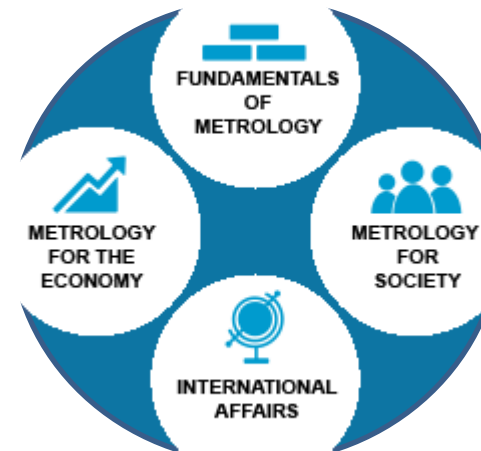




Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

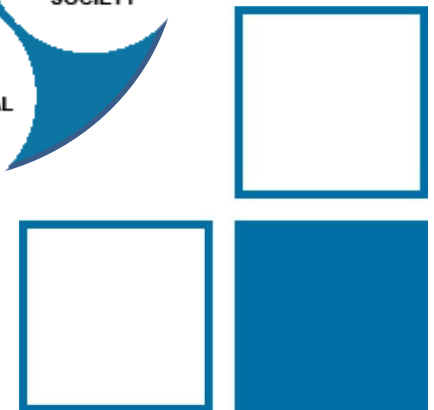


Physikalisch-Technische Bundesanstalt (PTB) is the National Metrology Institute of Germany



Bundesministerium
für Wirtschaft
und Energie

PTB is a scientific and technical higher federal authority falling within the competence of the Federal Ministry for Economic Affairs and Energy.





Metrology:

- Science and application of correct measurement
- Traceability of results to the SI through national standards
- Determination of results with verification of uncertainty

PTB:

- National Metrology Institute (NMI), within the competence of the BMWi (Federal Ministry of Economic Affairs and Energy)
- 170 Mio. € budget, plus third party funding
- Approx. 1250 permanent staff and 650 non-permanent staff including 110 PhD students
- More than 600 scientific papers and 900 presentations per year





1887 Founding of the Physikalisch-Technische Reichsanstalt (PTR) by Werner von Siemens and Hermann von Helmholtz

... the first national metrology institute world-wide

Selected scientific highlights

- Precision experiments on thermal radiation laws, Planck's Law → Nobel Prize for Willy Wien in 1911
- Counters for α and β particles by Hans Geiger
- Discovery of the element Rhenium by Ida Tacke and Walter Noddack
- Development of the coincidence method for particle physics → Nobel Prize for Walther Bothe in 1954
- Development of caesium atomic clocks
- First measurement of the Quantum Hall resistance together with Klaus von Klitzing



- 25 honorary members with leading positions in science and economy
- Supporting PTB and the Ministry in important PTB-related questions
 - ⇒ permanent evaluation of current tasks
 - ⇒ strategic recommendations
- Nobel Prize winners in the PTB Kuratorium:
Wilhelm Conrad Röntgen, Philipp Lenard, Willy Wien, Max von Laue,
Max Planck, Fritz Haber, Walther Nernst, Albert Einstein, James Franck,
Gustav Hertz, Walter Bothe, **Klaus von Klitzing**, **Theodor Hänsch**,
Wolfgang Ketterle

(marked persons are currently members of PTB-Kuratorium)



PTB locations

Braunschweig

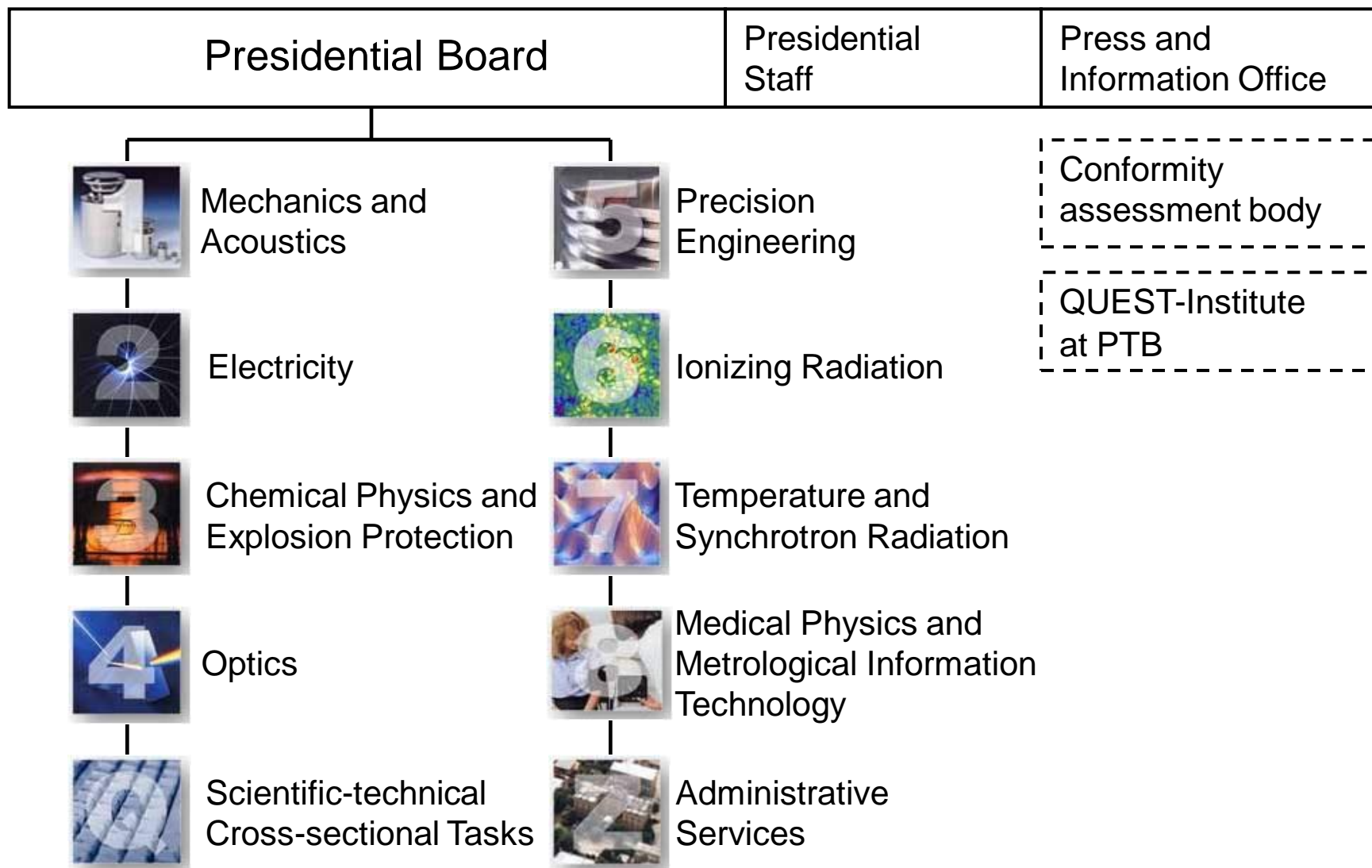


Berlin-Charlottenburg



MLS and PTB-Laboratory at BESSY II
Berlin-Adlershof

PTB Organisation Chart



What characterizes PTB?

PTB is not *a typical government agency*:

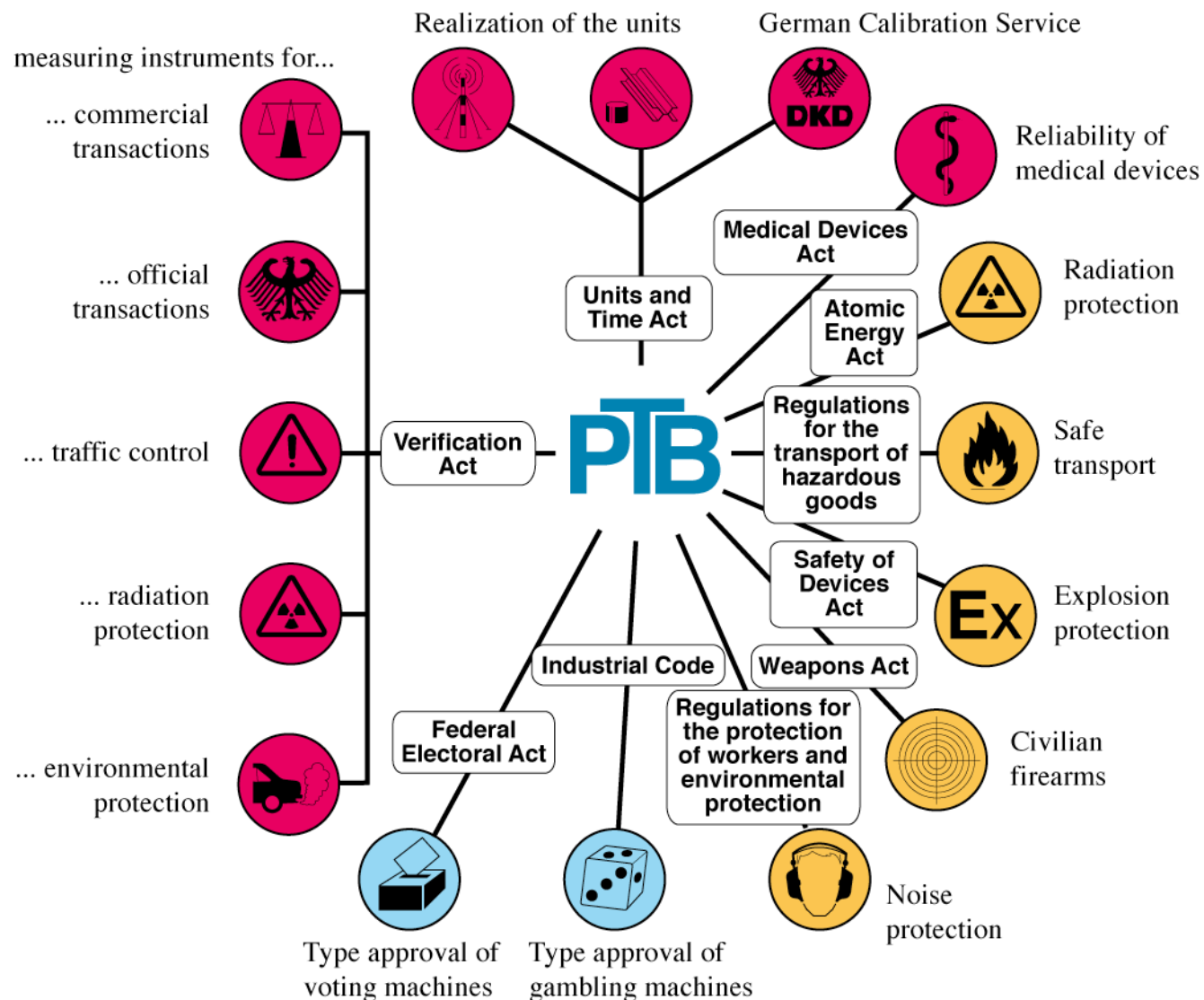
- 60 % research / development
- 30 % calibration / services
- 10 % consulting / cooperation in bodies

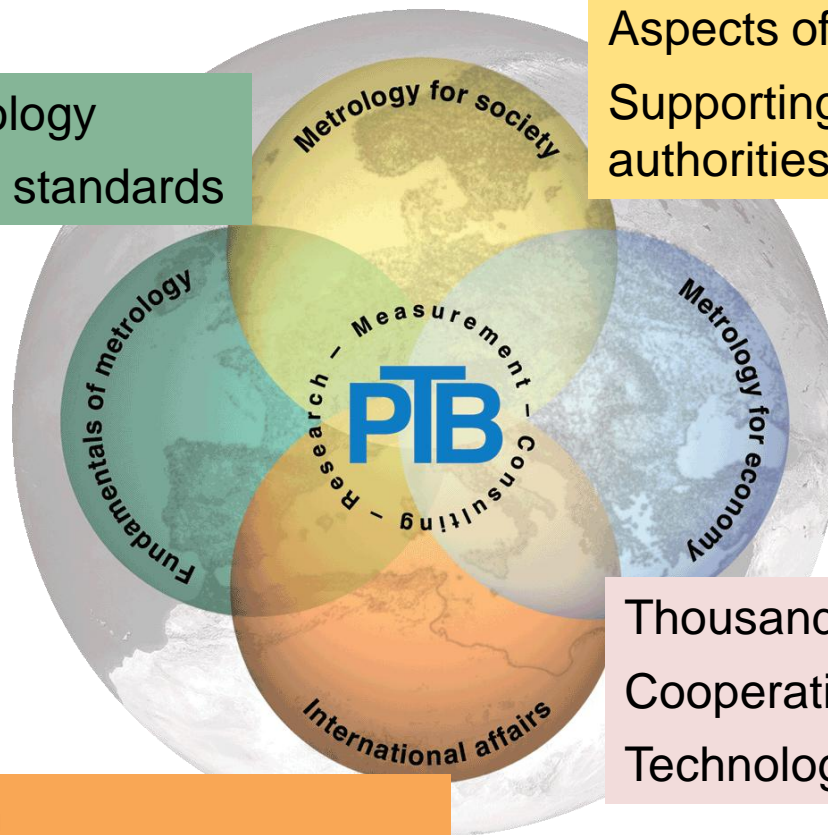
PTB is not *a typical research institute*:

- Constitutional mandate – ensuring uniformity of metrology in Germany
- Cutting-edge research required as inherent part of PTB's duties
- Many tasks are mandated by law.

PTB forms an essential part of the scientific and technical infrastructure of Germany

23 laws and directives
assign specific tasks
to PTB





Basic research for metrology
Improvement of national standards

Aspects of legal metrology
Supporting the verification
authorities

Technical cooperation
International representation of Germany
in metrology related issues

Thousands of calibrations per year
Cooperation projects with industry
Technology transfer

The Kilogram:

- Derivation of the mass scale from 1 mg to 5000 kg from the national kilogram prototype ($u_{\text{rel}} = 6 \cdot 10^{-9}$)
- Research and development of methods for a redefinition of the kilogram on an atomic basis



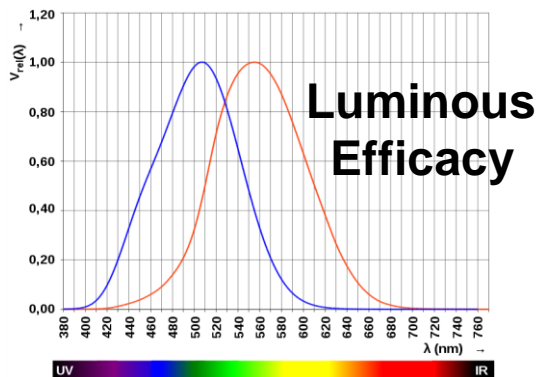
The Second:

- Atomic clocks of the latest generation
- Measurement uncertainty: $<10^{-15}$ (0.03 $\mu\text{s}/\text{year}$)
- Development of “optical clocks” for the future



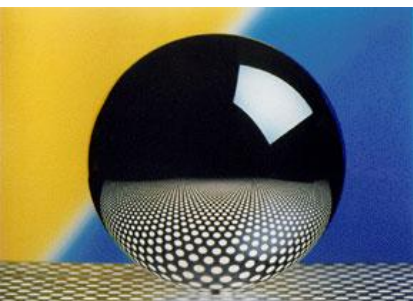
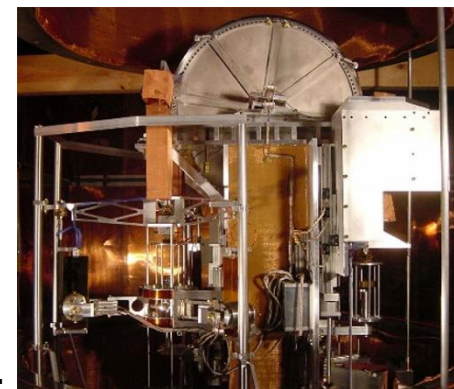
Fundamentals of Metrology

Aim: Definition of the Units on the basis of natural constants

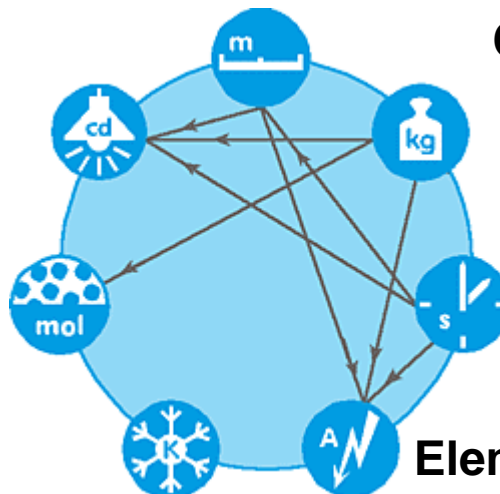


$c = \text{constant}$

Planck Constant



Avogadro Constant

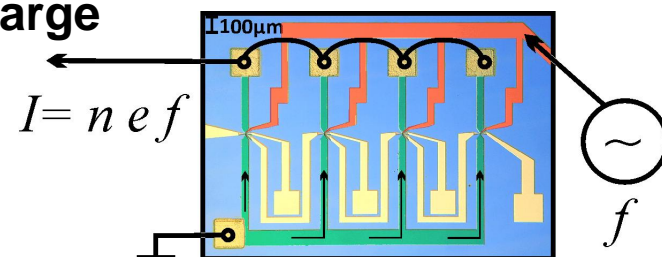


Development of optical clocks

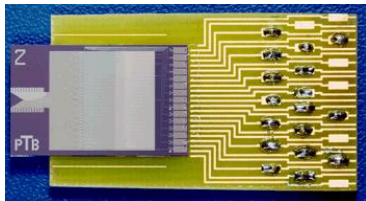


Elementary Charge

Boltzmann Constant



using multipliers...



National Standards

PTB and DIs (BAM, UBA, BVL)

Reference Standards

Accredited Calibration Laboratory

Working Standards

In-Plant Calibration Laboratory

In-Plant Test equipment

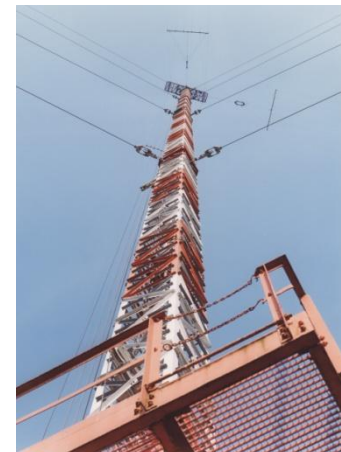
Products



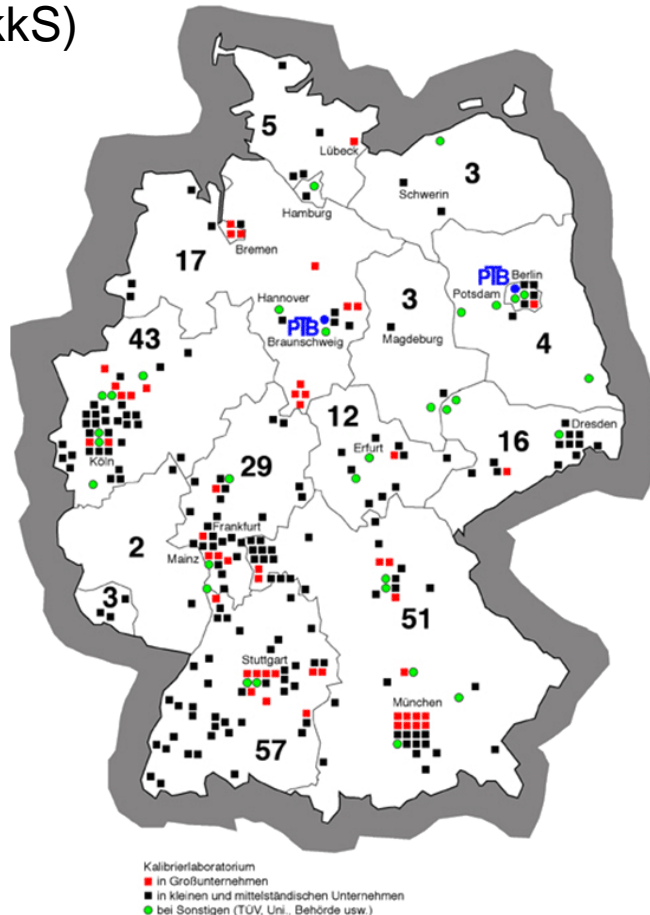
...or direct dissemination

Dissemination of PTB time:

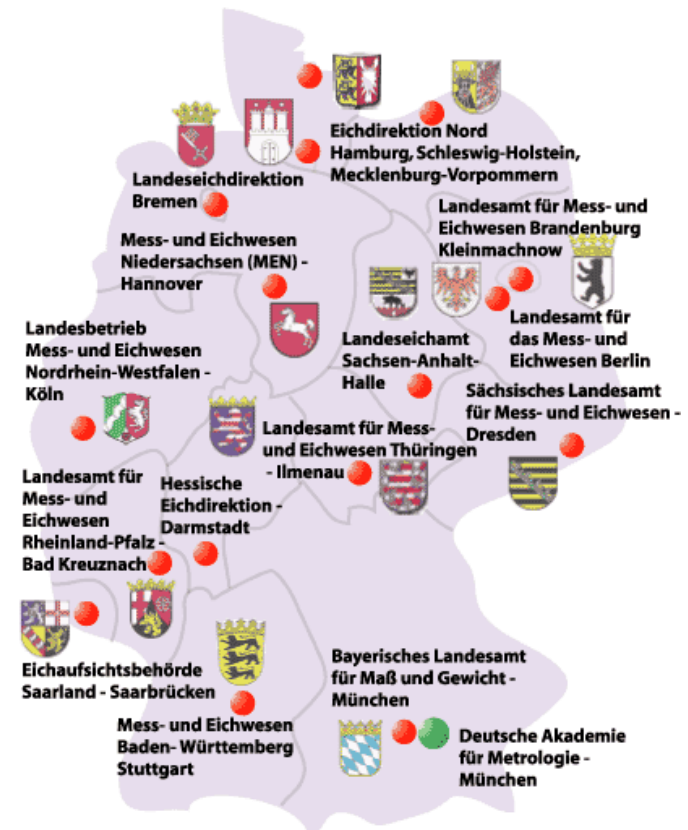
- Internet information service (ntp) *300 mio. accesses per day*
- DCF77 long-wave radio station *hundreds of millions of receivers in Germany and Europe*



Calibrations for industry: Accredited Calibration Laboratories (DAkkS)



Verification: Federal Verification Authorities



Direct Policy Support



- BMWi: Unit and Time Act, legal metrology
- BMUB: Commission on radiological protection
- BMI: Voting machines; central warning of population
- BMZ: Projects of technical cooperation

... in total guidance for nine federal ministries

Standardisation



- Collaboration in 219 national Standardisation Committees
- Collaboration in 303 international Standardisation Committees
(and 313 other international committees)

Others



- Technical experts and assessors for accreditation (DAkkS)
- Cooperation with industry – via associations as well as directly
- Questions from all parts of society

International Cooperation

Harmonizing metrology, removing trade barriers

- **Worldwide Metrology**

Cooperation with metrology institutes,
international comparisons
CIPM-MRA, OIML-MAA, WTO-TBT

- **Large-scale Projects**

e.g. EMRP/EMPIR, Galileo

- **Collaboration in international committees**

Meter Convention,
legal metrology,
standardisation bodies

- **Technical Cooperation**

Support of developing and threshold
countries (49 projects in 81 countries)



European Metrology Program for Innovation and Research

- Support the cooperation of the European metrology institutes
- Increase innovation, standardization and capacity building
- Basis: article 169 EC Treaty (article 185 Lisbon Treaty)
- Projects of PTB and the partner institutes funded until 2020 with 600 Mio. € of the EC.
- Projects of three year period concerning different topics:
 - Health
 - Energy
 - Environment
 - Industry
 - New Technologies (nano-science, security, etc.)
 - Special topics (e. g. SI base units, biotechnology)



“Measured once – Accepted everywhere” → Reduction of trade barriers

CIPM Mutual Recognition Arrangement MRA

- 1999 signed by 38 countries
- 03/2016 – 98 signatories from 58 member states, and 40 associated states
- One coordinating authority per country – PTB in Germany
- Several designated institutes (DI) per country possible – BAM, UBA, BVL in Germany
- Minimum requirements for international acceptance of measurement results



OIML Mutual Acceptance Arrangement MAA

- Implemented in January 2005
- Tool to increase the level of mutual confidence provided by OIML Certificates (MAA Certificates)
- Signed for three categories of measuring instruments – weighing instruments, load cells, water meters

- Within Europe putting on market of measuring instruments is regulated by two directives – MID and NAWID
- General and instrument specific requirements are stated
- Conformity with the requirements is presumed if an instrument is in line with
 - European harmonised standards
 - Normative documents as far as they were declared to be applicable by the European Commission
- Depending on class of instrument different conformity assessment modules have to be applied
 - certificates of notified bodies (conformity assessment bodies) needed
 - Conformity assessment body at PTB for moduls B, C, D and F
- Finally manufacturer declares conformity



- General requirements as stated in the German Verification Act:
 - Instruments have to comply with the state-of-the-art of technology
 - State-of-the-art is determined by German Committee of Rules (REA)
- Conformity of an instrument with the general requirements is presumed if an instrument is in line with
 - European harmonised standards
 - Normative documents, as far as they were declared to be applicable by the European Commission
 - Rules and Specifications determined by the German Committee of Rules (REA) with the respective references published officially
- Even nationally notified conformity assessment bodies are basis of the system
- Strong cooperation with verification authorities and market surveillance, but different responsibilities



- Part of Division 1 “Mechanics and Acoustics”
 - Head is Prof. Dr. Frank Härtig
 - Division consists of eight departments, dealing with gas flow, liquid flow, velocity, sound, acoustics and dynamics, force, torque and mass
- Structure of Department 1.1
 - Head of Department is Dr. Dorothea Knopf
 - Working group “Weighing Instruments” – Head is Dr. Oliver Mack
 - Working group “Dynamic Weighing” – Head is Michael Denzel
 - Working group “IT-Weighing Technology” – Head is Dr. Tobias Klein
- Main Tasks
 - Test and evaluation of weighing instruments and modules of weighing instruments
 - Certification of modules and weighing instruments within the conformity assessment body of PTB – European Directives, International Standards (OIML), National Legislation







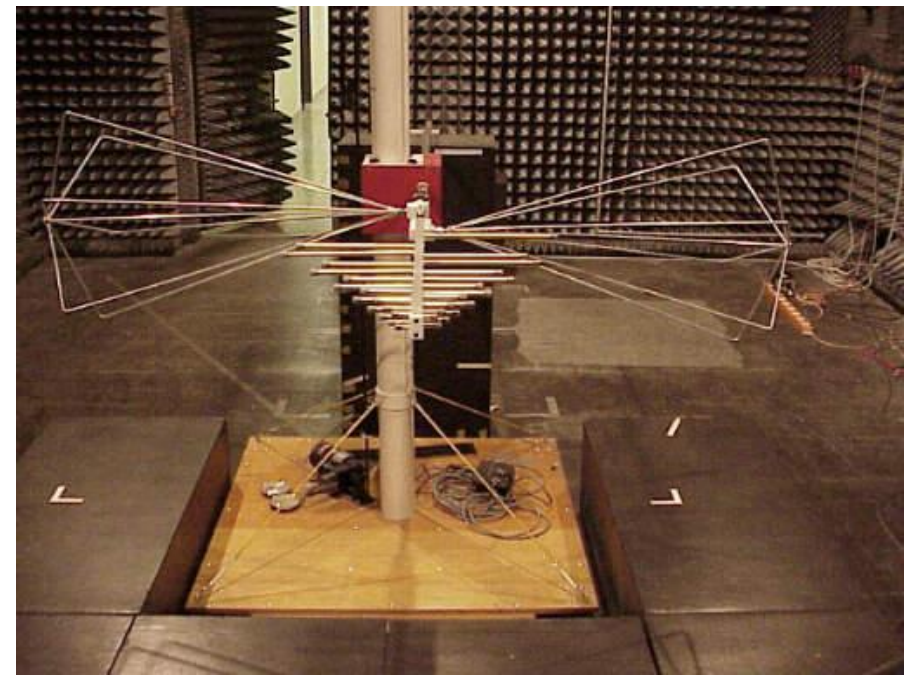
- Geometry
(W x D x H) mm = 700 x 800 x 800,
- Temperature range $(-20^{\circ}\text{C}/+150^{\circ}\text{C}) \pm 1,5^{\circ}\text{C}$
without Humidity, otherwise $(10^{\circ}\text{C}/90^{\circ}\text{C}) \pm 1^{\circ}\text{C}$,
- rel. Humidity $(15/95) \pm 5\%$, or $(10/98) \pm 3\%$



- Geometry
(W x D x H) m = 5 x 3 x 2,8,
- Temperature range $(-20^{\circ}\text{C}/+50^{\circ}\text{C}) \pm 1^{\circ}\text{C}$,
- rel. Humidity $(15/95) \pm 5\%$



- Test equipment for electrostatic discharge,
- ESD generator with discharge gun
- 1m coupling clamp for capacitive coupling of disturbance voltages into signal and control lines



- Broad band biconical logarithmic-periodical antenna
- Frequency range between 20 MHz ... 2 GHz
- Measurements in EMC-Testlab of PTB



- Geometry (W x D x H) mm = 941 x 680 x 1000,
- Temperature range (-30°C / +50°C) $\pm 1^\circ\text{C}$
- No humidity tests
- Max. weight: 5000 kg ($U_{\text{rel}} = 5 \times 10^{-6}$)

Masses for the tests are located in the laboratory below the thermostatic chamber. Load transmission is realised via a pull rod through the ground.

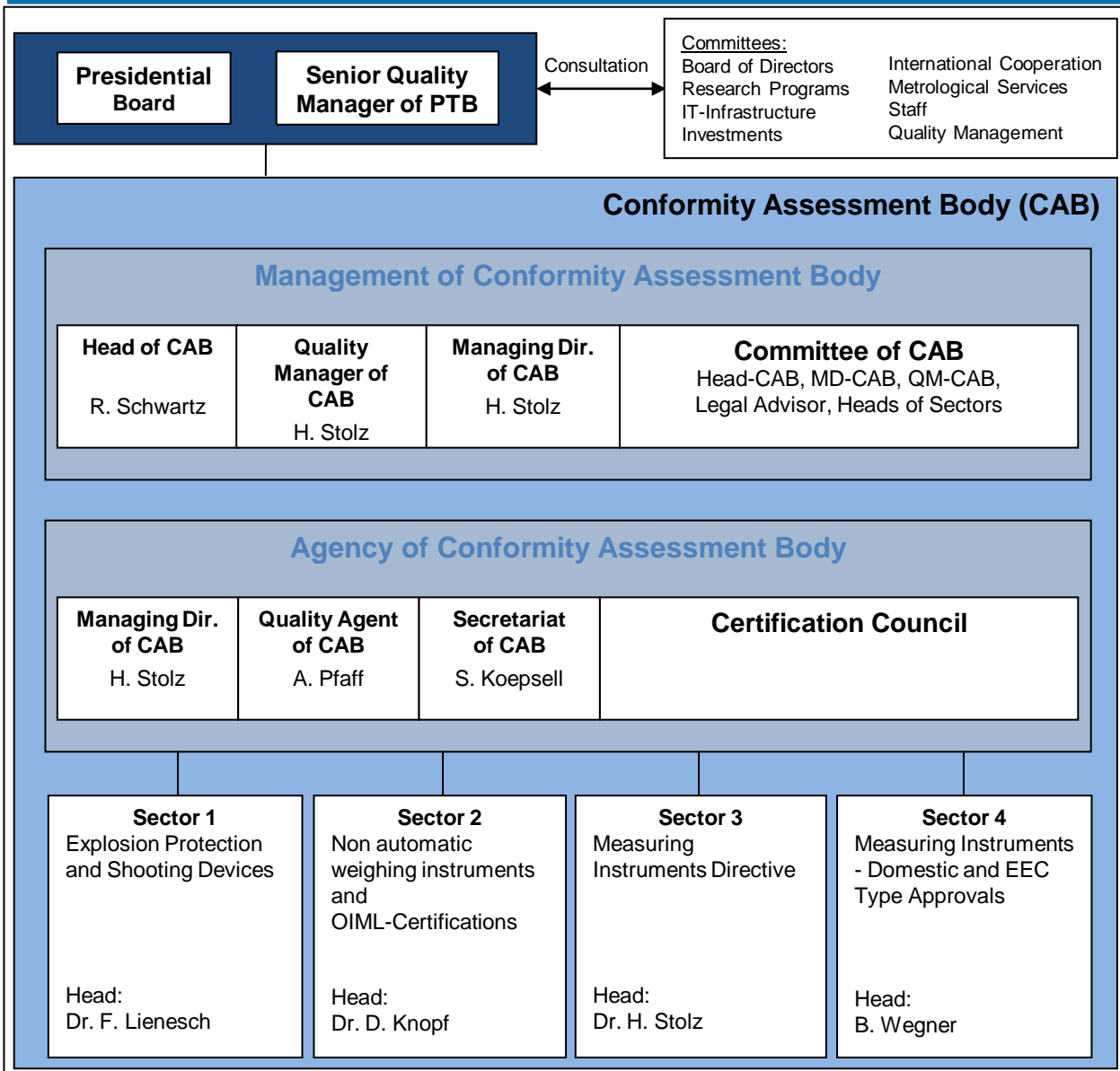




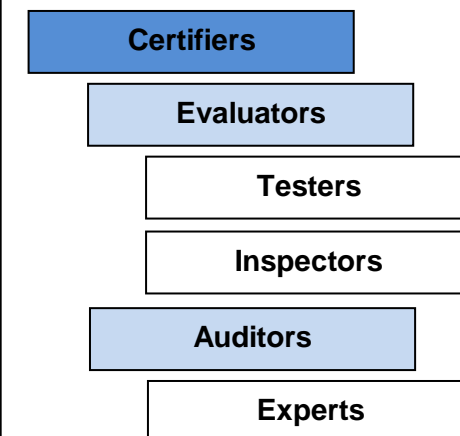
Climatic Chamber within the 2 MN Force Standard Machine

- max. weight: 200 t ($U_{rel}=2 \cdot 10^{-5}$)
- geometry (W x D x H) mm = 410 x 476 x 640,
- temperature range (-20°C / +55°C) $\pm 0,2^{\circ}\text{C}$

Conformity Assessment Body at PTB



Within each sector differentiation:



Thank you for your attention!



**Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin**

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