Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Digitalization from a Metrological Point of View

Symposium on International Trend of Metrology
·· Metrology for Industrial Innovation ··

Centre of Measurement Standards & National Measurement Standards
30th Anniversary Celebration

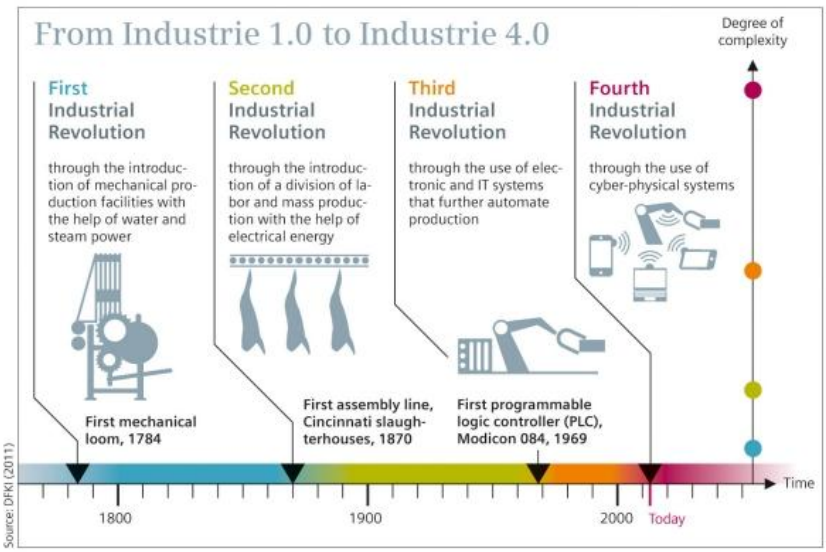
May 3, 2017 Taipei, Taiwan

S Eichstädt, F Härtig, J Ullrich, R Schwartz

Outline

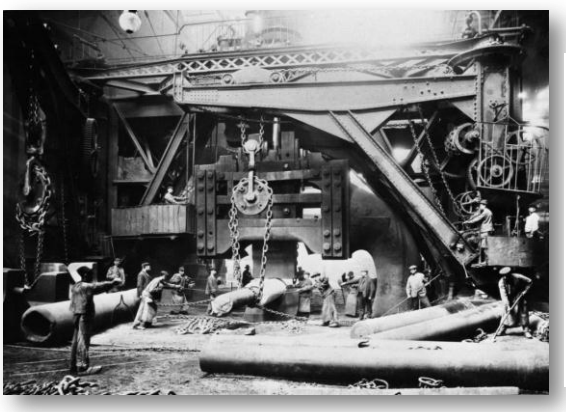
- Digitalization/Industry 4.0 - Introduction
- Metrology for the digitalization (PTB)
  - Time
  - E-Health
  - Legal Metrology
  - Standardization
  - Simulation
- Examples

Industrie 4.0 - What does it mean?

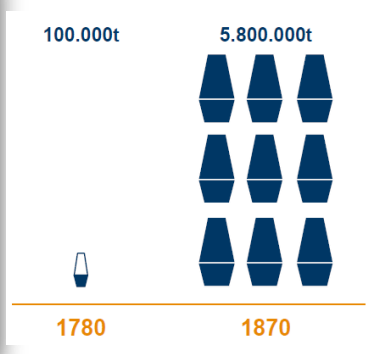


The first industrial revolution

Steam engines, machinery

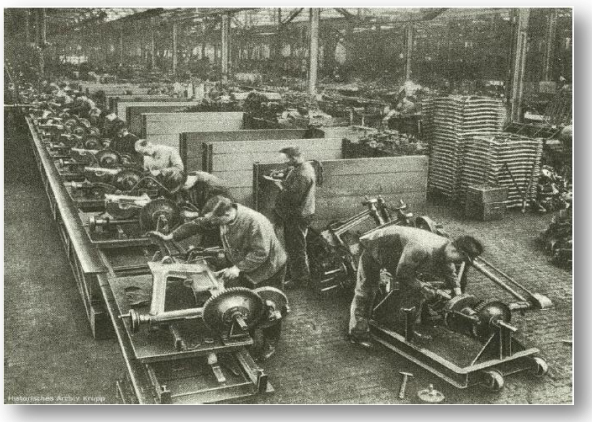


Steel production in England



The second industrial revolution

Assembly lines, electrification

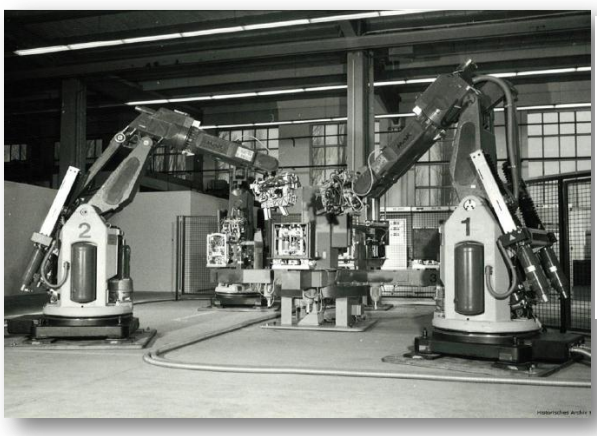


Assembly time chassis Model T:

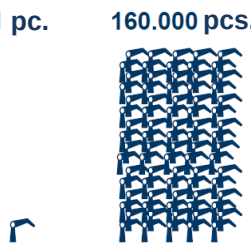
1913 1914

The third industrial revolution

Electronics, ICT, robots



World-wide sold industry robots



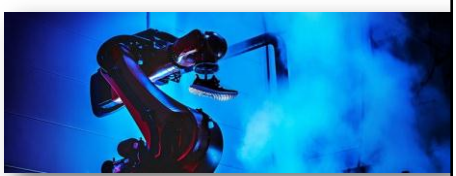
1961 2012

The fourth industrial revolution

Autonomous vehicle
Technical University Braunschweig

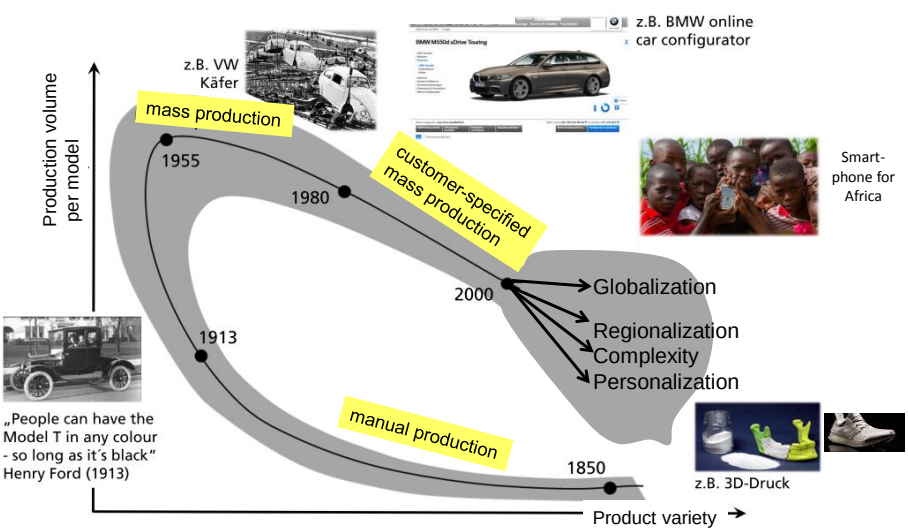
2016: Intelligent, flexible and individualized production:

Example: Adidas
Individual running shoe from 3D-printer



Source http://www.adidas-group.com/de/medien/newsarchiv/pressemitteilungen/2015/massgeschneidert-aus-dem-3d-drucker-erschaffe-deinen-individuell/

Industrial revolutions - Drivers



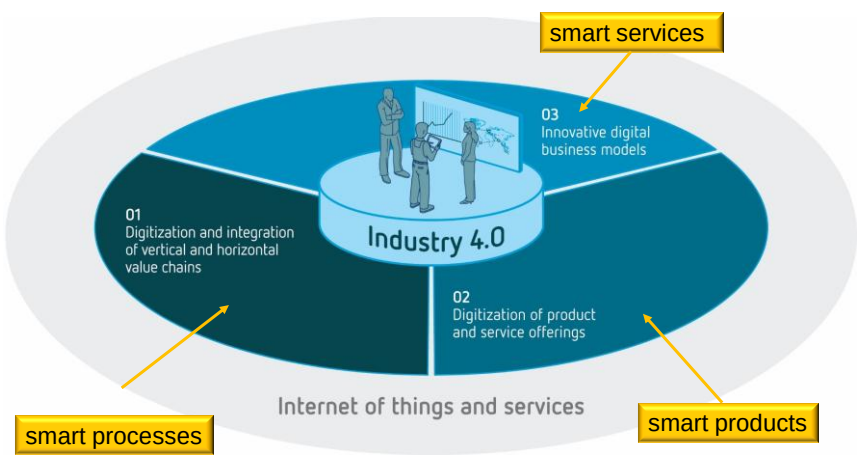
Source http://www.mav-online.de/c/document_library/get_file?uuid=1e6c64af-b5dd-4a74-85fe-e0751fb9250c&groupId=32571331

What is Industry 4.0[1]

- Industry 4.0 combines production methods with state-of-the-art information and communication technology
- the driving force behind this development is the rapidly increasing digitization of the economy and society
- the technological foundation is provided by intelligent, digitally networked systems that will make largely self-managing production processes possible
- in the world of Industrie 4.0, people, machines, equipment, logistics systems and products communicate and cooperate with each other

Source: http://www.plattform-i40.de/I40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html; 04/217

What is Industry 4.0



source: Siemens

Government and Ministries

The Federal Government
www.bundesregierung.de

Federal Ministry for Economic Affairs and Energy
www.bmwi.de

Federal Ministry of Education and Research
www.bmbf.de

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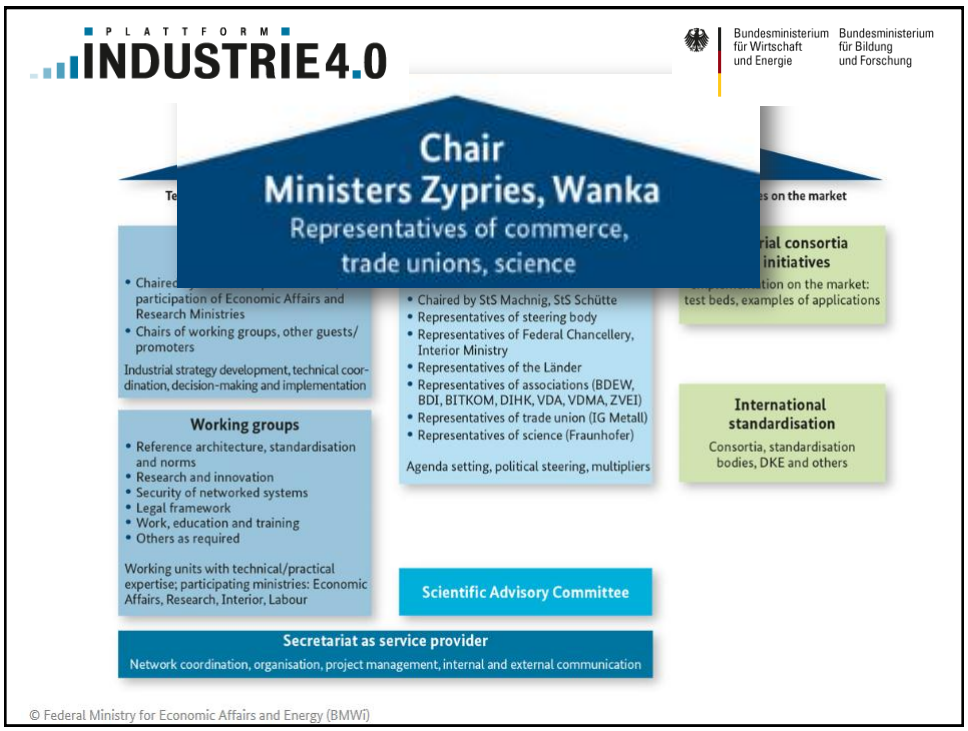
Bundesministerium für Bildung und Forschung

Chair
Ministers Zypries, Wanka
Representatives of commerce, trade unions, science

Technical/practical expertise decision-making	Policy guidance, society, multipliers	Activities on the market
Steering body (companies) • Chaired by business representatives, participation of Economic Affairs and Research Ministries • Chairs of working groups, other guests/ promoters Industrial strategy development, technical coordination, decision-making and implementation	**Strategy group (Government, business, unions, science)** • Chaired by StS Machnig, StS Schütte • Representatives of steering body • Representatives of Federal Chancellery, Interior Ministry • Representatives of the Länder • Representatives of associations (BDEW, BDI, BITKOM, DIHK, VDA, VDMA, ZVEI) • Representatives of trade union (IG Metall) • Representatives of science (Fraunhofer) Agenda setting, political steering, multipliers	**Industrial consortia and initiatives** Implementation on the market: test beds, examples of applications
Working groups • Reference architecture, standardisation and norms • Research and innovation • Security of networked systems • Legal framework • Work, education and training • Others as required Working units with technical/practical expertise; participating ministries: Economic Affairs, Research, Interior, Labour		**International standardisation** Consortia, standardisation bodies, DKE and others
	Scientific Advisory Committee	

Secretariat as service provider
Network coordination, organisation, project management, internal and external communication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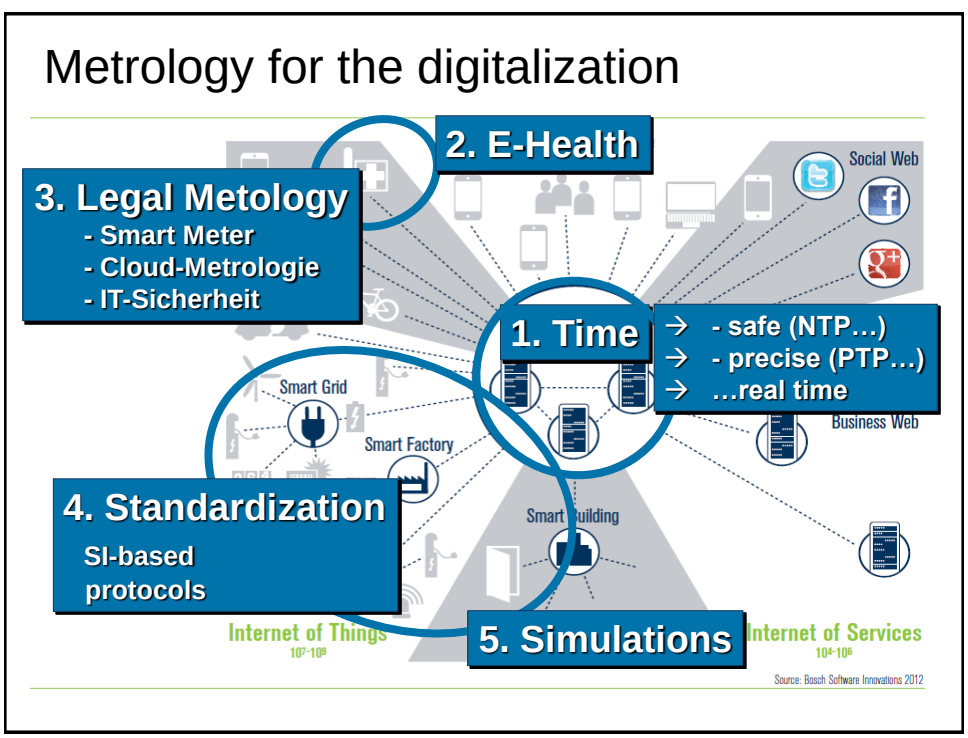
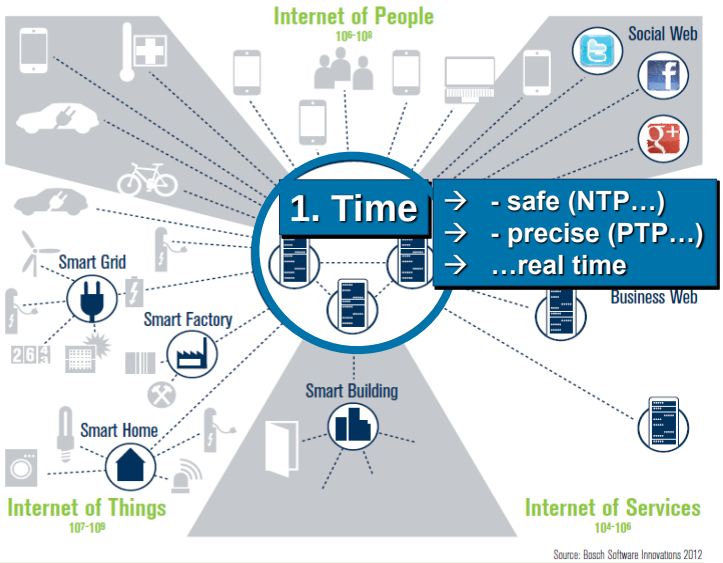

Metrology for the digitalization
2. E-Health
3. Legal Metology
- Smart Meter
- Cloud-Metrologie
- IT-Sicherheit
Social Web
1. Time
→ - safe (NTP…)
→ - precise (PTP…)
→ …real time
Smart Grid
Smart Factory
Business Web
4. Standardization
SI-based protocols
Smart Building
Internet of Things
10⁷-10⁹
5. Simulations
Internet of Services
10⁴-10⁶
Source: Bosch Software Innovations 2012

Metrology for the digitalization



Legal time in Germany

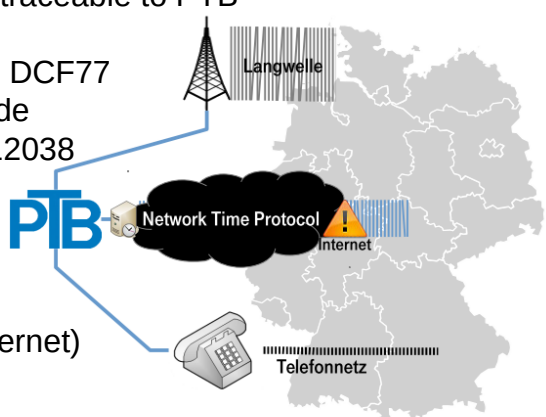
Ways for the dissemination of the legal time in Germany

time is realized by and traceable to PTB

- long-wave-transmitter DCF77
- internet ptbtime3.ptb.de
- telephone +49 531 512038

disadvantages

- slow (telephone)
- uncertain (DCF77, internet)

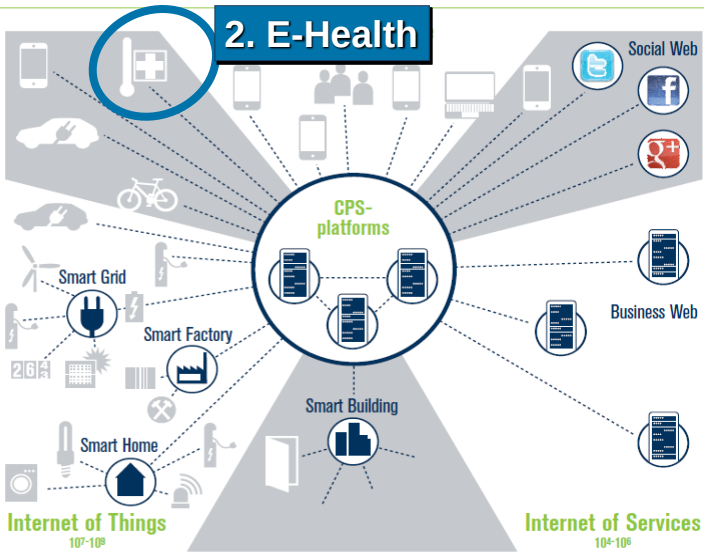


Who needs the exact time

- reliable and free time information for society
  Study: Economic benefit of DCF77 is 14 x higher than effort
- accurate, reliable, cost-effective time for Industrial use
- accurate, trustworthy, traceable time for the markets
  Stock market (high-speed trading)
  Trade of goods
- accurate time and frequency for research
  New opportunities through better clocks / time distribution

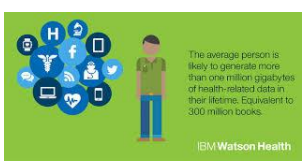
Time and frequency distribution

Metrology for the digitalization



E-Health - Medicine 4.0

- high backlog in digital healthcare
- interested patients are development drivers
- innovation potential for health care and economy



SIEMENS MeVis MEDICAL SOLUTIONS AGFA HealthCare

DeepMind Health CLINICIAN-LED TECHNOLOGY

DGN Deutsches Gesundheitsnetz

SATMED HEALTHCARE SOLUTIONS

NAKO

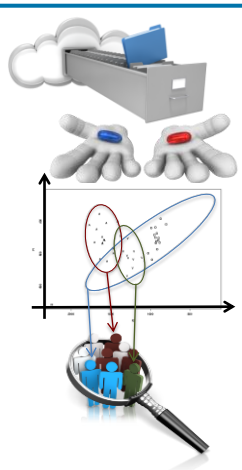
BOSCH Technik fürs Leben

Gefördert vom Bund, den Ländern und der Helmholtz-Gemeinschaft

E-Health - Medicine 4.0

- modern diagnostics rely on the variety of multiparametric data such as.
  - in vitro diagnostics DNA, vital parameters (blood pressure, ECG, breathing temperature)
  - multi modal images,
  - patient records
- systematic analysis by means of electronically supported health management (E-Health)
- potential is used to little:
  - lack of networks,
  - lack of interoperability,
  - lack of security,
  - lack of comparability and standardization

E-Health - Challenges

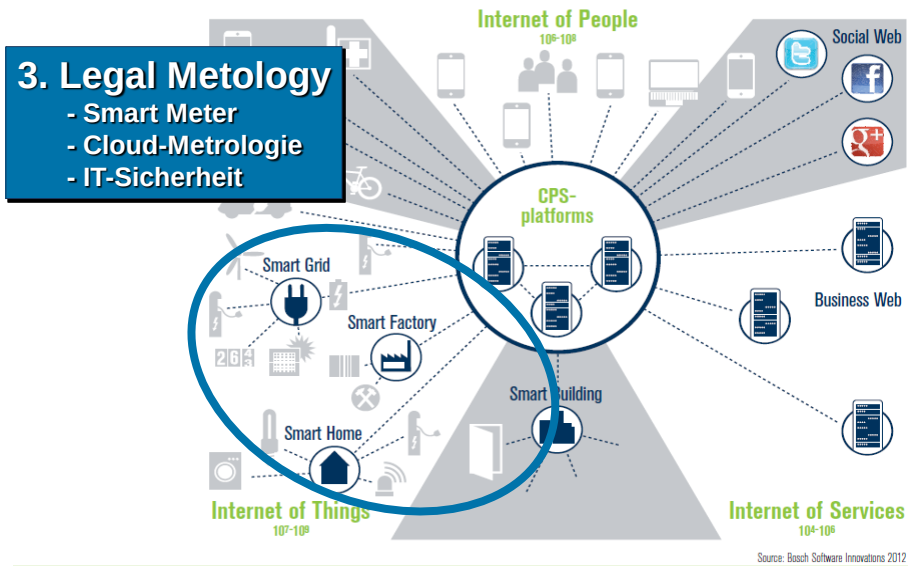


Electronic health management:

- target: classification of patients in order to provide appropriate therapies
- use of statistical methods („big data“) for the classification of patients
- metrological standardization provides the basis of a better combination of data (pooling)

Metrology for the digitalization

3. Legal Metology
- Smart Meter
- Cloud-Metrologie
- IT-Sicherheit



Source: Bosch Software Innovations 2012

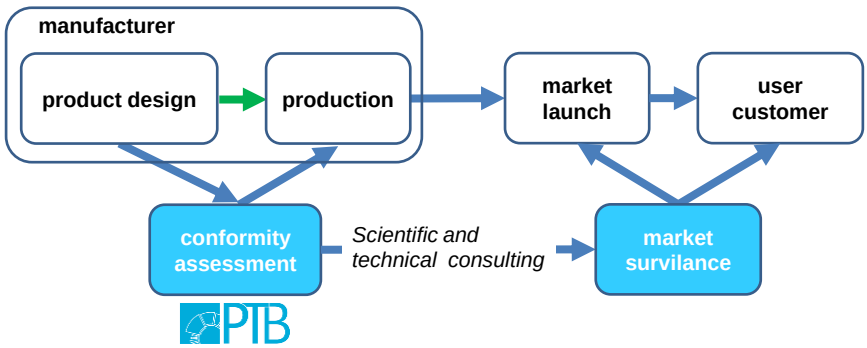
Legal metrology

PTB

- Protection for customers and users
- Confidence in the correctness of measurements

Legal metrology

From design to product



Industrie 4.0 and Legal Metrology

Criticism: Regulation is an "inhibitor for innovation"!

1. regulations increase „time-to-market“

2. costs for IT security are too high!

3. „technology gap“ (NBs, MSAs)

4. no harmonization in Europe!

- refuse innovative solutions
- „bend“ innovative solutions
- require too much security
- require inappropriate security

PTB aims to provide the following:

⇒ **Reference architectures** for new technologies (1, 2, 3, 4)

⇒ **Simple verification methods** for MSAs (3, 4)

⇒ **Risk analysis and assessment** to achieve „adequate“ IT security (2, 3)

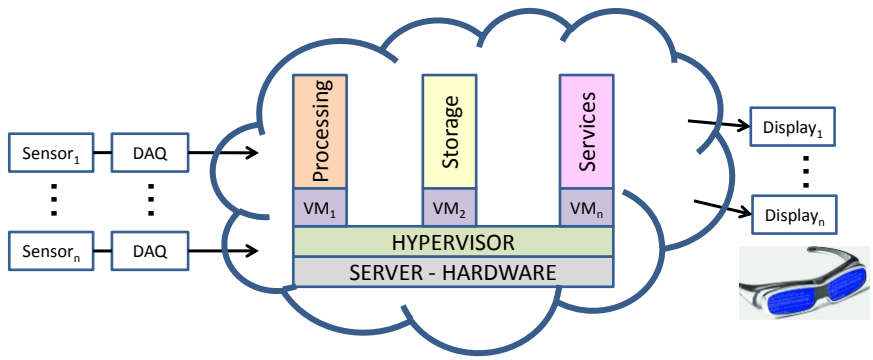
⇒ **Coordination of services** in Europe via WELMEC (4)

⇒ **Planning / handling security** for manufacturers

Industrie 4.0 and Legal Metrology

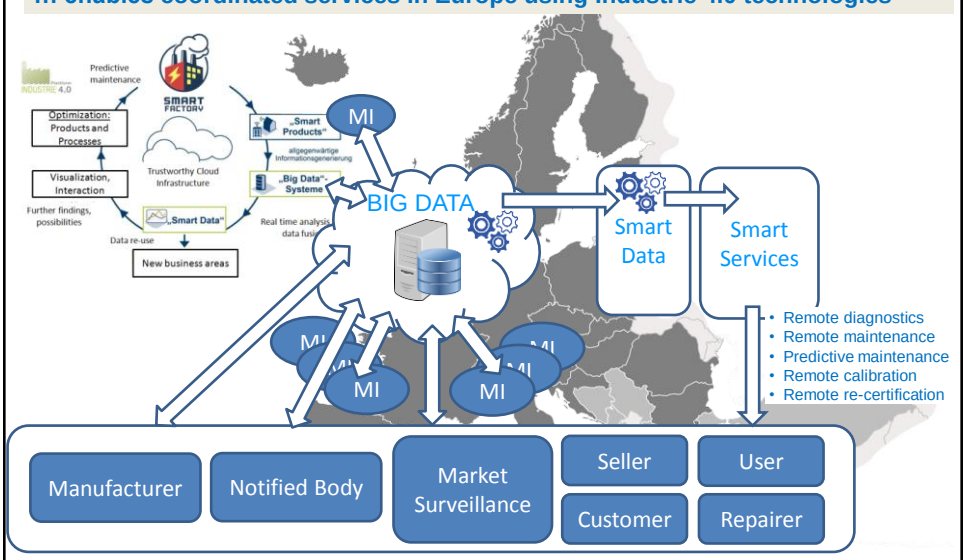
Virtual Measuring Instrument:

- Data stored in the cloud
- Measuring software in the cloud (SaaS)
- Access to the instrument / on parts via cloud

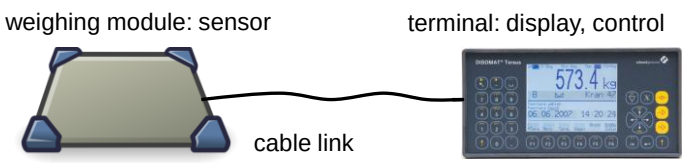


Vision: The “Metrology Cloud”…

… enables coordinated services in Europe using Industrie 4.0 technologies



Balance



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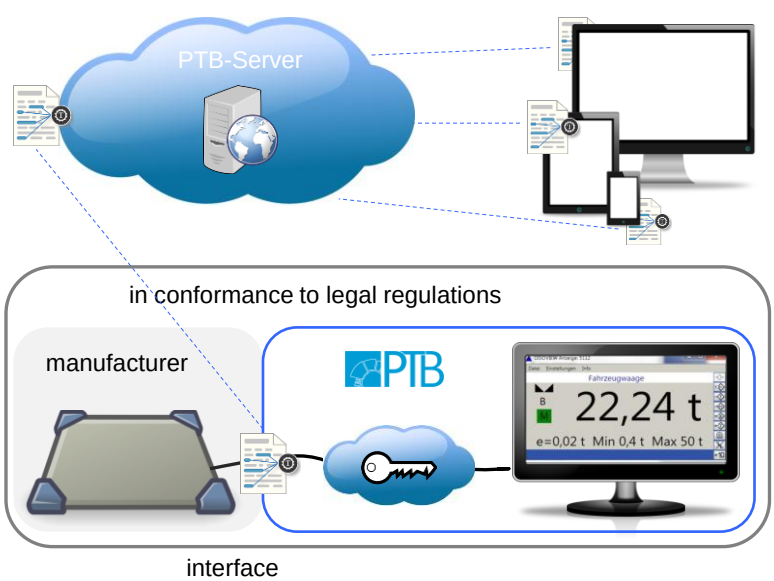

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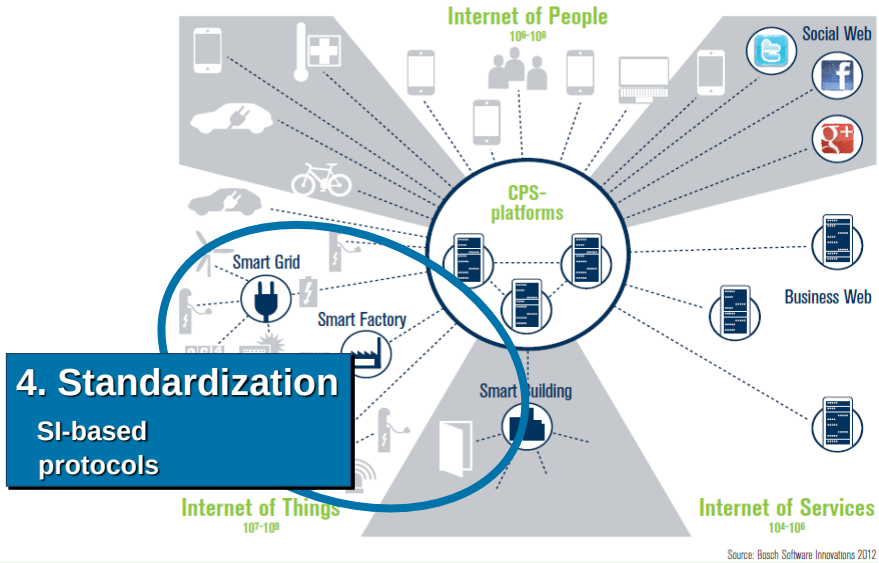
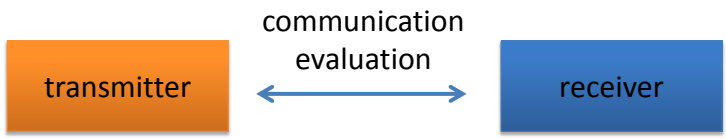


Communication



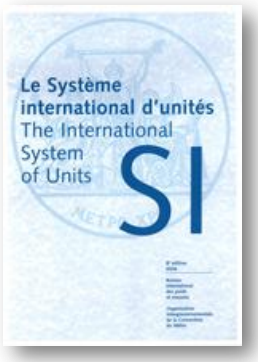
communications are essential
they allow to evaluate processes
all digital evaluations rely on numbers and rules
(how far, how fast, how expensive, ...)

Communication

Numbers have to be

unabbiguous,
efficient,
easy to understand,
…

exchangeable



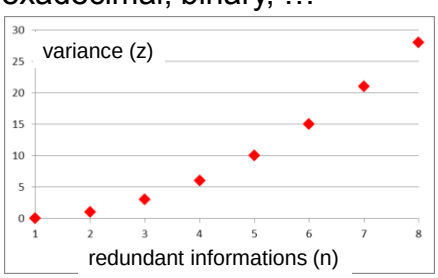
Underestimated risk - diversity

- problem: There is no unity and clarity in the digital communication
  the diversity of data seems to be increasing!

  units: meter, feet, sea-, land-, air-miles, …
  characters: Ä, Ö, Ü, كَلِماتٌ مُطابِقَة 公尺 [公尺] métpa, …
  number systems: decimal, hexadecimal, binary, …
  …

- economic disaster due to diversity and redundancies

$$z = \frac{n(n-1)}{2}$$



Kosten und fehlende Sicherheit

- Mars Climate Orbiter[1] 1999
  mix up of metric and imperial units
  destroyed at landing approach (**125 Mio US$)**

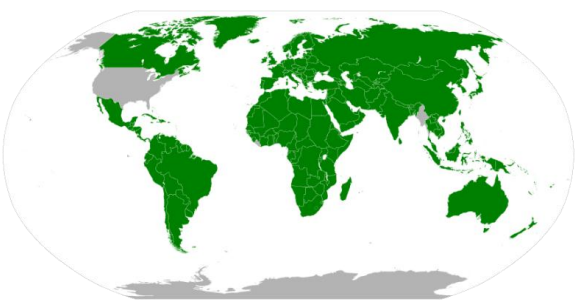
- 2005 NASA-“Constellation-Program“
  [landing on the moon] rejected!
  harmonisation of units would cost
  370 Millionen US$[2].

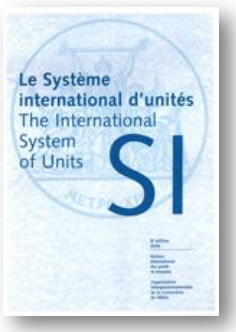
- 1983 Air Canada Flug 143 „Gimli-Glider“:
  refuelling in pound/litre instead of kg/litre

[1] *NASA; Mars Climate Orbiter Mishap Investigation Board Phase I Report.* ftp://ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf; Zugriff April 2016
[2] https://www.newscientist.com/article/dn17350-nasa-criticised-for-sticking-to-imperial-units/; Zugriff April 2016
[3] https://en.wikipedia.org/wiki/Gimli_Glider; Zugriff April 2016

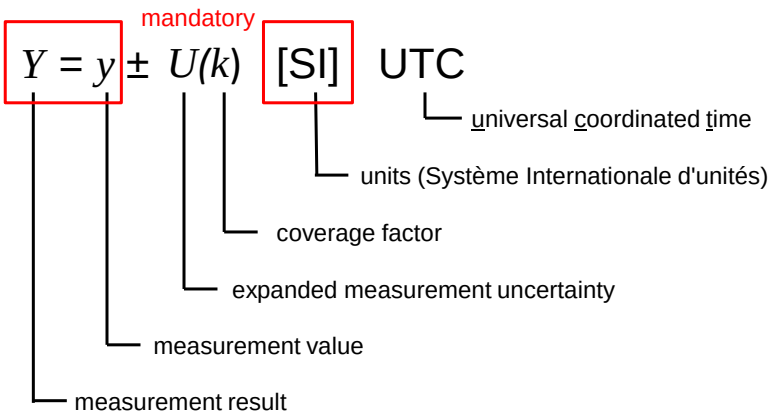
International agreed units

worldwide almost agreed common units





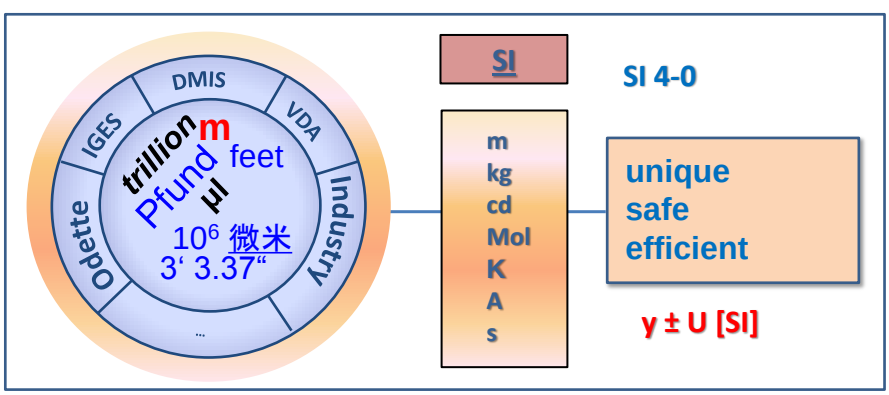
Common data exchange format



Example

$m = 5 \pm U(k=2)$ kg 2017-05-03T05:10:00

Common data exchange format



Digital Calibraition Certificate

Digital calibration certificate

Digital calibration certificate

Three parts

- unique information (strict regulated, XML format)
  e. g. manufacturer, date, identification, ….
- measurement results (partly regulated)
  regulated: SI-units; data format
  unregulated: (language, additional information, graphics)
- measurement-data (unregulated)

Validation of Metrological Algorithms

Software-Validation

GUM

VIM

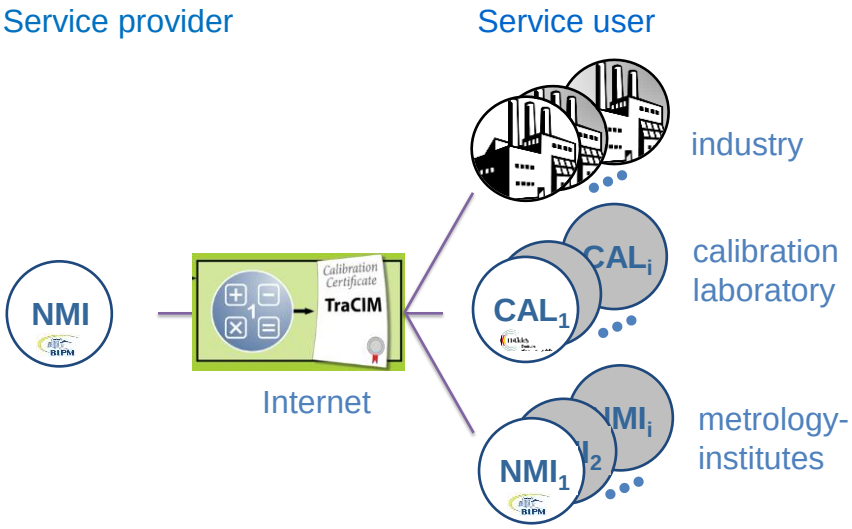
Validation of algorithm in the past

Individual NMIs offer validation
- almost without report
- PTB offers report for Gaussian test for prismatic objects

Manual operation via email -> cost intensive and time consuming

No agreement among NMIs

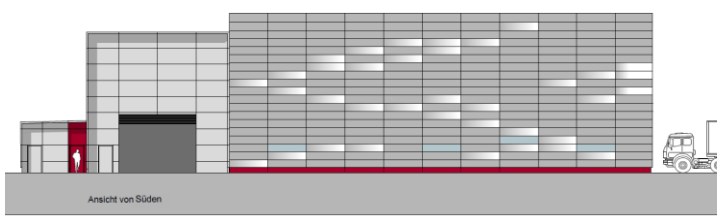
Validation of algorithm today



TraCIM - evaluation process

Test Bed
Competence Centre for Windenergy

Competence Centre - Windenergy

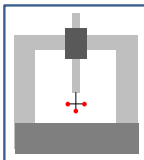


Building Euler I: March 2016 – December 2017
Building Euler II: June 2017 – December 2018
In operation: December 2020

Funding BMWi/PTJ:	9.5 Mio. €
PTB-Budget (building, infrastructure):	5.5 Mio. €
	15.0 Mio. €

Competence Centre - Windenergy

a



$3D\ in\ m$

coordinate metrology

b

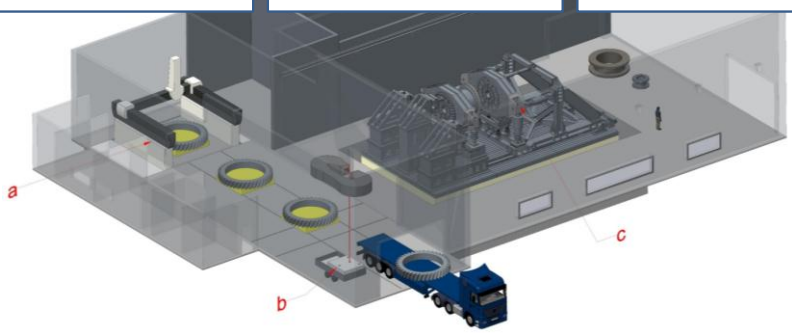
$3Dv\ in\ \frac{m}{s}$

3D wind-vector measurement

c

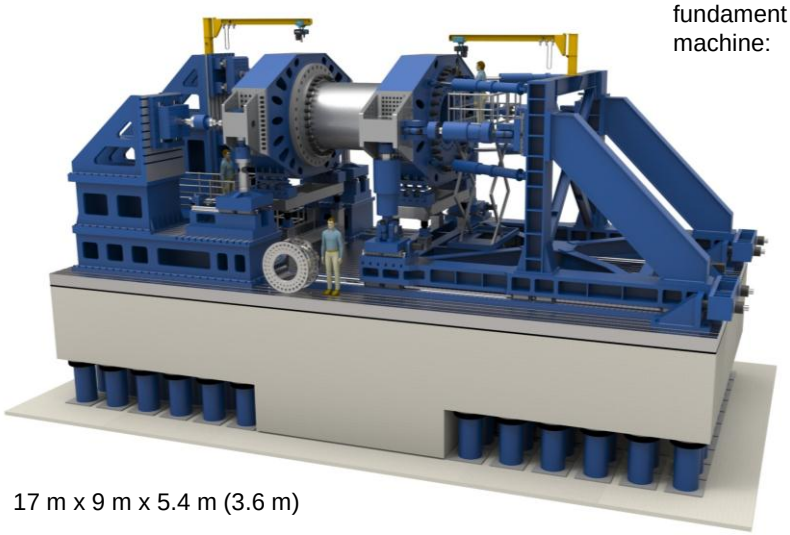
$F \cdot l\ in\ N \cdot m$

torque measurement



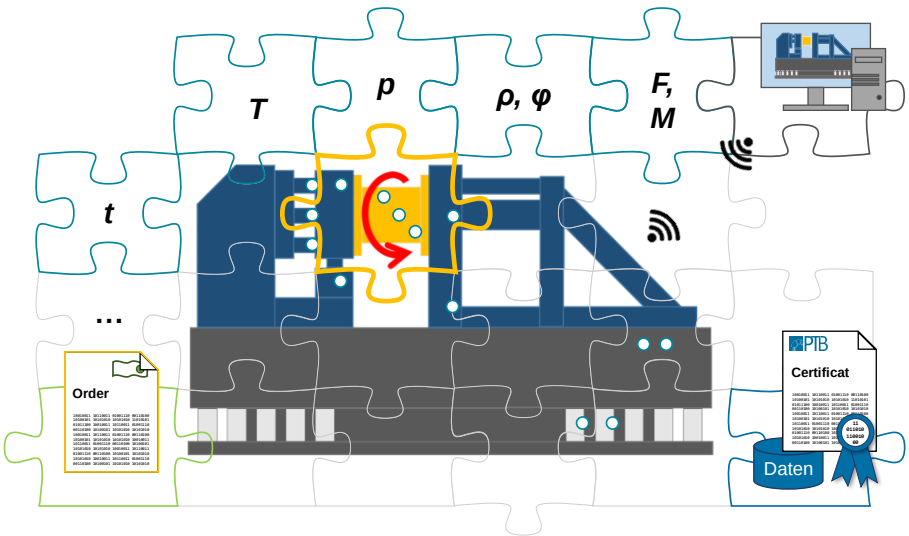
Torque standard measuring device

fundament 1.6 Mio. €
machine: 5.3 Mio. €

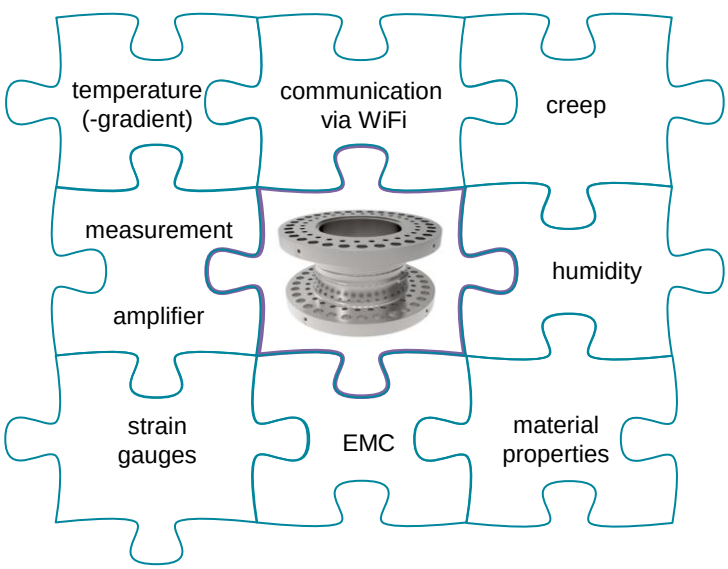


17 m x 9 m x 5.4 m (3.6 m)

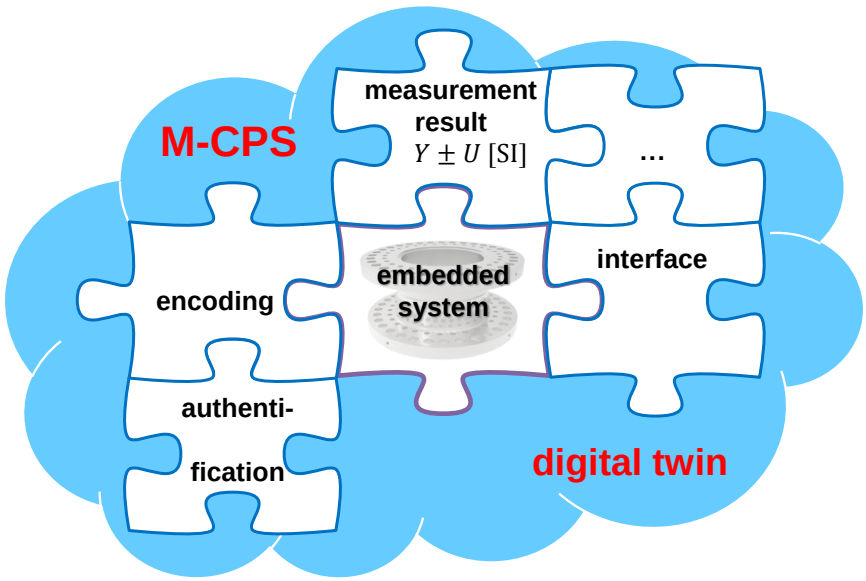
Torque standard measuring device



Transducer - digital twin



Metrological Cyber Physical System



Metrology for the Digitalization of Economy and Society

PTB Study

Metrology for the Digitalization of Economy and Society

to be published end of May 2017

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