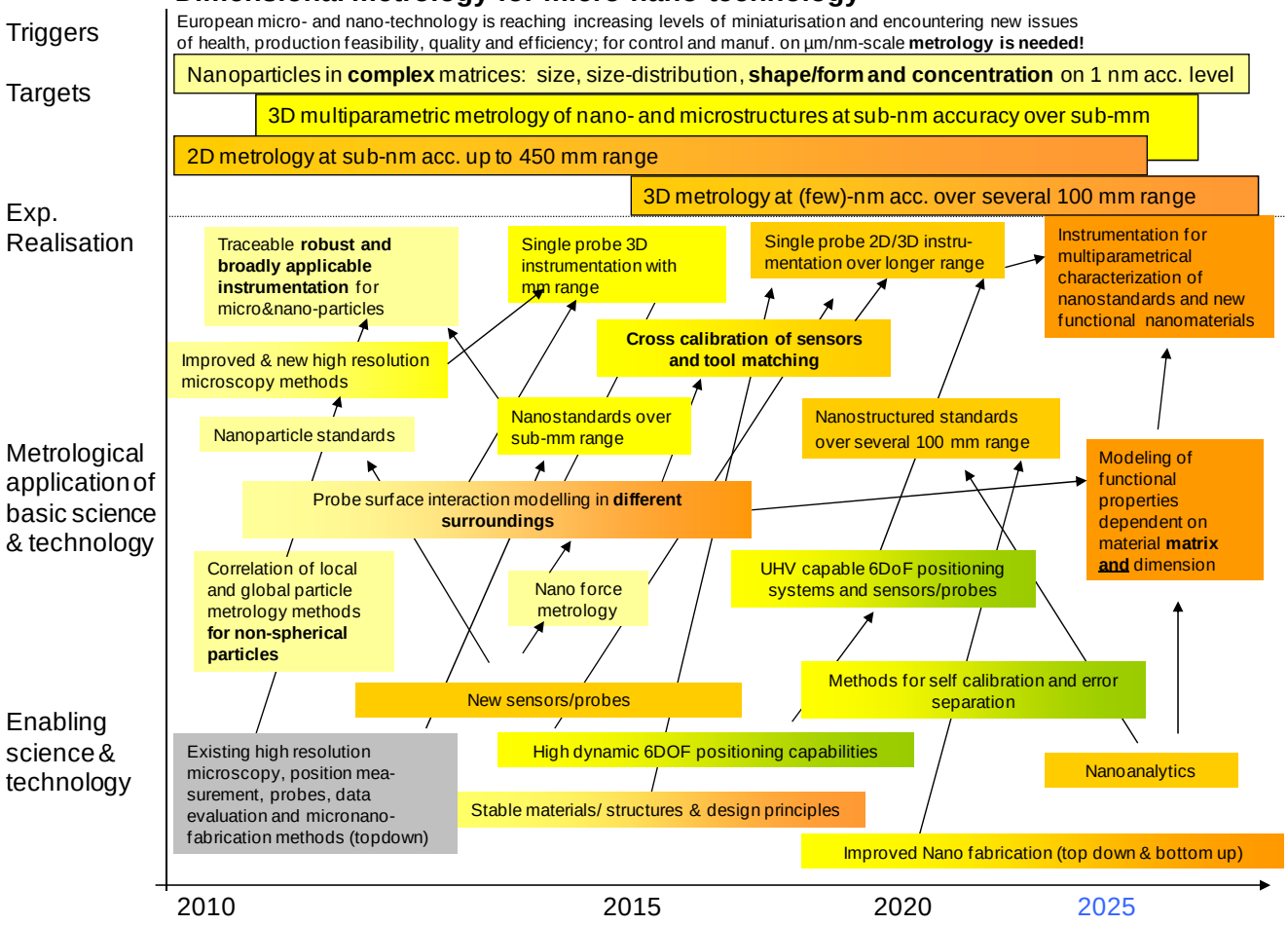
- WTEC report
  - **Nano2 phase 2010-2020**
  - Production **doubles every 3rd years**
  - **Improved metrology tools needed**
- CEN-352
  - **Standardization** for nanotechnology
  - Health, safety and environmental concerns

Micro- and nanotechnology

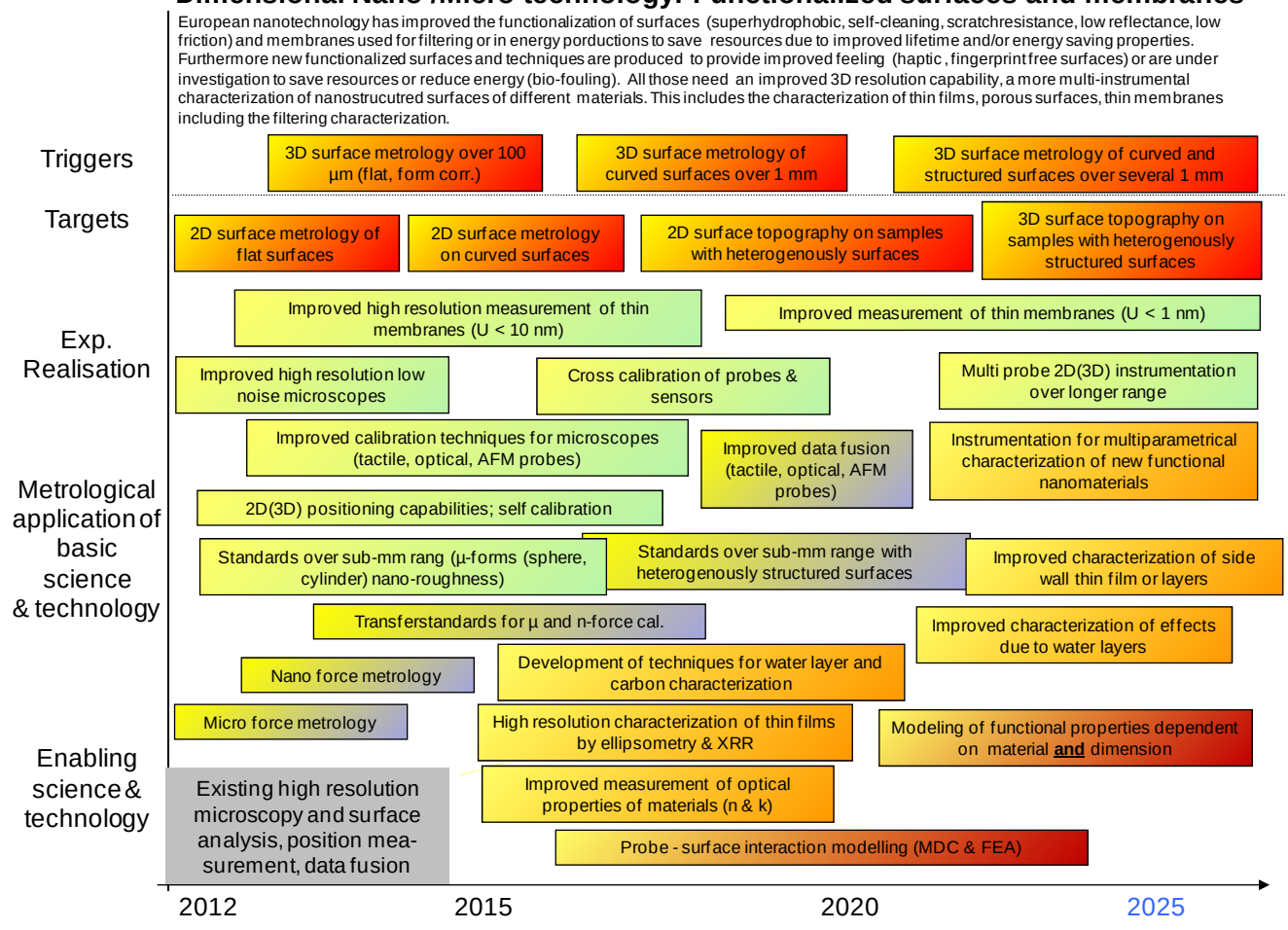
New targets:

- **Multiparametric metrology of nanostructures** : size(3D), shape, thickness, overlay and materials characteristics at the sub-nm level
- **6 DOF metrology stages with sub-nm uncertainty** and thermal- and long-term stability in ambient and vacuum conditions
- **Shape and form** measurements of nano-particles and **nano-objects**, like fibres, rods, wires, plates or surfaces
- **Traceability for the shop floor**
- Multi-parameter **measurements in different media** (solid, air, liquid) and state (individual or agglomerate): Dimensional: (size, size-distribution, shape morphology, porosity, concentration)

Dimensional metrology for micro-nano technology



Dimensional Nano /Micro technology: Functionalized surfaces and membranes



Dimensional metrology for fundamental research

New targets & triggers:

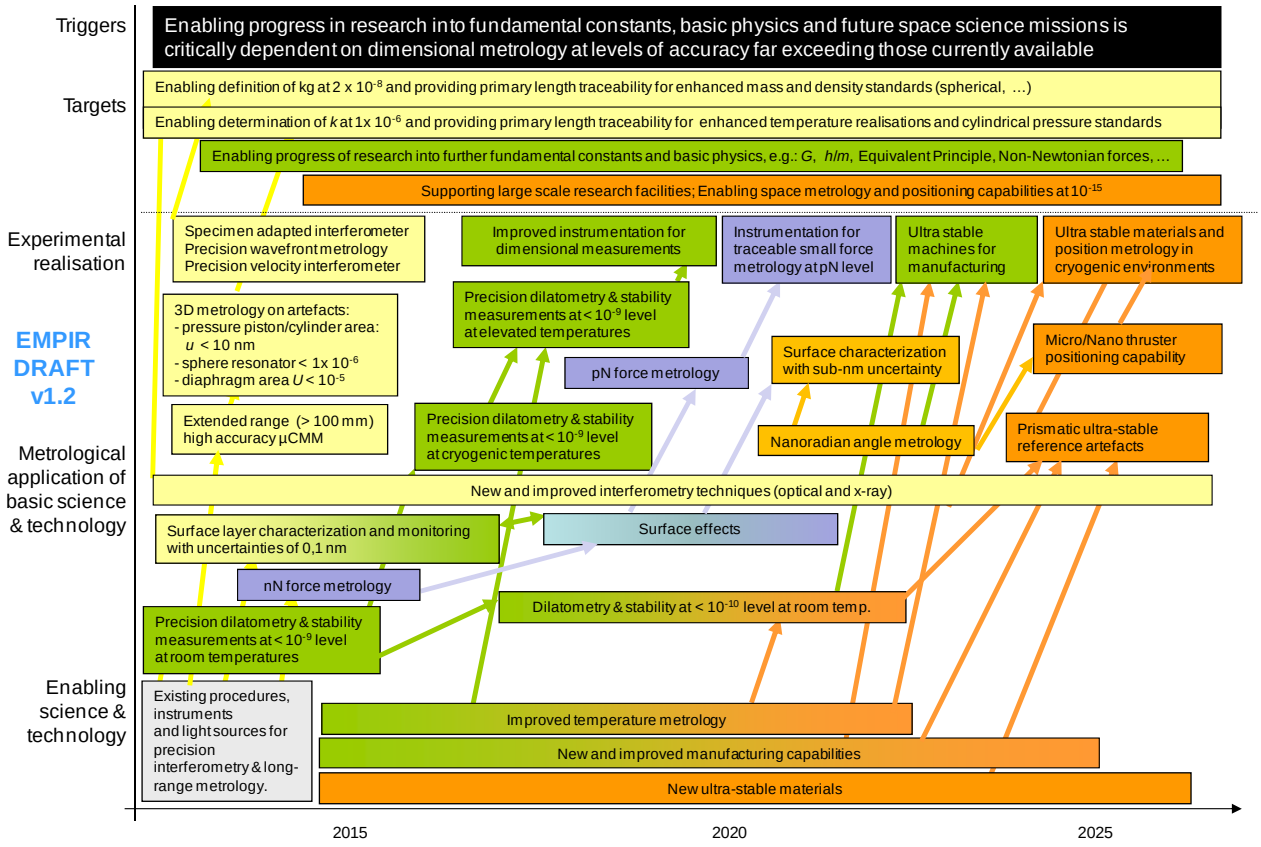
Re-definition of the SI

- mass unit, kg, Avogadro route (sphere d), Watt balance route (weight v)
- temperature scale, Boltzmann constant k, Dielectric-Constant Gas Thermometry (DCGT) route (piston A), Acoustic Gas Thermometry (AGT) route (resonator d)

Fundamental research

- Gravitational constant G (torsion balance l, α)
- $N_A \cdot h$, (α, nrad)
- equivalent principle
- non-Newtonian forces
- …

Dimensional metrology as enabling technology for long-term fundamental research – EMPIR, Mod1



Extraordinary Length comparison between Finland and Denmark

Height comparison
October 30, 2010

Allure of Seas from STX Europe's Turku Shipyard, FI
Nominal height
H =64.85 m

Meets (v= 40 km/h)

Great Belt Bridge, DK
Nominal height
H =65 m