

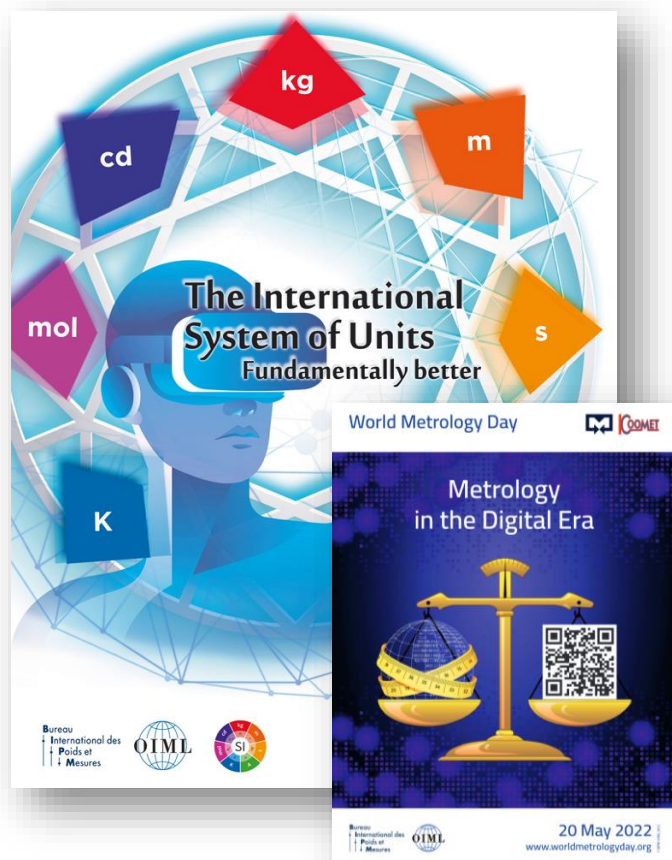
A common goal for interoperable digital data within the quality infrastructure

Joachim Ullrich

President of the German Physical Society, DPG

Vice President, International Committee for Weights and Measures, CIPM

Chair of the CIPM Task Group on the Digital SI, TG-DSI



Quality Infrastructure of the Future

by 2050 about 50 % to 80 % of the population live in cities

What will cities look like?

How will the **supply** work?

What **measurements** and **metrology** will be needed?

What **Quality Infrastructure** will be needed:

→ How can we guarantee high-quality and reliability in complex interlinked digital systems?

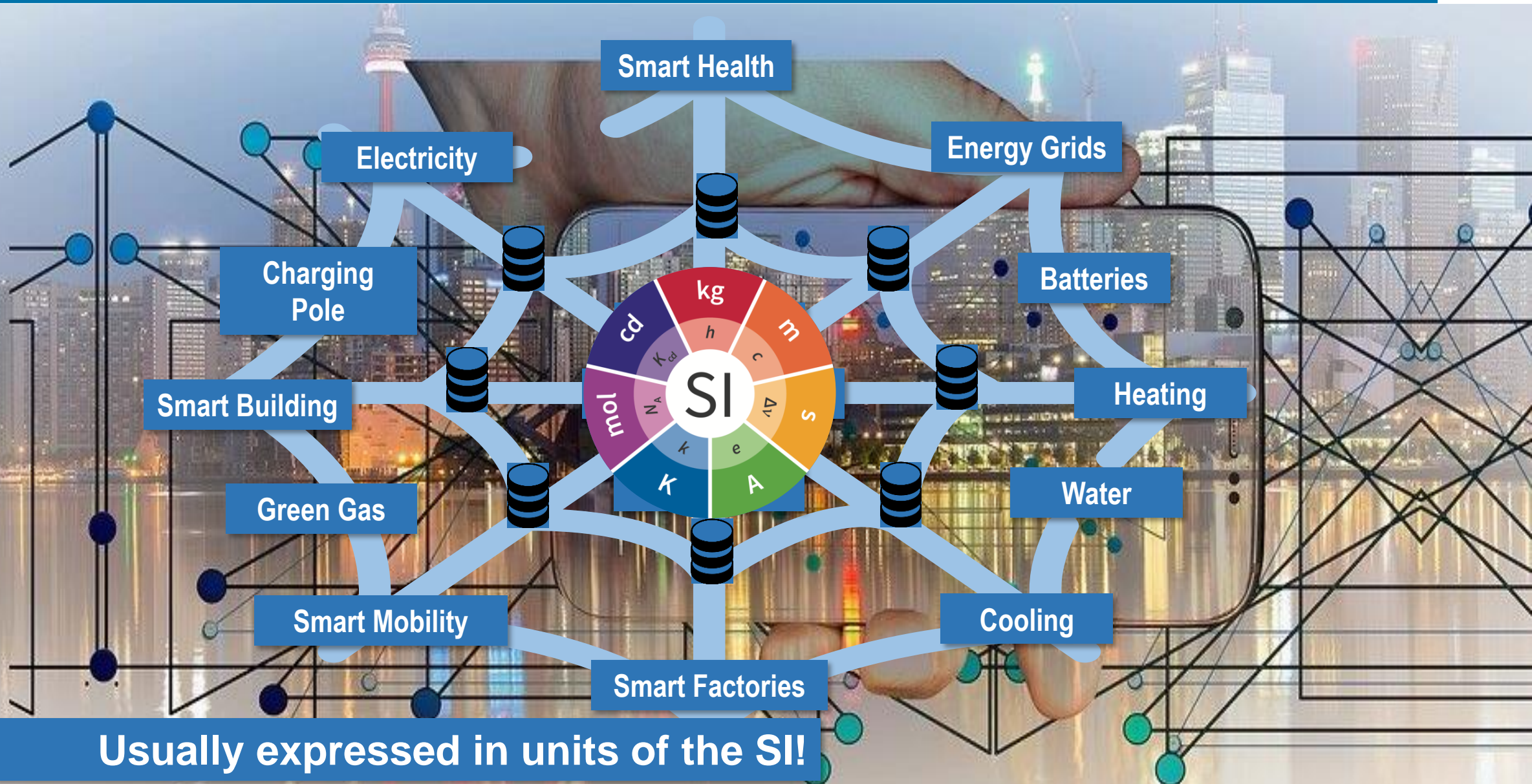
Smart Health

Smart Building

Smart Mobility

Smart Factories

Quality Infrastructure of the Future



The Metre Convention and the SI



Diplomatic Treaty signed in 1875

• accreditation

~ 65 000 laboratories are accredited along ISO/IEC 17025 requesting traceability to the SI

• standardization

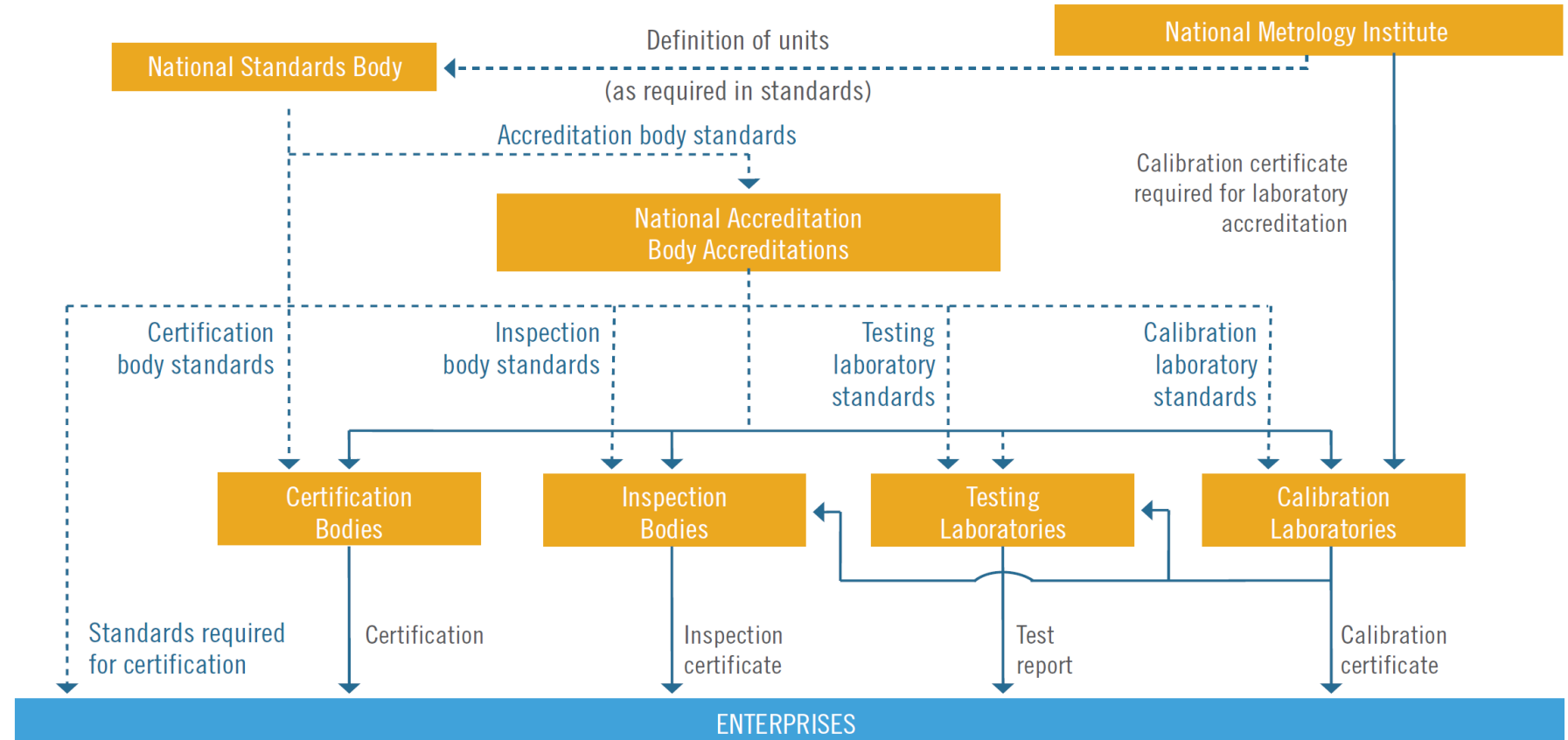
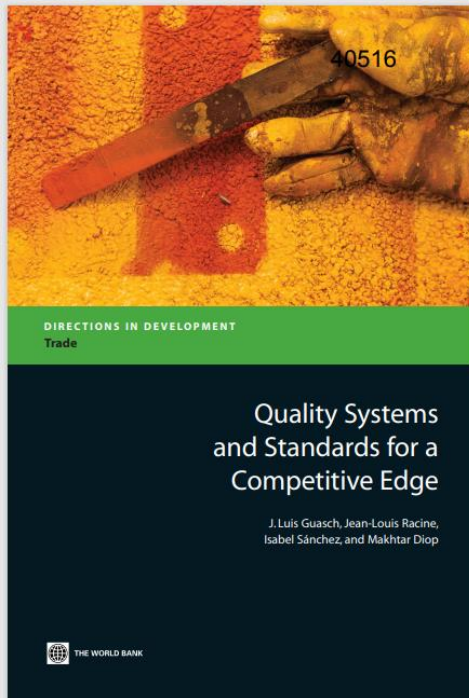
• metrology

102 Member, Associated States and Economies

- 97.6 % of the World's GDP participate
- Scientific basis for Quality Infrastructure



Worldwide Quality Infrastructure



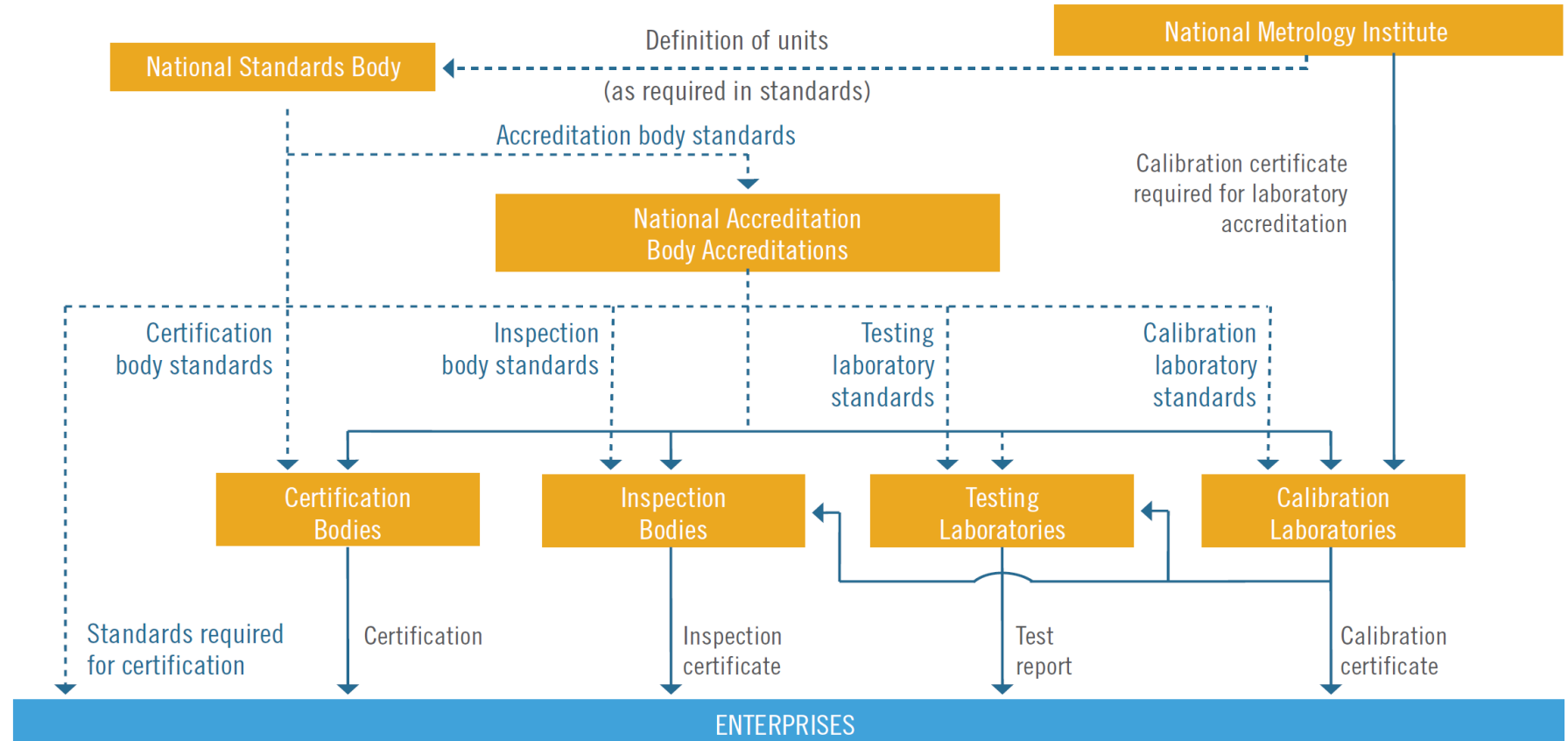
Source: World Bank, 2007, Quality Systems and Standards for a Competitive Edge, Washington D.C. Standards

Worldwide Quality Infrastructure

complex processes:
→ Fully digitalized



... a worldwide agreed
metadata format for all
measurement data



Source: World Bank, 2007, Quality Systems and Standards for a Competitive Edge, Washington D.C. Standards

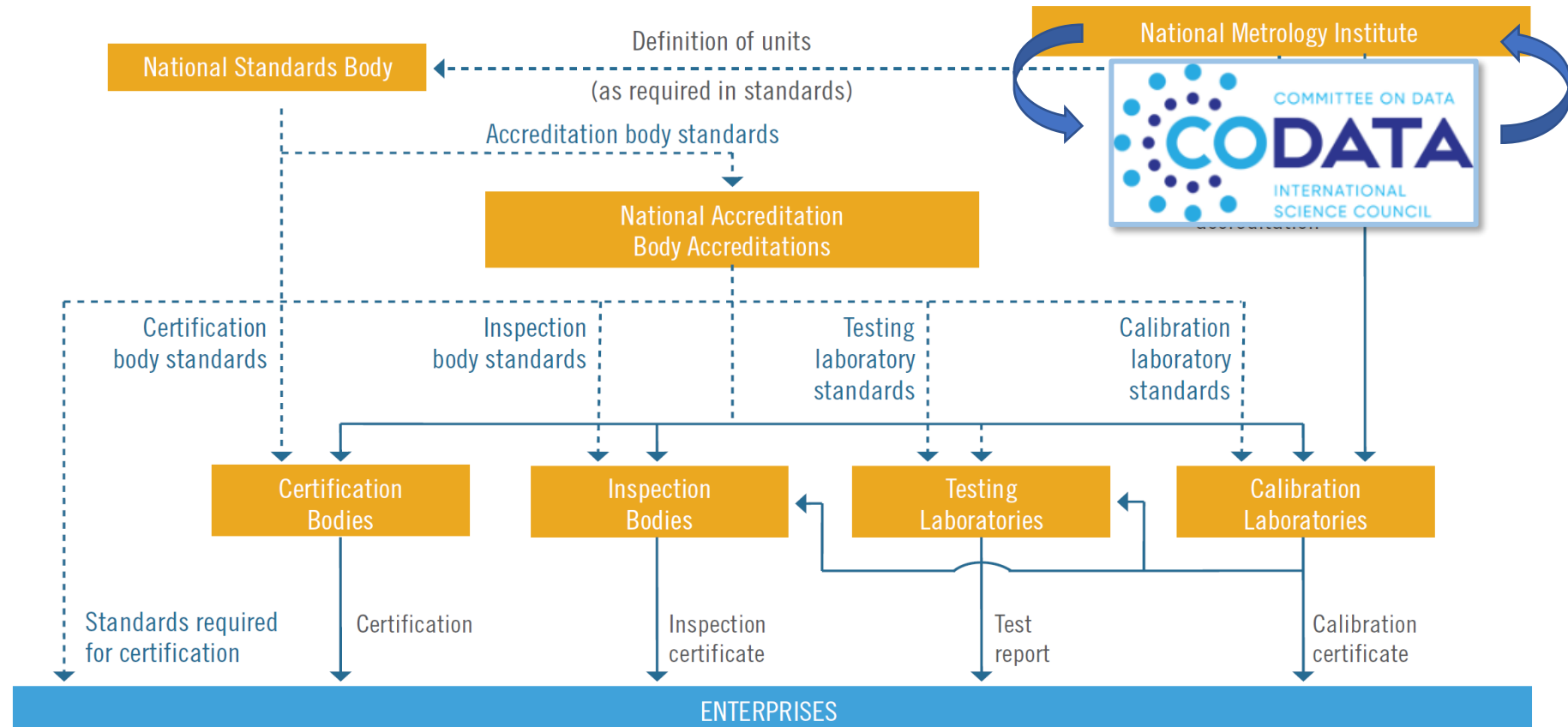
Worldwide Quality Infrastructure

complex processes:
→ Fully digitalized

... a worldwide agreed
metadata format for all
measurement data



- Quality Infrastructure
- Industry & Health
- Science



Source: World Bank, 2007, Quality Systems and Standards for a Competitive Edge, Washington D.C. Standards

Grand Vision: SI Digital Framework

The Grand Vision: SI Digital Framework

The International System of Units (SI), provided by the BIPM SI Brochure, provides a coherent foundation for the representation and exchange of measurement data, enabling interoperability and reproducibility in all scientific and technological domains. *The long-term aim of the TG “Digital SI” initiative is to establish a framework that meets FAIR principles (respecting business and privacy constraints) and allows all aspects of the international measurement system – measurement results, uncertainties, traceability and provenance – to be accessed and interpreted digitally, enabling **machine-to-machine communication and analysis**.* With this respect the SI, existing for more than one century – might be considered as an exemplar of interoperability principles for data. The envisioned framework encompasses foundational (core) models for SI based data representation, digital services and tools, and data stewardship and management activities, providing SI data and information that is transparent to (authorized) users and machines.



... machine-to-machine communication ...

From level 3 on all digital formats will need interoperable unit and quantity representations

5 degrees of digitalization for **Smart Standards** (ISO/IEC)



Level 1

Digital document

Digital representation



Level 2

Machine-readable document

Structured document format
Software processing with high manual workload



Level 3

Machine-readable and -executable content

Content completely (semantically) discovered
Semantic search and selective access on content level



Level 4

Machine-interpretable content

Information models describing and explaining the content and the relationships between items of information
Self-learning analysis together with automatic validation and optimization
Value-adding services possible e.g. conformity check, question answering,



Level 5

Machine-controllable content

The content of a standard is amended automatically and adopted by automated decision-making processes.
Digital standards are based on a system of artificial general intelligence with cognitive capabilities.
Digital standards adapt constantly to the current state of the art of technical and regulatory framework conditions.

SI Digital Framework
(machine-actionable)

The Grand Vision: SI Digital Framework

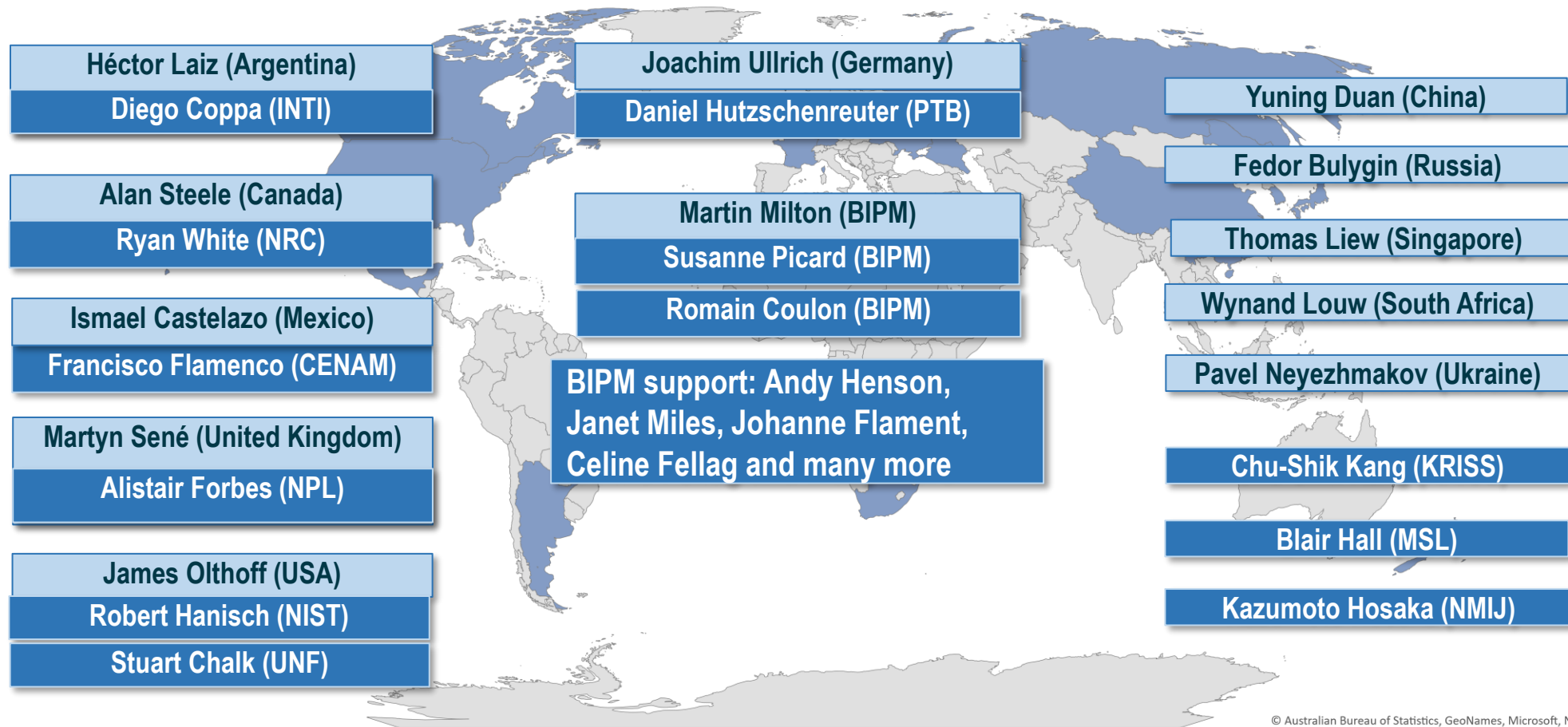
The International System of Units (SI), provided by the BIPM SI Brochure, provides a coherent foundation for the representation and exchange of measurement data, enabling interoperability and reproducibility in all scientific and technological domains. *The long-term aim of the TG “Digital SI” initiative is to establish a framework that meets FAIR principles (respecting business and privacy constraints) and allows all aspects of the international measurement system – measurement results, uncertainties, traceability and provenance – to be accessed and interpreted digitally, enabling **machine-to-machine communication and analysis**.* With this respect the SI, existing for more than one century – might be considered as an example of interoperability principles for data. The envisioned framework encompasses foundational (coherent) SI based data representation, digital services and tools, and data stewardship and management providing SI data and information that is transparent to (authorized) users and machines.

Established in the
108th meeting of
the CIPM



- International **Task Group “Digital-SI”** of the CIPM: November 2019
- International **Expert Group** for technical support and expertise

CIPM Task Group & Expert Group “Digital SI”



CIPM Task Group members

Expert Group members

The Grand Vision: SI Digital Framework



Long-term goal

World-wide agreed, uniform, unambiguous, authoritative and dependable data exchange framework based on the International System of Units (SI)

Coordination with all international QI and science stakeholders

First international workshop on the SI Digital Framework in 2021

- ◆ 785 Participants,
- ◆ 1287 Registrations
- ◆ 33 Talks
- ◆ Representative from
 - International QI
 - Science and industry
 - NMIs and RMOs



The International System of Units in FAIR digital data

The International System of Units (SI) in FAIR digital data.



Prof. Dr. Joachim Ullrich
CIPM Vice President
CCU and TG "Digital SI" Chair
22 February 2021

The Grand Vision: SI Digital Framework



Long-term goal

World-wide agreed, uniform, unambiguous, authoritative and dependable data exchange framework based on the International System of Units (SI)
Coordination with all international QI and science stakeholders

First international workshop on the SI Digital Framework in 2021

Joint Statement of Intent with international organizations of the quality infrastructure 2022

30 March 2022

Joint Statement of Intent

On the digital transformation in the international scientific and quality infrastructure

Recognising that

- governments, industry, academia, and civil society have been working toward comprehensive digital transformation for many years, and, in so doing, are increasingly
 - establishing systems to collect, aggregate, analyse and interpret digital data;
 - introducing networked sensor systems for diverse scientific and industrial applications;
 - sharing data at local, national, regional, and international scales;
- the scientific community has made significant progress in establishing reliable foundations for digital data interchange and management, including the FAIR principles for data management and stewardship;
- the organisations of the international quality infrastructure (metrology, accreditation, standardization, and conformity assessment) have a critical role working together to ensure sustainable economic development;
- the International System of Units (SI) plays a particular role in the international quality infrastructure providing confidence in the accuracy and global comparability of measurements needed for international trade, manufacturing, human health and safety, protection of the environment, global climate studies, and scientific research;
- maintaining this confidence in the accuracy and global comparability of measurements will require the creation and adoption of a full digital representation of the SI, including robust, unambiguous, and machine-actionable digital representations of units of measurement and of measurement results and uncertainties;
- progress on global challenges such as this requires the participation of, and critical thinking from, diverse communities;
- successfully effecting such a comprehensive digital transformation for metrology and ensuring its benefits are fully realised will require the active participation of a wide range of stakeholders; particularly other members of the International Quality System;

We the undersigned undertake to support in a way appropriate to each organisation the development, implementation, and promotion of the SI Digital Framework as part of a wider digital transformation of the international scientific and quality infrastructure.

Joint Statement of Intent



Sergio Mujica
(ISO Secretary-General)



Wynand Louw
(CIPM President)



Mathieu Denis
(ISC Science Dir.)



Barend Mons
(CODATA President)



Philippe Metzger
(IEC Secretary-General & CEO)



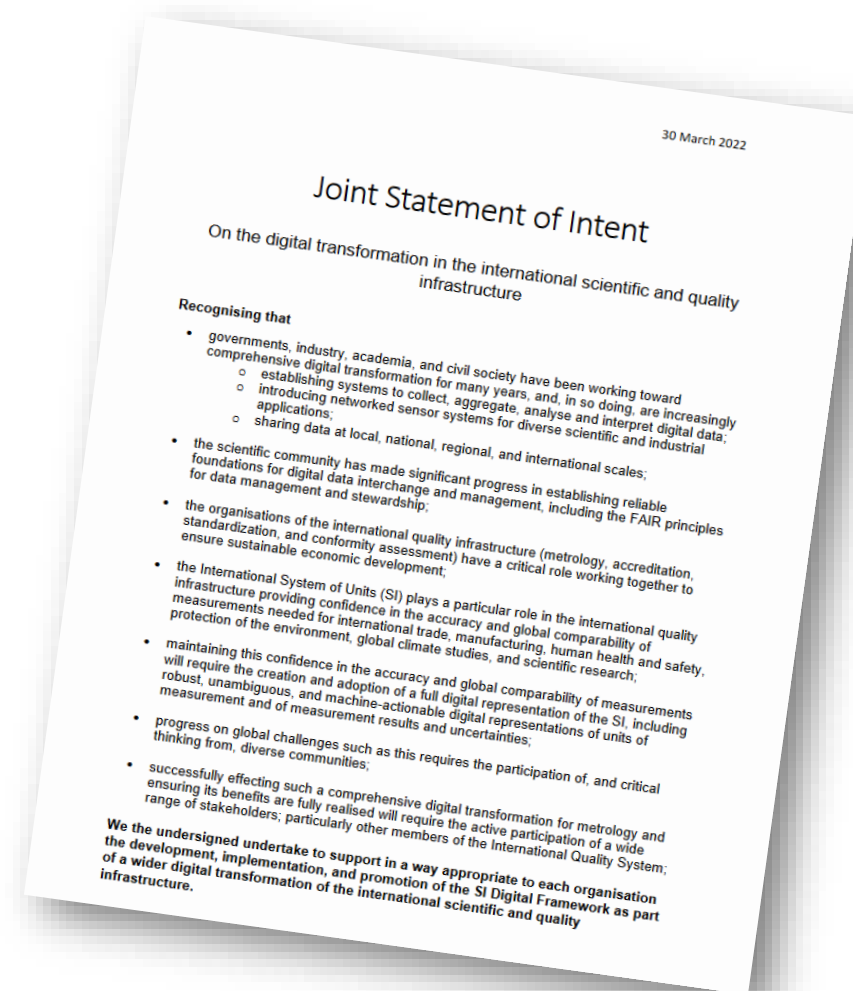
Etty Feller
(ILAC Chair)



Frank Härtig
(IMEKO President)



Roman Schwartz
(CIML President)



<https://www.bipm.org/en/-/2022-03-30-digital-statement>

Joint Statement of Intent



ISO



CIPM



ISC



CODATA



IEC



ILAC



IMEKO



OIML

We the undersigned undertake to support in a way appropriate to each organisation the development, implementation, and promotion of the SI Digital Framework as part of a wider digital transformation of the international scientific and quality infrastructure.

<https://www.bipm.org/en/-/2022-03-30-digital-statement>

The Grand Vision: SI Digital Framework



Long-term goal

World-wide agreed, uniform, unambiguous, authoritative and dependable data exchange framework based on the International System of Units (SI)
Coordination with all international QI and science stakeholders

First international workshop on the SI Digital Framework in 2021

Joint Statement of Intent
with international organizations of the quality infrastructure 2022

Metre Convention Resolution
for governmental support 2022

20 • Draft Resolutions – 27th meeting of the CGPM

Draft Resolution B

On the global digital transformation and the International System of Units

The General Conference on Weights and Measures (CGPM), at its 27th meeting, considering

- that governments, industry, academia, and civil society have been working toward a comprehensive digital transformation for many years, and, in so doing, are:
 - establishing systems to collect, aggregate, analyse and interpret digital data,
 - introducing networked sensor systems for diverse scientific and industrial applications,
 - sharing data at local, national, regional and international levels,
- the essential role of the International System of Units (SI) in providing confidence in the accuracy and global comparability of measurements needed for international trade, manufacturing, human health and safety, protection of the environment, global climate studies and scientific research,

anticipating that

- maintaining and building confidence in the accuracy and global comparability of measurements will require the creation of a full digital representation of the SI, including robust, unambiguous, and machine-actionable representations of measurement units, values and uncertainties,
- successfully effecting such a comprehensive digital transformation will require engagement with a wide range of stakeholders including, but not limited to, the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Organization of Legal Metrology (OIML), International Laboratory Accreditation Cooperation (ILAC), Committee on Data for Science and Technology (CODATA) of the International Science Council, and other scientific, regulatory, and quality infrastructure communities,

welcomes

- the recent efforts to articulate guiding principles for a digital transformation in metrology,
- the establishment of a flexible and inclusive governance structure supporting the development and implementation of that transformation,

Metre Convention Resolution

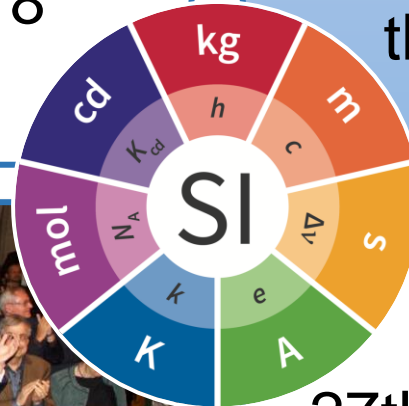
26th General Conference on Weights and Measures November 2018

Draft Resolution B

On the global digital transformation and the International System of Units



Revised definition of the SI



27th General Conference on Weights and Measures November 2022

Metre Convention Resolution

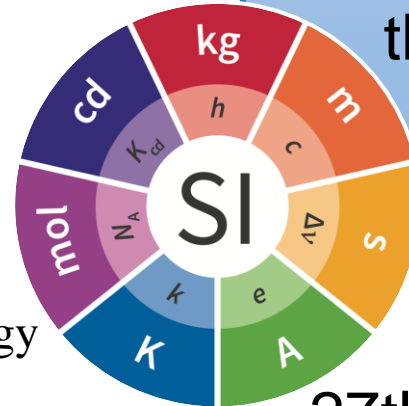
On the global digital transformation and the International System of Units

The General Conference on Weights and Measures (CGPM), at its 27th meeting,

[...]

Invites

National Metrology Institutes, Regional Metrology Organizations and other stakeholders to maintain and, where possible, increase their existing level of commitment and collaboration with the CIPM to continue the development, promotion and implementation of the SI Digital Framework,



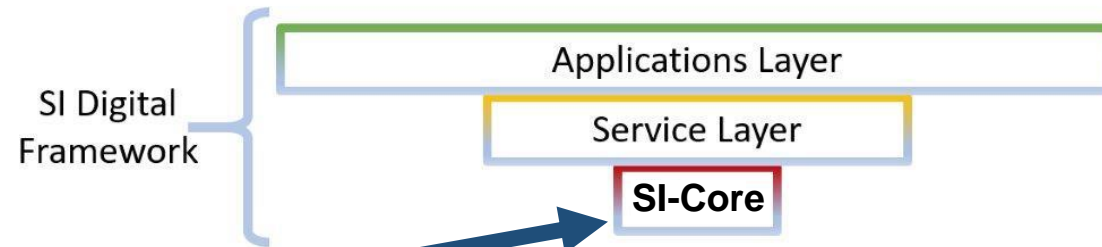
Draft Resolution B

On the global digital transformation and the International System of Units

27th General Conference on Weights and Measures November 2022

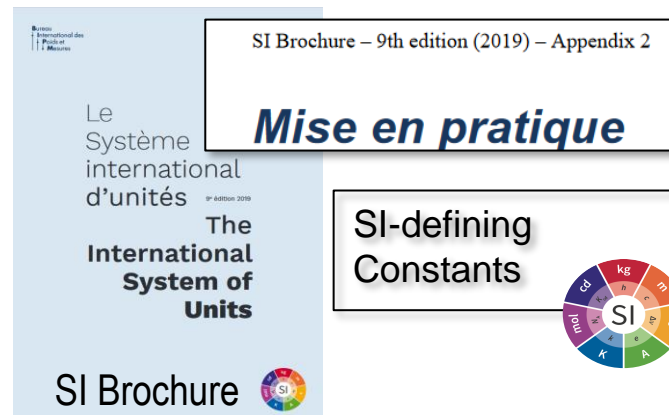
The Grand Vision: SI Digital Framework

Sustainable framework for the SI in a digital world

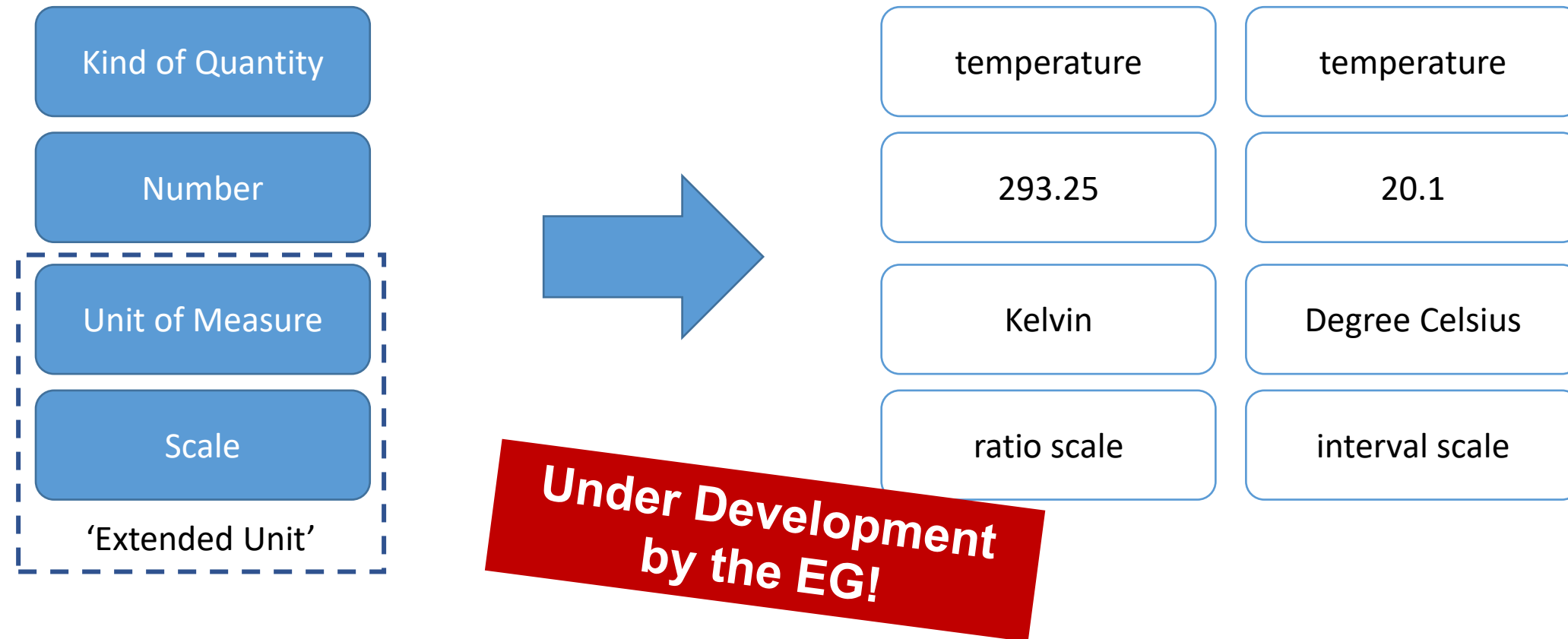


Endorsed by CIPM!
(Decision 109-17)

value, unit, kind of
quantity, uncertainty



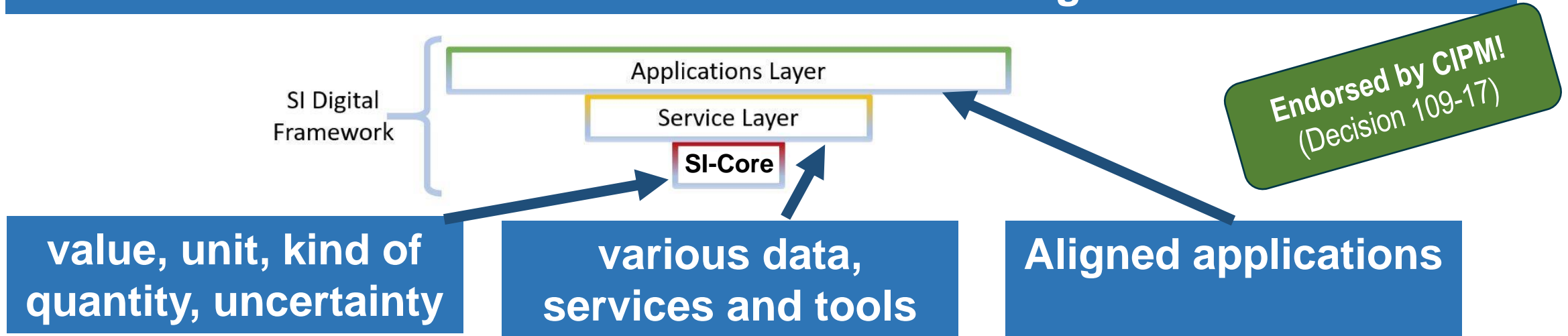
Essential Metrological Information (M-Layer*)



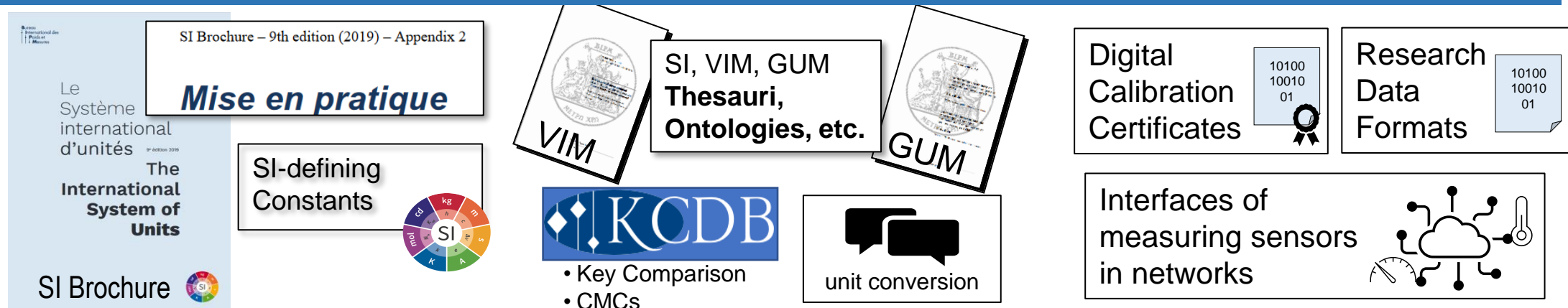
* B.D. Hall and M. Kuster: Metrological support for quantities and units in digital systems. Measurement: Sensors, 18:100102, 2021

The Grand Vision: SI Digital Framework

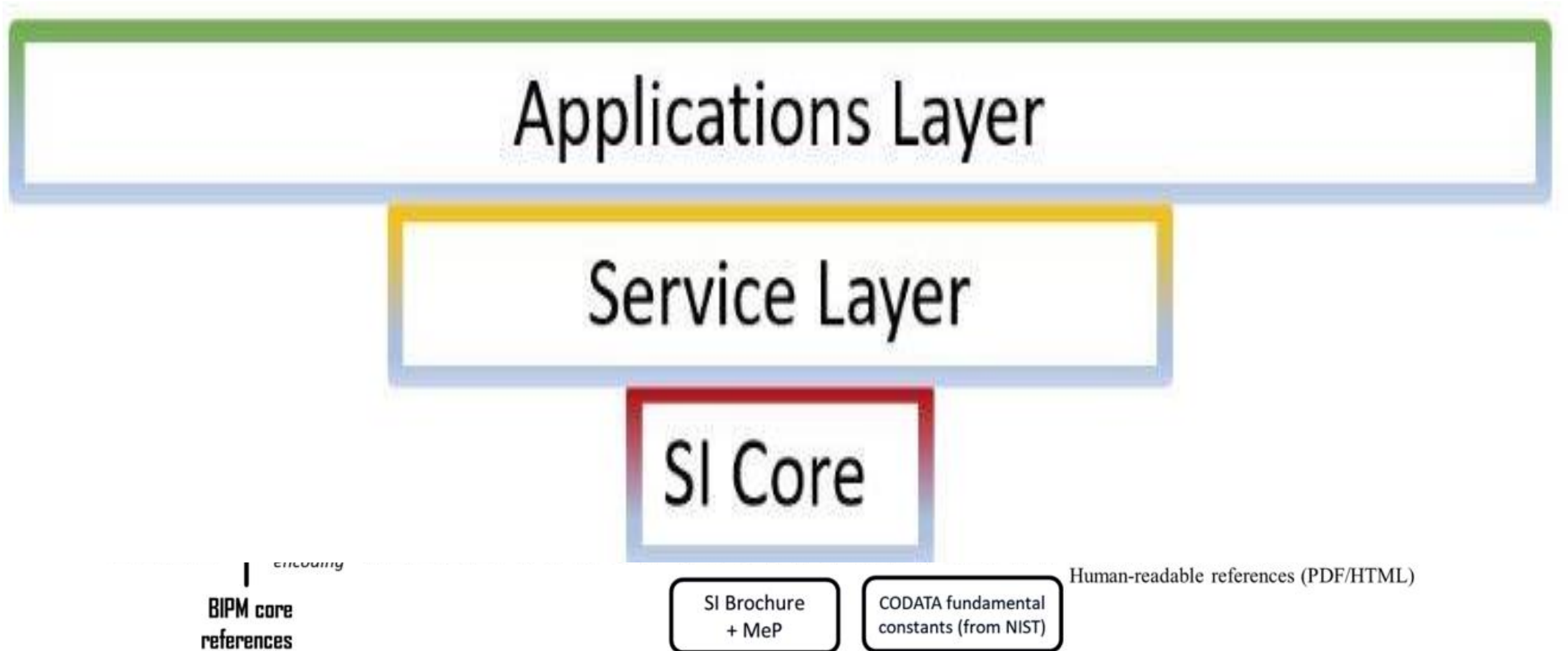
Sustainable framework for the SI in a digital world



All following FAIR principles (Findable, Accessible, Interoperable, Reusable)



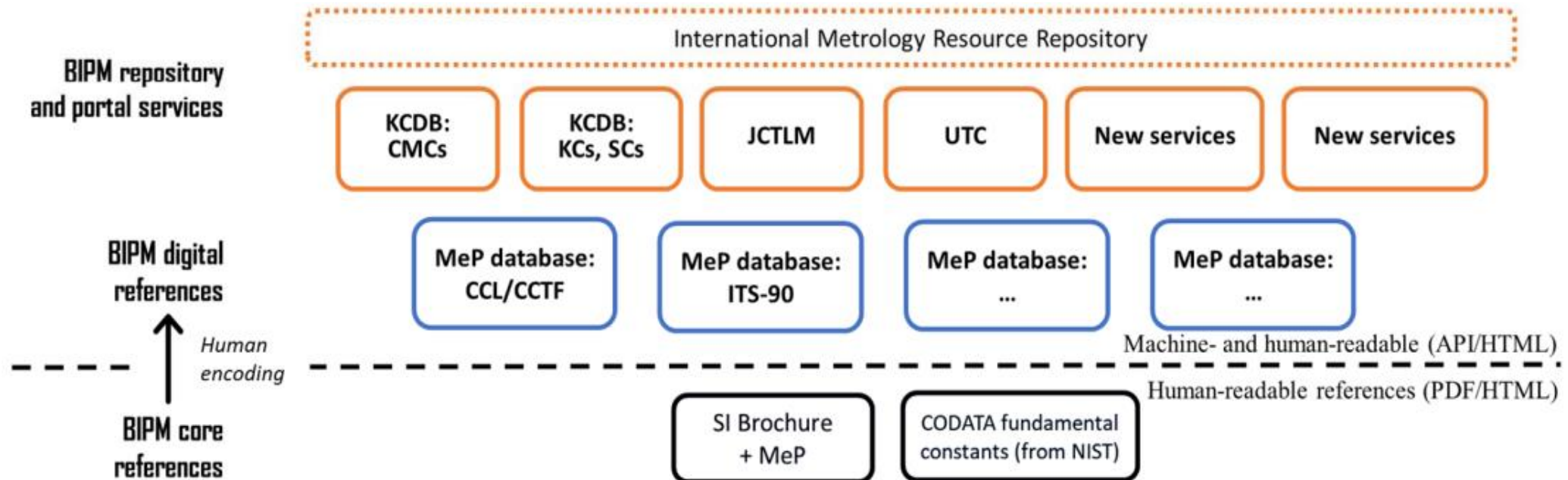
BIPM Data Plane: Findable & Accessible



BIPM Data Plane: Findable & Accessible

! Draft version !
BIPM Headquarters
Martin Milton et al.

Applications Layer

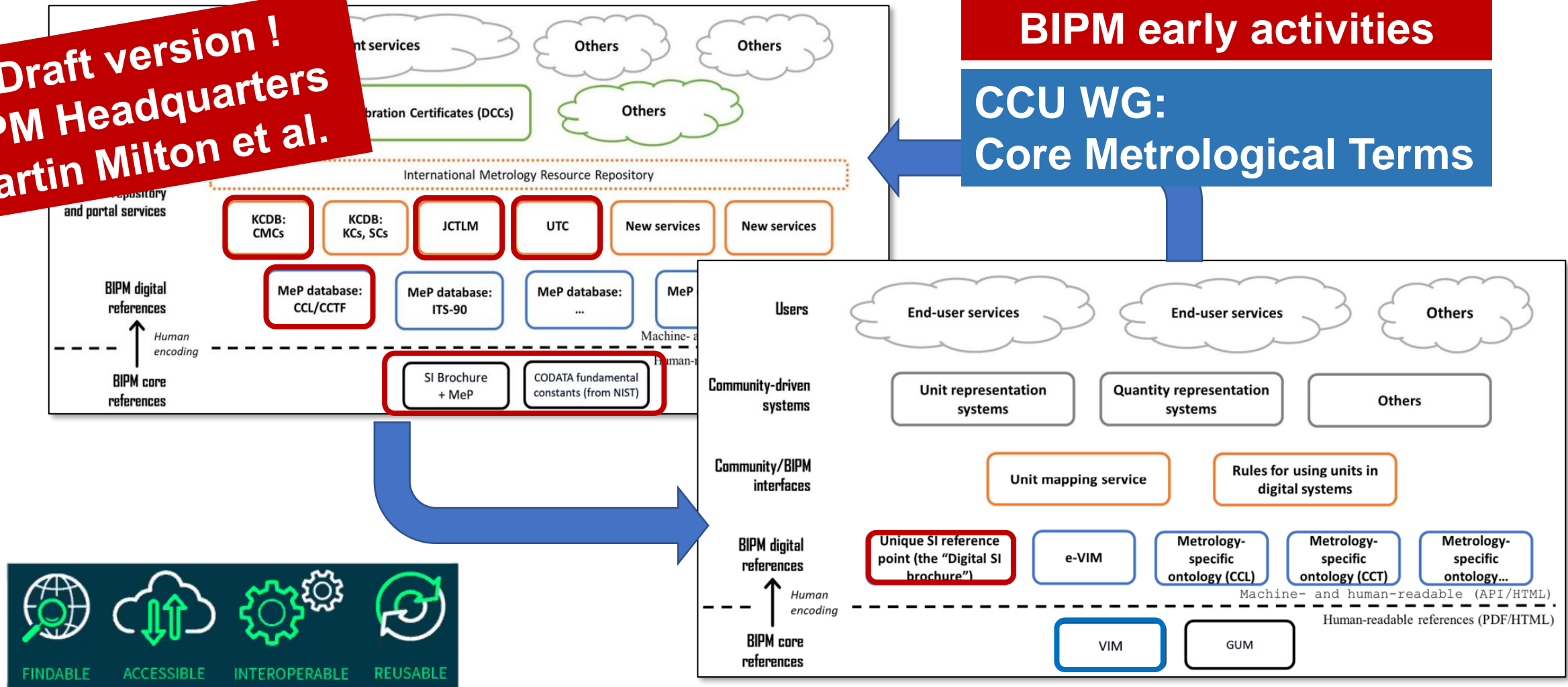


BIPM Data Plane & Interoperability Plane

! Draft version !
BIPM Headquarters
Martin Milton et al.

BIPM early activities

CCU WG:
Core Metrological Terms



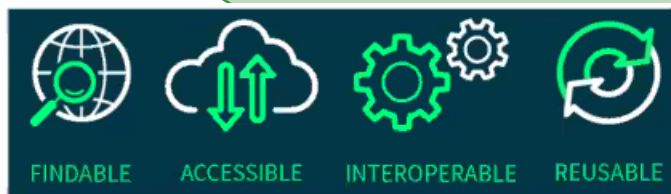
BIPM Data Plane & Interoperability Plane

! Draft version !
BIPM Headquarters
Martin Milton et al.

... a QI joint FAIR effort!

**ILAC, ISO, IEC, OIML,
CIPM, IMEKO, ISC, CODATA
+ IEC, IUPAP, IUPAC,**

... creating a joint Forum in 2023!



Ongoing Joint Efforts: Outreach


“Stop squandering data: make units of measurement machine-readable”

- Comment in Nature, May 10 2022
 - Highlighted in Nature News Feed on May 11
- Spreading the word and encouraging others to join the effort is important to the mission!



Liaison with CODATA DRUM

Thank You



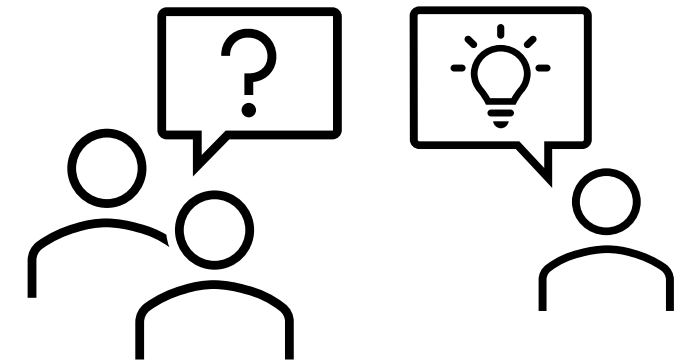
The International System of Units (SI) is represented by a circular diagram with the SI symbol in the center. The units are arranged in a ring around the center, with their symbols and names: kg (kilogram), m (metre), s (second), A (ampere), K (kelvin), mol (mole), and cd (candela). The units are color-coded: kg (red), m (orange), s (yellow), A (green), K (blue), mol (purple), and cd (dark blue).

The International System of Units (SI)
in **FAIR** digital data.

The International System of Units (SI) is the basis for all scientific and technical measurements. It is a system of units that is used by scientists, engineers, and the general public. The SI is based on seven base units: the kilogram, the metre, the second, the ampere, the kelvin, the mole, and the candela. These units are used to measure mass, length, time, electric current, temperature, amount of substance, and luminous intensity, respectively. The SI is a system of units that is used by scientists, engineers, and the general public. It is a system of units that is used by scientists, engineers, and the general public.

Prof. Dr. Joachim Ullrich
CIPM Vice President
CCU and TG "Digital SI" Chair
22 February 2021

FAIR: FINDABLE, ACCESSIBLE, INTEROPERABLE, REUSABLE



Q&A

END