A Taxonomy of Radiometric-Measurand Metadata

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Measurement-Information Infrastructure

Section 1

Introduction

Today's Topics

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1. Introduction
2. Motivation and Strategy
3. Tools and Process
4. Conclusion

Acronyms

- BIPM—International Bureau of Weights and Measures
- CMC—calibration and measurement capability
- DCC—digital calibration certificate
- DCR—digital calibration request
- DX—digital transformation
- FAIR—findable, accessible, interoperable, reusable
- KCDB—key comparison database
- M-layer—metrology information layer to support measurement systems
- NCSLI—NCSL International
- NMI—national metrology institute
- PID—persistent identifier
- PR—photometry-radiometry
- SIRP—SI reference point
- SoA—scope of accreditation

MII (measurement information infrastructure)

set of normative standards that unambiguously define data structures, taxonomies, service protocols and security for locating, communicating and sharing measurement information

Section 2

Motivation and Strategy

Motivation

- We want interoperability and reusability for machine-actionable measurement data.
    - Time and labor savings
    - Automatic data validation and verification
    - New productivity, services, data value and insight
    - Digital documents such as DCCs won't realize their potential otherwise.
- This requires standardized metrology metadata.
- One of least standardized data elements: measurand descriptions
    - Various DCC and other DX projects currently seek a measurand identifier.
    - Wanted: unique measurand PIDs

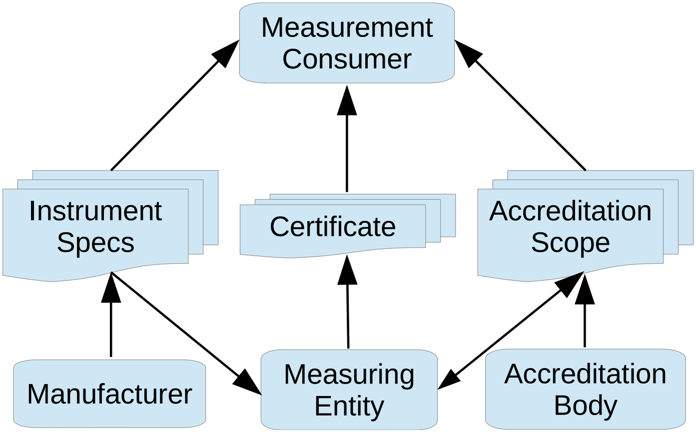
MII Proposal for Measurand Metadata

1. Standardize a measurand taxonomy.
2. Link taxa to KCDB CMC IDs.
3. Tag digital document data and service offerings with the taxa as metadata.

Spec: `Source.Voltage.DC`

SoA: `Measure.Voltage.DC`

Cert: `Source.Voltage.DC`
Cert: `Measure.Voltage.DC`



Solution: abstract taxon definitions customized for any context

Measure.Coefficient.Current.SpectralIrradiance

Definition: https://cie.co.at/eilvterm/17-25-063, https://cie.co.at/eilvterm/17-21-053

- **Required Parameters (instantiated with ranges)**
  - SpectralIrradiance
  - DetectorType {SiliconSingleElement, SiliconTrap, InGaAs, GaN, Ge, Photomultiplier, Pyroelectric, Thermopile, CryogenicRadiometer, Photocell, ...}
  - Wavelength
  - SpectralBandwidth
- **Optional Parameters (instantiated with ranges)**
  - Irradiance
  - OpticalPower
  - Current[.Output]

Uptake and Interest

Known interest in the MII Measurand Taxonomy

- Metrology companies: Cal Lab Solutions, IndySoft, Keysight
- "Enhancing the interoperability of Calibration Certificates", Diego Nahuel Coppa, Marcos Bierzychudek, Andrés Torn, Héctor Laiz, FORUM-MD Workshop 2025
- "Proposal to improve the interoperability of the DCC", Diego Coppa, DCCC 2024
- "Toward standardized language and structure for machine interpretable DCCs", David Balslev-Harder, DCCC 2024
- "Digital workflows and e-services in metrology for small and medium NMIs", Søren Kynde, DTI's DCC Theme Day 2023
- "Machine Readability—Automating the Extraction of Data from DCCs", David Balslev-Harder, DCCC 2023

Uptake requires a wide-ranging taxonomy.

Current Project

We would like to link the taxonomy to KCDB CMCs.

- Started with one service category (photometry) to test the process
- Extend coverage across the KCDB: electrical-RF, radiometry, . . .
- Extend coverage for additional measurand demand down the traceability chain.
  - Derived NMI measurement services
  - Lower laboratories' accredited CMCs
  - Unaccredited CMCs

The MII taxonomy will point to the KCDB since it already exists but future digital documents and enterprise systems may use the taxonomy as a FAIR standardized metadata resource.

Differences in Approach

BIPM proceeds with its own digital transformation, which includes PIDs and digitalized CMCs.

So what does the MII Measurand Taxonomy add?

- Coverage for all CMCs: NMI services, accreditation scopes, unaccredited services
- Interoperability for all measurement data: CMCs, DCCs, instrument specs, DCRs
- Comprehensive M-layer coverage
  - All quantity and unit systems (e.g., Dobson units)
  - All scale types (e.g, ordinal scales for hardness)
  - Aspects that disambiguate traditional quantity systems
  - Machine-targeted unit conversions and scale transformations

All MII metadata systems will point back to BIPM CMCs, SIRP, etc., whereever relevant.

Section 3

Tools and Process

Tools

- Open-source taxonomy editor at `https://github.com/CalLabSolutions/Metrology.NET_Public`
- Project hosted on GitHub at https://github.com/NCSLI-MII/measurand-taxonomy
- Provides the taxonomy as a combined XML file and as separate XML taxa
- In process: a repository to integrate quantities, units, measurands, CMCs
  - Pull data from the M-layer and KCDB APIs
  - Link taxa to M-layer quantities (aspects) and units (scales)
  - Link taxa to KCDB CMCs and service categories
  - Monitor coverage, find orphans, expose gaps, facilitate development

Process

Third effort: radiometry branch of the PR area. Steps:

1. Review documentation: “Classification of Services In Photometry And Radiometry”.
2. Draft initial taxa to match the services, sub services or individual services.
3. Focus on taxon names first, though parameter sets influence the names
4. Pull all the relevant KCDB CMC-entry data.
5. Sort and filter on service, subservice, individual service, quantity and instrument.
6. Analyze the method, units, uncertainty, comments and parameter data.
7. Supplement the data from other sources—experts, literature, standards, etc.—as required.
8. Draft a taxon set to represent the unique measurands and their parameters.

The information assembled at BIPM through CIPM and its Consultative Committees greatly facilitates taxon creation. The BIPM’s KCDB digitalization should speed the process considerably.

Example KCDB CMC Data

KCDB Field(s)	Data
metrologyAreaLabel	PR
branchValue, serviceValue	Properties of detectors and sources, (2) Properties of detectors
subServiceValue	(2.2) Responsivity, spectral, irradiance
individualServiceValue	(2.2.2) Broad band detector
quantityValue	Responsivity, spectral, irradiance
instrument	Broad band detector
instrumentMethod	Substitution with spectral responsivity standards
cmc	unit: $A/(W/m^2)$, $V/(W/m^2)$, reading$/(W/m^2)$
traceabilitySource	—
comments	Other type of detector could be measured
internationalStandard	—
parameters	Wavelength: 400 nm to 500 nm; Bandwidth: 4 nm to 50 nm; Irradiance: 1 μW to 50 μW

Branch: Properties of detectors and sources, Service: Detectors

Sub Service	Individual Service	Quantity	Taxon(s)—PRELIMINARY
Responsivity, spectral, power	Broad band detector	Responsivity, spectral, power	Measure.Ratio*.OpticalPower
Responsivity, spectral, irradiance	Broad band detector	Responsivity, spectral, irradiance	Measure.Ratio*.SpectralIrradiance*
|	Spectroradiometer	|	Measure.Ratio*.SpectralIrradiance*
Responsivity, spectral, radiance	Broad band detector	Responsivity, spectral, radiance	Measure.Ratio*.SpectralRadiance*
Responsivity, laser, power	General detector	Responsivity, laser, power	Measure.Ratio*.OpticalPower.CW.Laser
Responsivity, laser, energy	General detector	Responsivity, laser, energy	Measure.Ratio*.Energy.Pulse.Laser
Responsivity, solar, irradiance	General detector	Responsivity, solar, irradiance	Measure.Ratio*.Irradiance.Solar
|	|	|	Measure.Current.DC.DSR
|	Broadband detector	|	Measure.Ratio*.Irradiance.Solar
Resp., UV, BB irradiance	UV radiometer	Resp., UV, BB irradiance	Measure.Ratio*.Irradiance.UV
Resp., UV, BB rad. exposure	UV radiometer	Resp., UV, BB radiant exposure	Measure.Ratio*.RadiantExposure.UV
Resp, solar, spectral, irradiance	Solar spectroradiometer	Resp., solar, spectral, irradiance	Measure.Ratio*.SpectralIrradiance.Solar*

*These sub services also include . . . Coefficient.Voltage. . . and . . . Coefficient.Current. . . taxa (omitted for space).

Branch: Properties of detectors and sources, Service: Sources

Sub Service	Individual Service	Quantity	Taxon(s)—PRELIMINARY
Irradiance, spectral	Tungsten lamp	Irradiance, spectral	Measure.SpectralIrradiance*
|	Deuterium lamp	|	|
Radiance, spectral	Tungsten lamp	Radiance, spectral	Measure.SpectralRadiance*
|	Deuterium lamp	|	|
|	General source	|	|
Power, spectral total radiant	Laser	Power, spectral total radiant	Measure.OpticalPower.CW.Laser
|	|	|	Measure.OpticalPower.Pulse.Laser
Radiant intensity, spectral	Tungsten lamp	Radiant intensity, spectral	Measure.SpectralRadiantIntensity*
|	Deuterium lamp	|	|
Radiant flux, spectral	General source	Radiant flux, spectral	Measure.SpectralRadiantFlux*
|	Tungsten lamp	|	|

* Tokens including "Spectral" indicate spectral-density quantities, e.g., per nm.
Some KCDB CMC entries inevitably contradict themselves. Digitalization and input validation will help.

Example KCDB-Linkage Results

Taxon	**kcdbCode**
...	...
Measure.Coefficient.Voltage.SpectralIrradiance Measure.Coefficient.Current.SpectralIrradiance Measure.Ratio.SpectralIrradiance	AFRIMETS-PR-ZA-000006G1-1
Measure.Coefficient.Current.OpticalPower	APMP-PR-JP-000005T7-2
Measure.Coefficient.Voltage.Irradiance.Solar	EURAMET-PR-CH-00000DR2-1
Measure.Energy.Pulse.Laser	SIM-PR-US-00000A2B-2
Measure.SpectralRadiance	SIM-PR-CA-000009MC-1
...	...

Section 4

Conclusion

Photometry and Radiometry Service Coverage as of Feb 22nd, 2025

PR Services

1. Photometry ✓
2. Properties of detectors ✓
3. Spectral emission properties of sources ✓
4. Spectral properties of materials—taxa drafted
5. Spectrally-integrated measurements for sources and detectors—taxa drafted
6. Colour and other spectrally-integrated measurements of materials—taxa drafted
7. Fibre optics

Some PR sub services have no CMC entries in the KCDB.

KCDB CMC Coverage as of Feb 22nd, 2025

Area Code	CMC Count	Metrology Area	Taxon Coverage
AUV	Acoustics, Ultrasound, Vibration	1260	scattered
EM	Electricity and Magnetism	4640	$\approx$ 79 %*
L	Length	1696	scattered
M	Mass and related quantities	2973	scattered
PR	Photometry and Radiometry	1551	$\approx$ 56 %*
QM	Chemistry and Biology	6455	none
RI	Ionizing Radiation	3708	none
T	Thermometry	3001	scattered
TF	Time and Frequency	825	scattered
	Total	**26109**	**17 % to 29 %**

* Reported at NCSLI 2024 Conference

* Reported at DCC 2024, 2025 Conferences

Recommendations

Establish and use a measurand taxonomy

- Unique measurand PIDs with unlimited human-readable aliases
- Fully qualifies measurands for interoperable digital documents
- (DCCs, instrument specs-DCRs, SoAs, . . .)
- Provenance to BIPM: KCDB, SIRP, etc.

Collaboration

- Available for metrologists to augment, review and critique
- Current information
  - GitHub for configuration management (submission, review, approval): `https://github.com/NCSLI-MII`
  - Open-source taxonomy and SoA editors: `https://github.com/CalLabSolutions/Metrology.NET_Public`
  - Further info: http://miiknowledge.wikidot.com/

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And Thank You for your time!

Collaboration opportunities? Please bring your expertise!

Questions?