

The EMN for Advanced Manufacturing and its view on Digital Transformation

The logo for the Advanced Manufacturing Network, featuring the text "Advanced Manufacturing Network" in a blue, sans-serif font, with a small red and white circular icon to the right of the word "Advanced".

Advanced
Manufacturing
Network

Metrology for Digital Transformation
Online Sessions

23 - 24 & 29 September 2021

Harald Bosse, harald.bosse@ptb.de

Outline

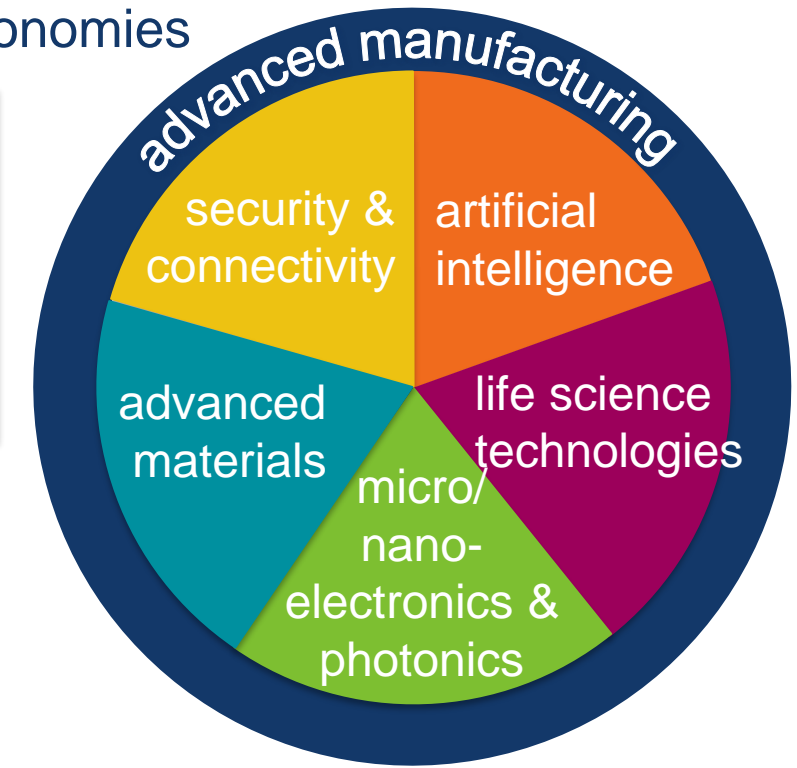


- Advanced Manufacturing as Key Enabling Technology
- The new European Metrology Network for Advanced Manufacturing
- Digitalization in manufacturing industry: INDUSTRY 4.0
- Virtual Instruments
- Software Validation
- Data Interfaces for Manufacturing Integration
- QI Digital and Digital SI: links to manufacturing
- Summary and outlook



Advanced manufacturing (EC): one of six Key Enabling Technologies (KETs)

- Applications in multiple industries
 - full exploitation of KETs: creating advanced & sustainable economies
- European Technology Platform **MANUFuture**:
 - Vision 2030 strategy document (HLG, 12/2018):
- **Manufacturing: backbone of European economy**
- 2014: 2.1 million enterprises, 30 million people, 1 710 B€. However: European manufacturing has been losing ground
- In 2030, European manufacturing will be competitive at global level due to its high-performance and technological level, targeting **zero-defect, zero-delay, zero-surprise and zero-waste production processes**

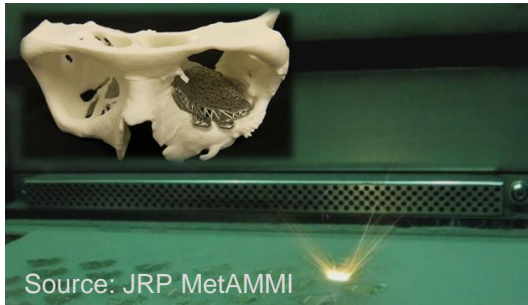


prioritised **KETs** in the Horizon Europe programme 2021-2027 (EC)

Metrology demands in Advanced Manufacturing

Aim for production processes:

zero-defect



Example:

- Additive Manufacturing:
- in-process metrology
 - fast & holistic metrol.

zero-delay



Example:

- Machine tools:
- improved control by 5G sensor technology
 - sensor integration: metrology data interface

zero-surprise



Example:

- Lithography tools:
- full simulation of relevant processes
 - metrology tools using AI data algorithms

zero-waste



Example:

- Machine tools & Additive Manufacturing:
- less scrap via hybrid manufacturing chains (MT & AM)
 - reduced energy consumption by advanced machining processes

General structure of manufacturing chains

- Advanced Materials
- Smart Manufacturing Systems
- Manufactured Components and Products



EMN sections

Examples of Joint Research Projects (JRP) related to advanced manufacturing

JRPs in IND Calls 2014&2017
related to advanced manufacturing

Project #	Acronym	Project name (coordinator)
17IND02	SmartCom	Communication and validation of <u>smart data</u> in IoT-networks (PTB)
17IND03	LaVA	<u>Large Volume Metrology Applications</u> (NPL)
17IND04	EMPRESS 2	Enhancing process efficiency through <u>improved temperature meas. 2</u> (NPL)
17IND05	MicroProbes	Multifunctional <u>ultrafast microprobes</u> for on-the-machine measurements (PTB)
17IND08	AdvanCT	<u>Advanced CT</u> for dimensional and surface measurements in industry (PTB)
17IND12	Met4FoF	Metrology for the <u>Factory of the Future</u> (PTB)
14IND03	Strength-ABLE	Metrology for <u>length-scale engineering</u> of materials (NPL)
14IND07	3D Stack	Metrology for manufacturing <u>3D stacked integrated circuits</u> (LNE)
14IND09	MetHPM	Metrology for <u>highly-parallel manufacturing</u> (NPL)
14IND12	Innanopart	Metrology for <u>innovative nanoparticles</u> (NPL)
14IND13	PhotInd	Metrology for the <u>photonics industry</u> - optical fibres, waveguides & appl. (MIKES)
14IND14	MNm Torque	<u>Torque measurement</u> in the MN•m range (PTB)

JRPs in HLT & ENG Calls
related to adv. manuf.

15HLT09	MetAMMI	Metrology for <u>additively manufactured medical implants</u> (LNE)
19ENG07	Met4Wind	Metrology for enhanced reliability and efficiency of <u>wind energy systems</u> (PTB)

EURAMET'S EUROPEAN METROLOGY NETWORKS

Close collaboration in measurement science with a new sustainable structure

The vision of EURAMET and its members is to ensure Europe has a world-leading metrology capability, based on high-quality scientific research and an effective and inclusive infrastructure, that meets the rapidly advancing needs of end users. EURAMET's European Metrology Networks (EMNs) help realising this aim.

Currently there are nine EMNs: [Advanced Manufacturing](#), [Climate and Ocean Observation](#), [Energy Gases](#), [Mathematics and Statistics](#), [Quantum Technologies](#), [Radiation Protection](#), [Smart Electricity Grids](#), [Smart Specialisation in Northern Europe](#), and [Traceability in Laboratory Medicine](#).

The EMNs will analyse the European and global metrology needs and address these needs in a coordinated manner. EMN members will then formulate common metrology strategies including aspects such as research, infrastructure, knowledge transfer and services. The members will be committed to contributing to the EMN, helping to establish sustainable structures that are strategically planned from the outset.

By providing a single point of contact for information, underpinning regulation and standardisation, promoting best practice and establishing a comprehensive, longer-term infrastructure, the EMNs aim to create and disseminate knowledge, gain international leadership and recognition, and build collaboration across the measurement science community.



Background of the EMN: JNP as supporting project

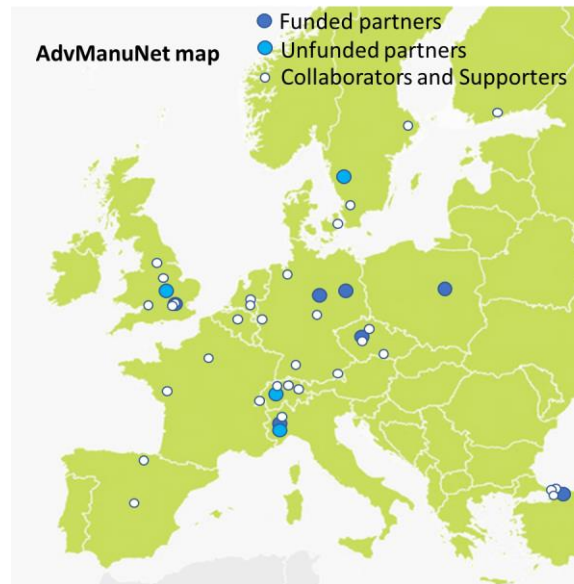
JNP [19NET01](#) AdvManuNet
4 years, start 6/2020: Project partners



euspen HQ, UK:
Dishi Phillips



NPL, UK:
Daniel O'Connor



BAM, DE:
Alexander Evans



RISE, SE:
Olena Flys



METAS, CH:
Felix Meli



PTB, DE:
Harald Bosse
JNP coordination



CMI, CZ:
Vit Zeleny



GUM, PL:
Dariusz Czulek



PTB, DE:
Anita Przyklenk



INRIM, IT:
Alessandro Balsamo



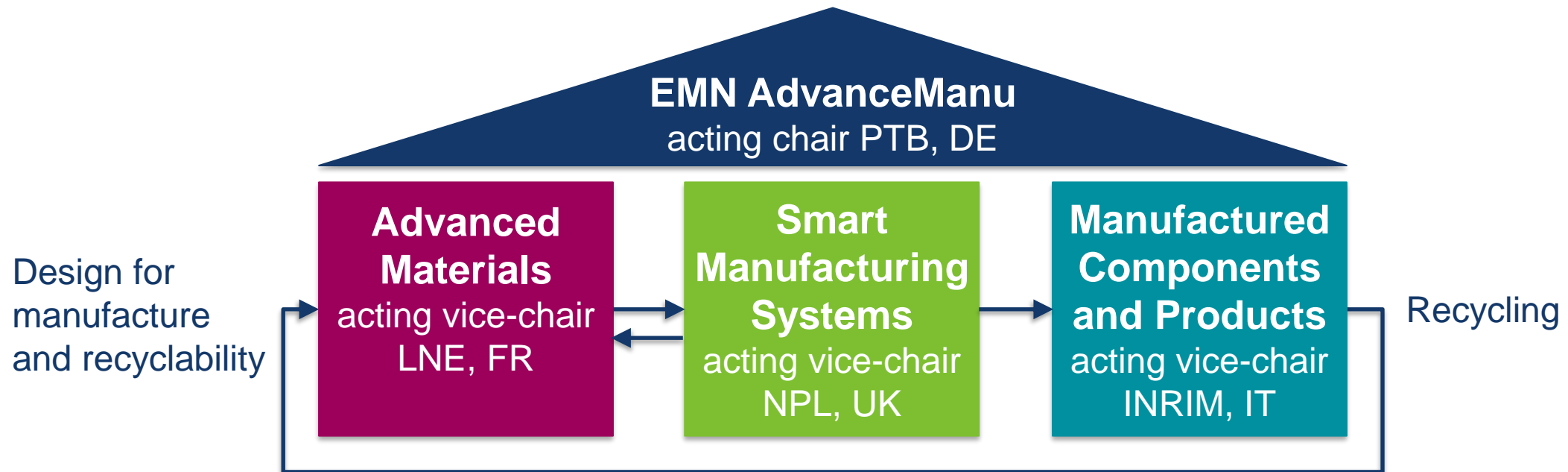
POLITO, IT:
Carlo Stefano Ragusa



TUBITAK UME, TR:
Tanfer Yandayan

EMN for Advanced Manufacturing

- EMN for Advanced Manufacturing approved on June 7, 2021
- EMN is organised in three sections:



- Formal kick-off meeting on Oct 11-12, 2021
- Engage with Stakeholders (Large companies & SME, industry organiz., networks, academia, ...)
- Prepare Strategic Research Agenda (SRA / Roadmap) for Metrology for Advanced Manufacturing
- Prepare [Orientation Papers](#) for calls of the [European Partnership for Metrology](#) ➡ [Green Deal](#)

EMN: current status

OPEN ACCESS

IOP Publishing

Measurement Science and Technology

Meas. Sci. Technol. 32 (2021) 111001 (14pp)

<https://doi.org/10.1088/1361-6501/ac0d25>

Perspective

New European Metrology Network for advanced manufacturing

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Introductory Meeting of EMN Advanced Manufacturing

The European Metrology Network for Advanced Manufacturing has been approved by the General Assembly of EURAMET on 7 June 2021.

In this introductory meeting

- an overview will be given on the objectives of the EMN,
- the support provided by JNP AdvManuNet will be presented and
- the next steps within the EMN will be discussed.

The meeting will be complemented by a keynote presentation of a stakeholder council member and an overview of partner organisations of the EMN.

EVENT INFORMATION

DATE

2021-06-23 to 2021-06-23

LOCATION

Online Meeting

CATEGORIES

EMNs (European Metrology Networks), EMN Advanced Manufacturing

European Metrology Network for Advanced Manufacturing stakeholder meeting 2021 Agenda



Time

11 October 2021 13:00 – 17:30 (CEST)

Place

Online Meeting

=> Registration open!

Time	Item	Speaker
13:00	Welcome and introduction	Harald Bosse, Acting EMN Chair
13:15	EURAMET and the role of EMNs	Jörn Stenger, EURAMET Chairperson
13:30	Keynote: Challenges and trends in advanced manufacturing - also related to metrology	Hans Hansen, DTU, CIRP president
14:10	Overview of EMN partner organisations: - ETP ManuFuture - EFFRA and Made in Europe Partnership - NanoFabNet - euspen	Maurizio Gattiglio Željko Pazin Steffi Friedrichs Dishi Phillips
15:00	Break	
15:15	Keynote: Assuring manufacturing quality in the Industry 4.0 environment	Thomas Engel, Siemens
15:45	Keynote: The role of shop floor metrology and process data as critical enablers for smart manufacturing	Paul Maxted, Renishaw
16:15	EURAMET activities related to EMN Advanced Manufacturing: - EMN MATHMET - TC-IM WG M4D	Markus Bär, PTB Daniel Hutzschenreuter, PTB & Sascha Eichstädt, PTB
16:30	Forum discussion on metrology needs for advanced manufacturing	All
17:30	End of the meeting	

Digitalization in manufacturing industry: INDUSTRY 4.0

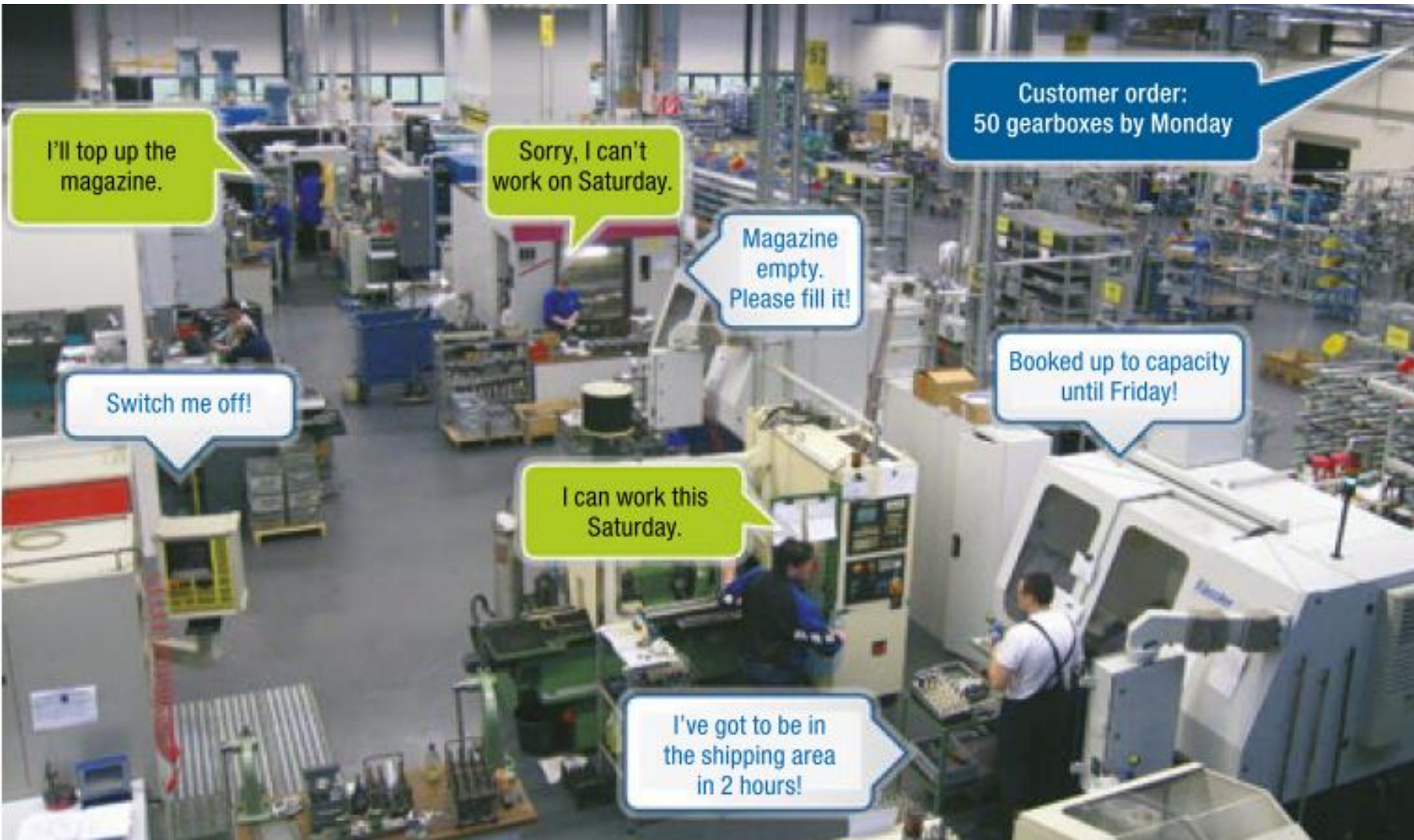


Industry 4.0:

Flexible manufacturing infrastructure with autonomously interacting manufacturing systems

Challenges for metrology:

- Trusted quality for measurements in integrated systems
- Reliability of sensors and measurement systems
 - Reliable communication of measurement systems
- ! - metrolog. data interfaces
 - result, uncertainty, SI-units
- Validated results:
 - ! - virtual meas. instruments
 - ! - validated data analysis SW
- Synchronization of instruments/machines
 - network time protocols, 5G, ...



Source: FhG IAO

Digital twins in industry

Digital twin concept:

- introduced by David Gelernter's 1991 book [Mirror Worlds](#)
or: The day software puts the universe in a shoebox...
how it will happen and what it will mean

Digital twin definition and application in manufacturing:

- introduced by Dr. Michael Grieves (Univ. Michigan) in 2003
White Paper, 2014: "[Digital Twin](#): Manufacturing Excellence
through Virtual Factory Replication"

Digital Twin concept model contains three main parts:

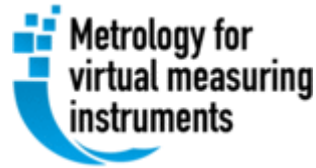
- physical products in Real Space,
- virtual products in Virtual Space, and
- the connections of data and information that ties
the virtual and real products together

- Simulation-Based Systems Engineering (TABS 3.3): [NASA Digital Twin](#)
M. Shafto et al: DRAFT Modeling, Simulation, Information Technology &
Processing Roadmap, Technology Area 11, 2010
- Digital Twin one of [Gartner's](#) Top 10 Strategic Technology Trends for 2017



digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin.

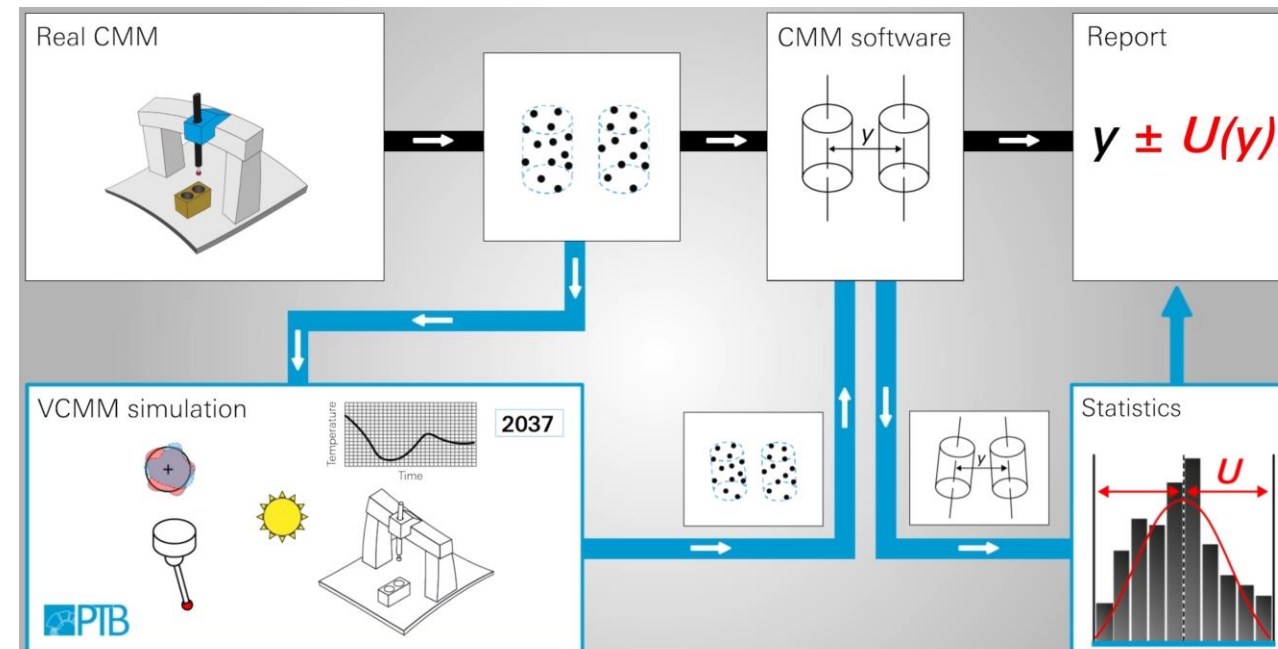
Examples of digitalization in industrial quality control (dim.metr.)



VCMM (VirtMet)

- Virtual Coordinate Measuring Machine
- Metrological digital twin
- Tool for uncertainty evaluation in an increasingly digitalized industry
- Monte-Carlo-based software
- Idea came up in the early 90s
- Since 2003, the VCMM is used by DAkkS-accredited calibration laboratories in DE
- The VCMM is independent of manufacturers and CMM brands, the research cooperation is open for new participants and contributors
- Traceability is assured by intercomparison measurements using calibrated measurement standards and validated reference data

- Under ongoing development and extension
- Currently only tactile measurements are covered
- Extensions for non-contact and optical measurements are conceivable



Principle of the "Virtual Coordinate Measuring Machine"

VirtMet and Digital Metrological Twin (D-MT)



Advanced
Manufacturing
Network



1st International Workshop on Metrology for Virtual Measuring Instruments and Digital Twins



HELMHOLTZ
FONDS e.V.

Date

21. – 22. September 2021

Keynote “VirtMet – applications and overview” (Frank Härtig, VP PTB)
Keynote “Digital twins in medicine” (Olaf Dössel, KIT)

Sessions:

Medical applications, Material properties and more, Coordinate measuring systems, Flow and nanometrology, Optics, Simulation and measurement uncertainty

Digital Metrological Twin:

(definition proposed by PTB and discussed at VirtMet)

A digital metrological twin (D-MT) is a **numerical model** that depicts a **specific measurement process** and indicates an associated **measurement uncertainty** for a specific measurement value, which is **traceable** to the **international system of units**.

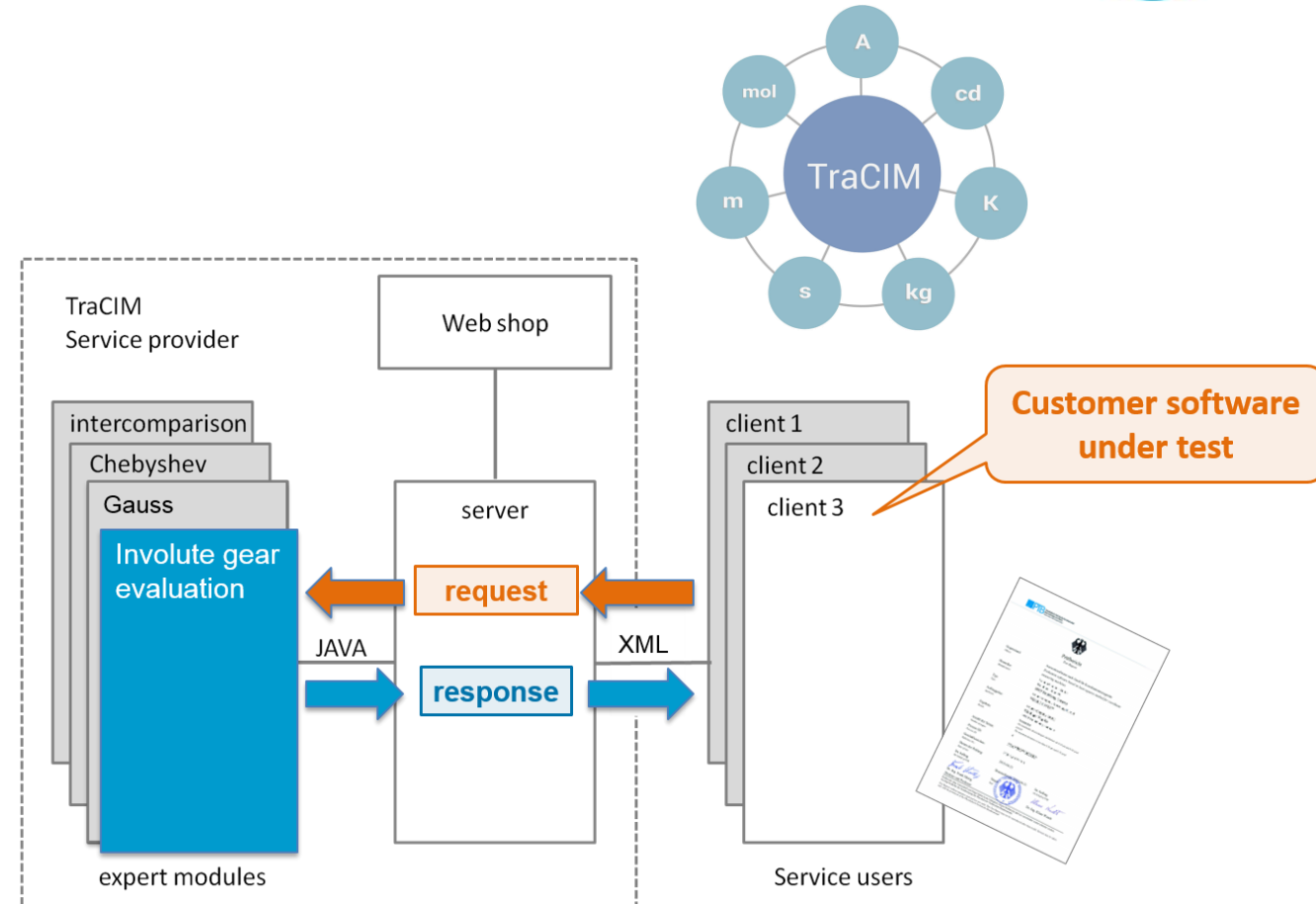
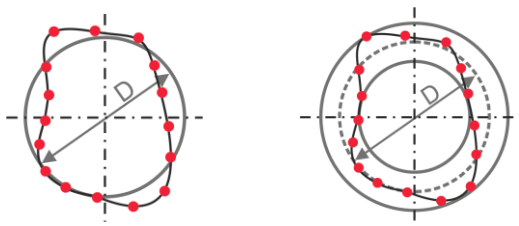
Moreover, it complies with the requirements that

- the measurement uncertainty is calculated according to **valid standards**
- all input parameters are determined traceably and are stated with the corresponding **measurement uncertainty**
- it is **validated** by traceable measurements

Examples of digitalization in industrial quality control (dim.metr.)

TraCIM (SW validation)

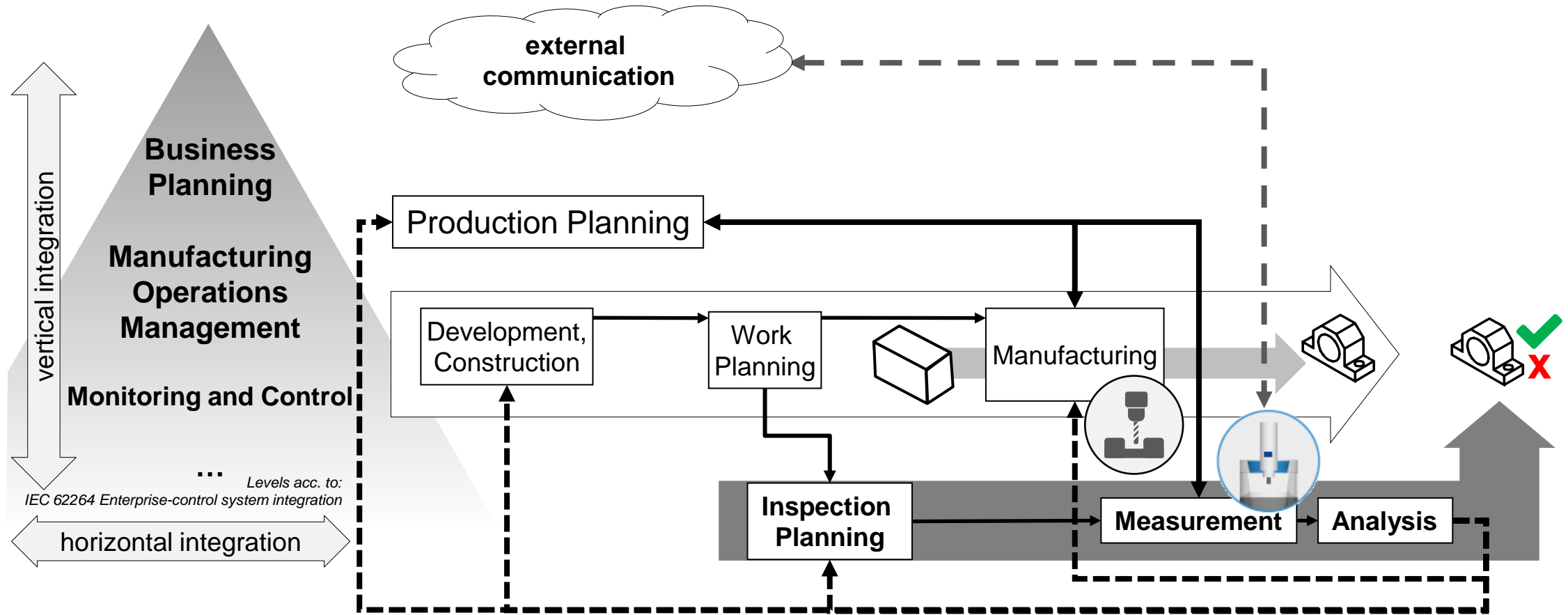
- Traceability for computationally intensive metrology
- [TraCIM](#) service for software validation
- Idea came up in the early 90s
- SW-Validation for fitting e.g. roundness data
- CMC entry for SW-Validation Service in 2001
- Association TraCIM e.V. founded in 2014
- In 2019 costumers from 54 countries
- Test is regularly used by ≈ 100 customers
- Under ongoing development and extension
- Extensions for testing AI algorithms and big data algorithms are conceivable



Principle of the TraCIM software validation process

Integration into digital production – horizontal and vertical

Slide kindly provided by Dietrich Imkamp, Zeiss



↙ ↘ OPC UA Companion Specification for length measurement systems

Source (Translated from): Imkamp, D., Heil, H. G.: [Messtechnik goes Digital](#) – Schnittstellen und Modelle für die digitale Produktion, QZ Qualität und Zuverlässigkeit, Carl Hanser Verlag, München Jg. 66 (2021), Nr. 5, S. 40-43.

Interfaces for Integration

Important: Provide all relevant metrological data in Industry 4.0 communication networks!



Slide kindly provided by Dietrich Imkamp, Zeiss

Source: VDI/VDE-Gesellschaft für Mess- und Automatisierungstechnik (Hrsg.):
VDI Positionspapier: Fertigungsmesstechnik in der digitalen Produktion,
geplante Erscheinung Herbst 2021
VDI position paper: Manufacturing metrology in digital production,
scheduled publication autumn 2021
VDI/VDE GMA, Düsseldorf (German language)

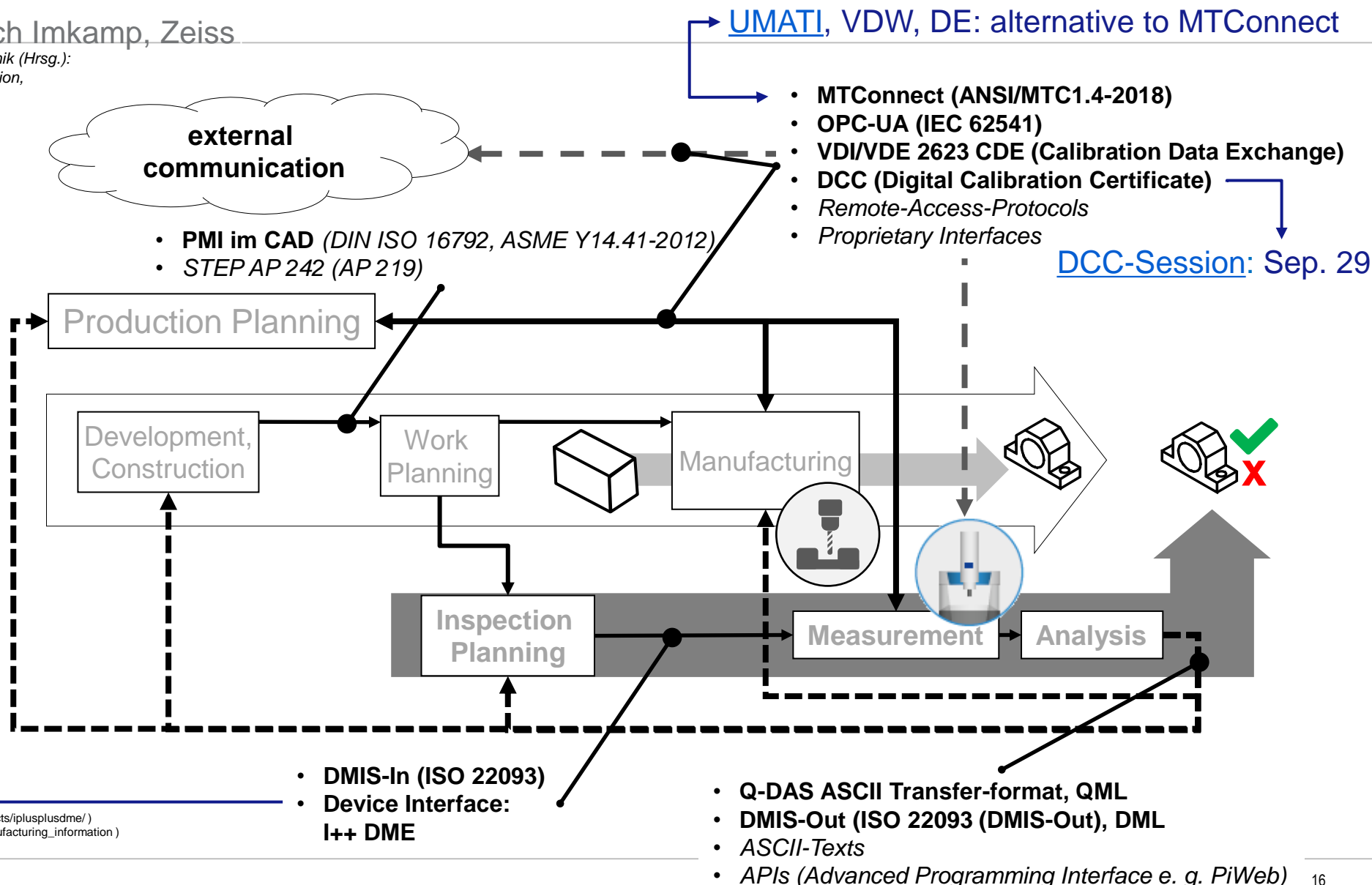
ISO 23952:2020

Automation systems and integration
Quality information framework (QIF)
An integrated model for manufacturing quality information

QIF is a free XML framework standard which defines, organizes, and associates quality information needed in today's complex cyber-physical manufacturing systems

Abbreviations:

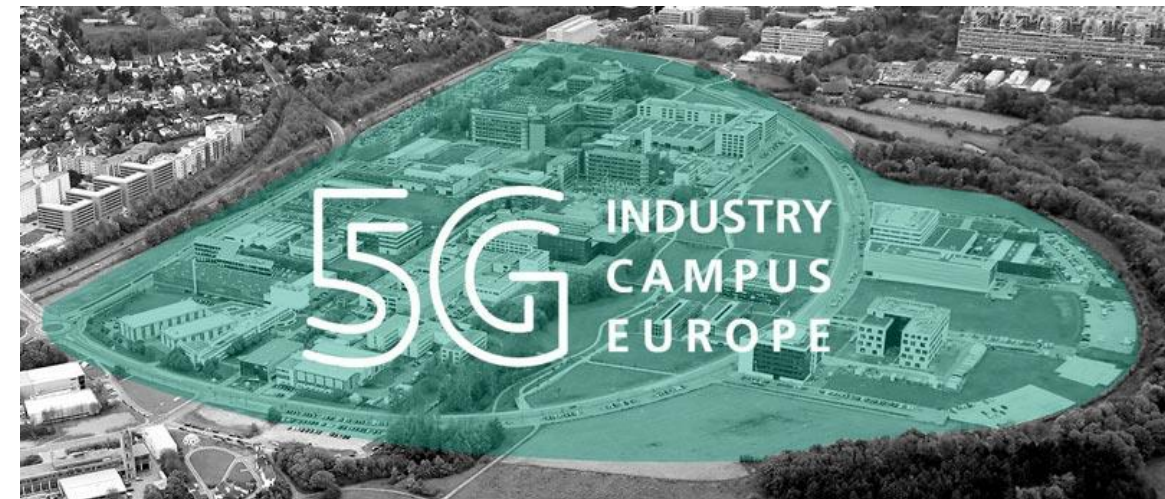
CAD=Computer Aided Design
DCC=Digital Calibration Certificate (<https://www.ptb.de/dcc/>)
DMIS=Dimensional Measuring Interface Standard (ISO 22093)
I++DME=Inspection++ Dimensional Measuring Equipment (<https://sourceforge.net/projects/iplusplusdme/>)
PMI=Product Manufacturing Information (https://en.wikipedia.org/wiki/Product_and_manufacturing_information)



5G-Industry Campus Europe (RWTH Aachen, FhG IPT, Ericsson)



- The 5G-Industry Campus Europe is one of the four 5G testbeds of the 5G Alliance for Connected Industries and Automation (5G-ACIA) since April 2021.
- The 5G-Industry Campus Europe is the first site in Europe with a comprehensive 5G network to explore and test new applications for 5G in production environments under real-world conditions.
- With an outdoor network of around 1 km² and a shop floor of 7000 m², the 5G network covers the area of the RWTH Aachen Campus Melaten and the entire machine hall of the Fraunhofer IPT.
- Use Cases:
 - 5G Robotics for synchronized processing
 - 5G Wireless sensor for fast tool monitoring
 - 5G Edge Cloud for real-time capable comm.
 - 5G Multisensor for BLISK production process



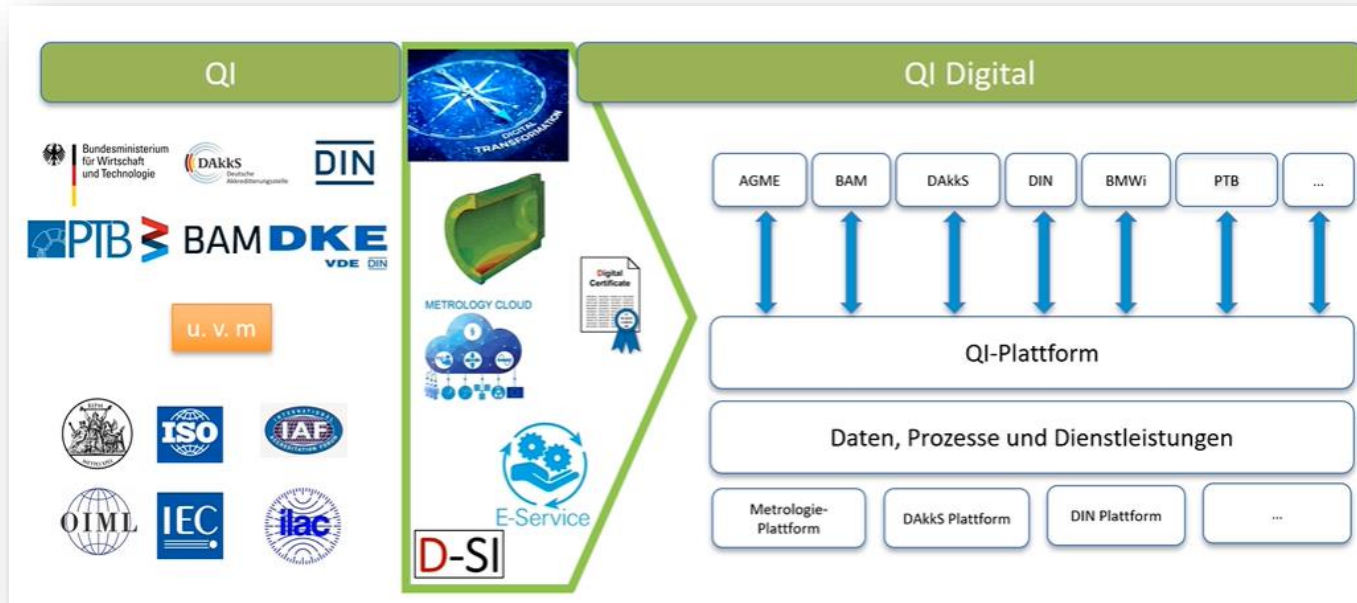
Important: Provide all relevant metrological data in Industry 4.0 communication networks!

Source: 5G-Industry Campus Europe

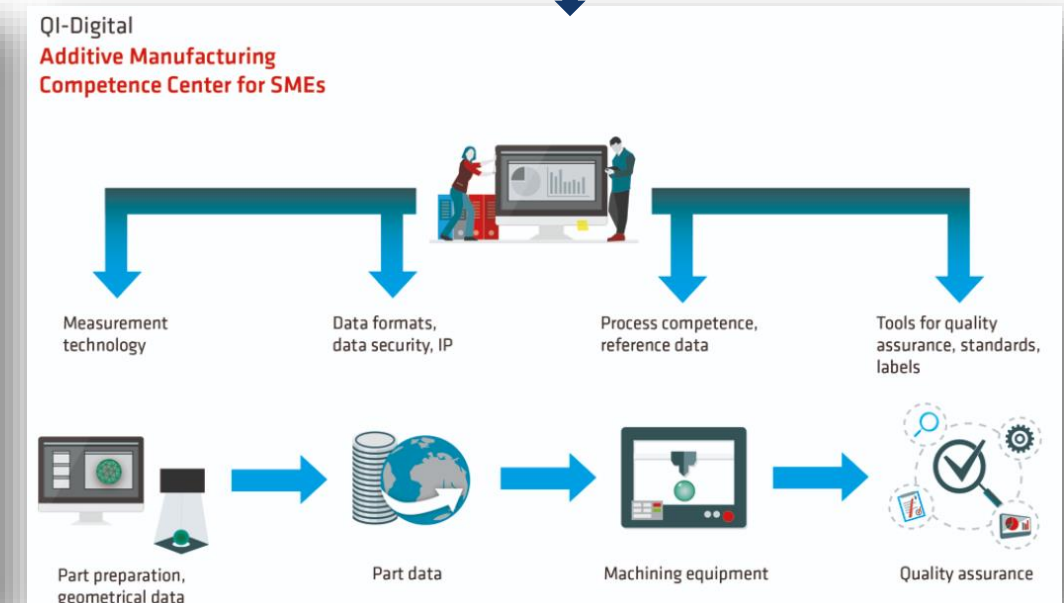
QI Digital – Digital Transformation of Quality Infrastructure



- Joint project by QI players in Germany (BMW, DIN, DKE, DAkkS, BAM, PTB)
- 3 pillars: Test Environments, Transfer Measures, Research & Development
- Cross-sectional: QI-Cloud, QI services, SMART standards, legal framework
- 3 Use Cases:
Hydrogen filling stations, Medical Data Hub (med. AI), Additive Manufacturing



Source: S. Eichstädt, PTB

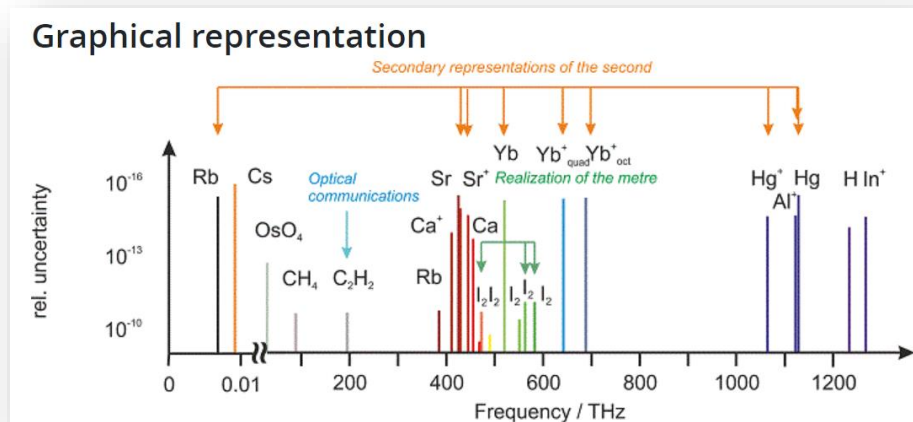


Source: Kai Hilgenberg, BAM

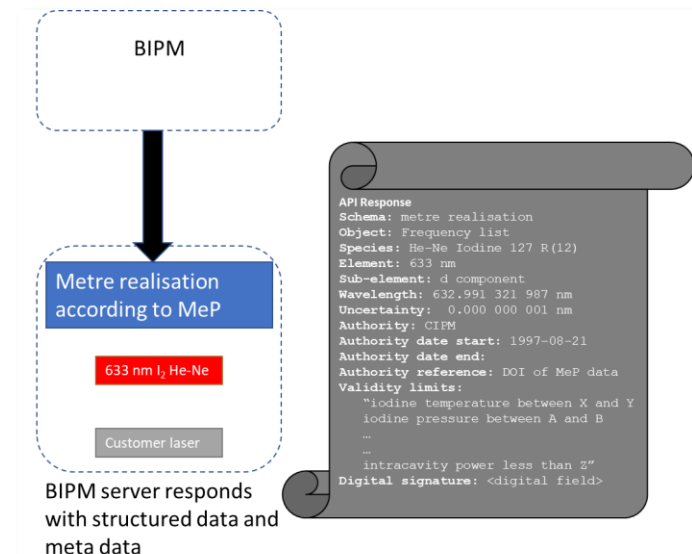
D-SI: The digital SI (International System of Units)

BIPM-Workshop:
[The SI in FAIR digital data](#)

- The ToR of the CIPM “Task group on the digital SI” ([CIPM-TG-DSI](#)) are: [The SI in FAIR digital data](#)
- To develop and establish a world-wide uniform, unambiguous and secure data exchange format for use in IoT networks based on the International System of Units (SI) described in the current SI Brochure
- To coordinate this effort with all relevant stakeholders by exploring and/or establishing suitable liaisons.
- To propose suitable actions towards making the SI Brochure machine readable.
- Proposal from Andrew Lewis, NPL for discussion at CCL-meeting in Oct. 2021:
- make [recommended values of standard frequencies](#) of stabilized laser **machine readable**:
 (=> stabilized lasers are at the top of **length traceability chains** in all lab and fab applications)



Source: BIPM



Source: A. Lewis, NPL

Summary and Outlook

- European Metrology Network for Advanced Manufacturing
=> *stakeholder dialogue, SRA development, ...*
- Digitalization in manufacturing industry: INDUSTRY 4.0
=> *guarantee reliable metrological data in flexible manufacturing infrastructures*
- Virtual Instruments and Digital Twins => *VCMM as a Digital Metrological Twin (D-MT)*
- Software Validation => *TraCIM approach for internet-based SW validation service*
- Data Interfaces for Manufacturing Integration => *Keep standards compatible!*
- QI Digital and Digital SI: links to manufacturing => *Use case AM; machine readable laser freq.*
- => **Achievements** were made, but there are also remaining **Challenges** in Digital Transformation

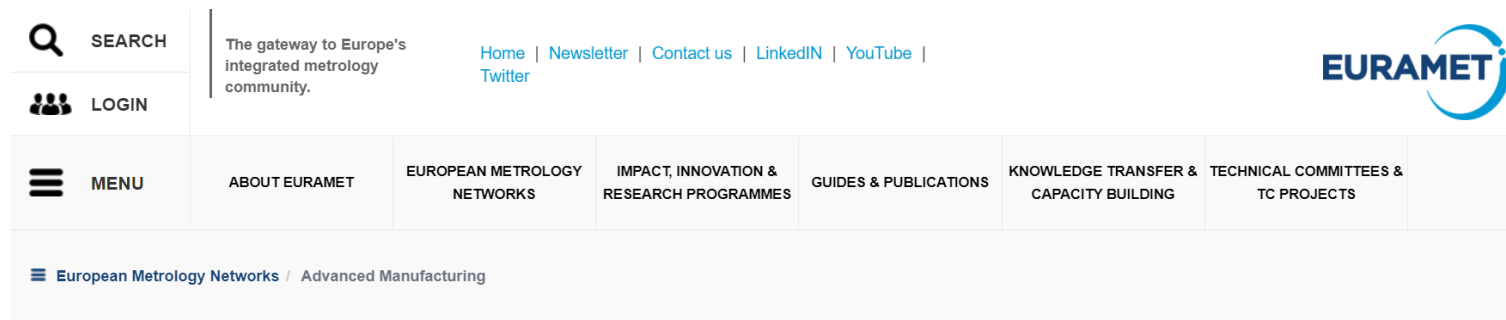
EMN contacts



Acting EMN Chair: Harald Bosse, harald.bosse@ptb.de

<https://www.euramet.org/european-metrology-networks/advanced-manufacturing/>

=> advancemanu@euramet.org



EMN FOR ADVANCED MANUFACTURING

Advanced manufacturing requires new and enhanced metrology methods to assure the quality of manufacturing processes and the resulting products.

The newly approved European Metrology Network for Advanced Manufacturing will drive the high-level coordination of the metrology community in this field and will foster the impact of metrology developments for advanced manufacturing.

The network is run by National Metrology Institutes (NMIs) and Designated Institutes (DI) in close cooperation with stakeholders interested in advanced manufacturing. The objectives of the network are to set up a permanent stakeholder dialogue, to develop a Strategic Research Agenda for the metrology input required for advanced manufacturing technologies, to create and maintain a knowledge sharing programme and to implement a web-based service desk for stakeholders.



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New network for Advanced Manufacturing held introductory meeting
28-06-21

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<https://www.euramet.org/meta-menu/subscribe-to-newsletter/>

Acknowledgement



Thanks to all colleagues who provided input for this talk,
in particular those from the JNP AdvManuNet / EMN AdvanceManu

Thank you for your attention!



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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States