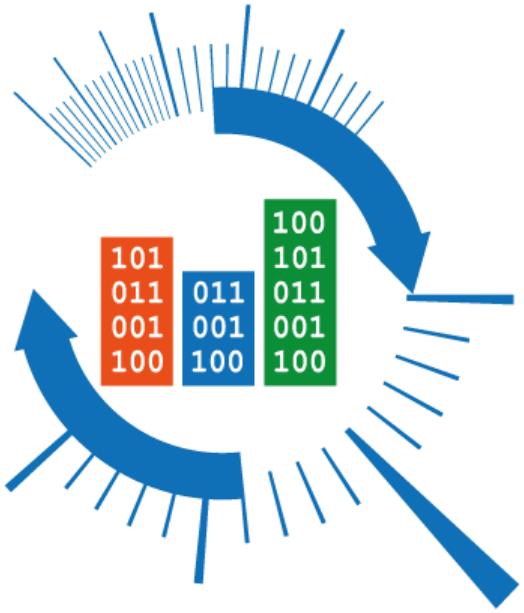

RDM in EPM projects: Module 3 - Breakout session: exploration of the SI digital framework

Peter Blattner (Chief Metrology Officer)

METAS, Switzerland

Member of various FORUM-MD WG/TGs

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METAS
Ihre Referenz.

Objectives of my talk

- Examples of how information (data/metadata) can be made accessible.
- Promote the SI Digital Framework.
- Provide practical hints on how to access and deal with structured data.

27th CGPM in November 2022

Resolution 2

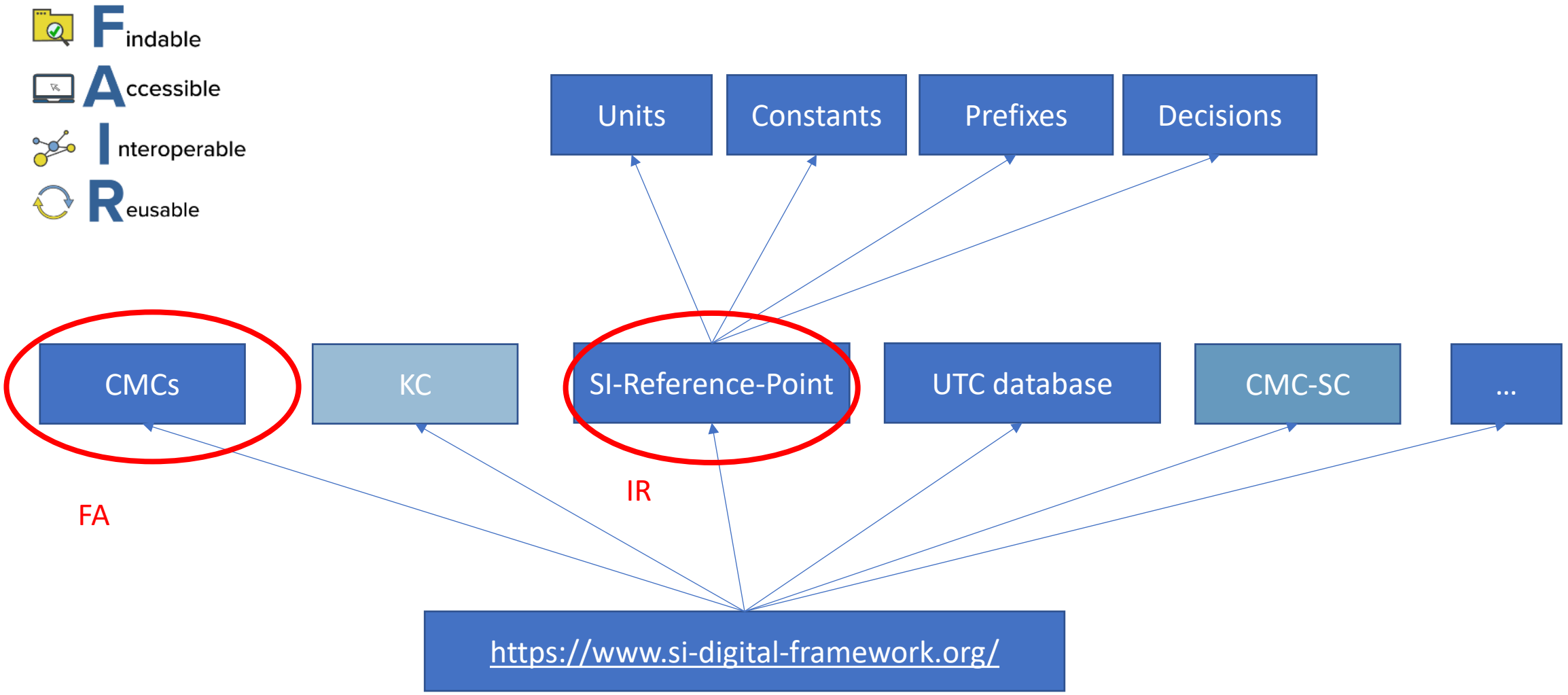
"On the global digital transformation and International System of Units"

Encourages

the CIPM to undertake the development and promotion of an SI Digital Framework, that will include the following features:

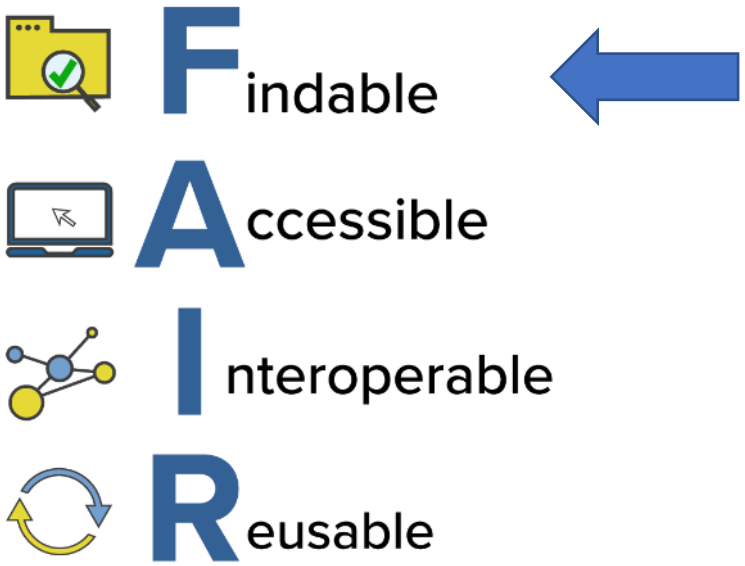
- a globally accepted digital representation of the SI, compatible with, and useable within, digital data exchange standards and protocols, whilst maintaining compatibility with existing non-digital solutions,
- facilitating use of digital certificates in the existing robust infrastructure for the world-wide recognition and acceptance of calibration and measurement capabilities,
- the adoption of the FAIR principles (Findable, Accessible, Interoperable, and Reusable) for digital metrological data and metadata, ensuring that other communities recognize the critical importance of metrological traceability for measurement data, the latter being an established requisite for building trust.

BIPM/CIPM initiative: SI Digital Framework (SIDF)



Digital references for all CMCs

CMC: calibration and measurements capabilities



Persistent identifier (pid): kcdbCode

RMO-Area-A2-ID-V

where

- RMO acronym of the Regional Metrology Organization through which the CMC was submitted
- Area acronym of the metrology area
- A2 ISO 3166-1 2-letter country code (or BIPM code for an international organization participating in the CIPM MRA)
- ID 8-character alphanumeric code
- V 1-character alphanumeric version value (from 1 to Z).

Example:

EURAMET-EM-CH-00000GF9-5

How to find the kcdbCode?

Method 1 : CMC search

Results for: Mass and related quantities > Mass, mass standards > Mass > Mass standard > Mass standard > Switzerland

10 results

SELECT ALL

EXPORT XLS

New since Feb 2025

In the CMC uncertainty statements, $Q[a,b] = [a^2 + b^2]^{1/2}$

Unless otherwise stated the expanded uncertainties given below correspond to $k = 2$ (at a 95 % level of confidence)

GROUP ID	SERVICE PROVIDER	INSTITUTE SERVICE CODE	EXPANDED UNCERTAINTY CMC	PARAMETERS	APPROVAL DATE	KCDB CMC ID
	Switzerland **METAS**		[0.7 to 1.4] µg		2008-07-02	EURAMET-M-CH-00000CHH-1
	Switzerland **METAS**		[1.4 to 2] µg		2008-07-02	EURAMET-M-CH-00000CHI-1
	Switzerland **METAS**		[4 to 1.0E1] µg		2008-07-02	EURAMET-M-CH-00000CHK-1
	Switzerland **METAS**		[2 to 4] µg		2008-07-02	EURAMET-M-CH-00000CHJ-1

How to use the kcdbCode?

- Human readable access through permanent link: https://si-digital-framework.org/kcdb-cmc/
- Example: https://si-digital-framework.org/kcdb-cmc/EURAMET-EM-CH-00000GF9-5

KCDB-CMC Identifier: EURAMET-EM-CH-00000GF9-5

Published in the KCDB

Approved on 04 January 2022

KCDB Service Category: EM/RF-11.3.2

Switzerland, METAS (Federal Institute of Metrology)

Institute service identifier : 217.01.02

Radio frequency measurements , Scattering parameters: reflection coefficient (Sii) in waveguide, phase : **-180 degree to 180 degree**
Passive device
Absolute expanded uncertainty : **0.9 degree to 1.1E1 degree**

Uncertainty table

Connector	abs(Sxx)	67 GHz to 75 GHz	75 GHz to 90 GHz	90 GHz to 110 GHz	110 GHz to 116.5 GHz
WR10	0	-	-	-	-
WR10	0.1	11.1 deg to 6.6 deg	6.6 deg to 4.7 deg	4.7 deg to 4.2 deg	4.2 deg to 4.3 deg

Access to earlier versions

- https://si-digital-framework.org/kcdb-cmc/EURAMET-EM-CH-00000GF9-4
- https://si-digital-framework.org/kcdb-cmc/EURAMET-EM-CH-00000GF9

without “V” -> most recent version (dynamic!!)

KCDB-CMC Identifier: EURAMET-EM-CH-00000GF9-4

Archived

Approved on 11 May 2017. Archived on 04 January 2022. Superseded by EURAMET-EM-CH-00000GF9-5.

KCDB Service Category: EM/RF-11.3.2

Switzerland, METAS (Federal Institute of Metrology)

Radio frequency measurements , Scattering parameters: reflection coefficient (Sii) in waveguide, phase : **-18(**

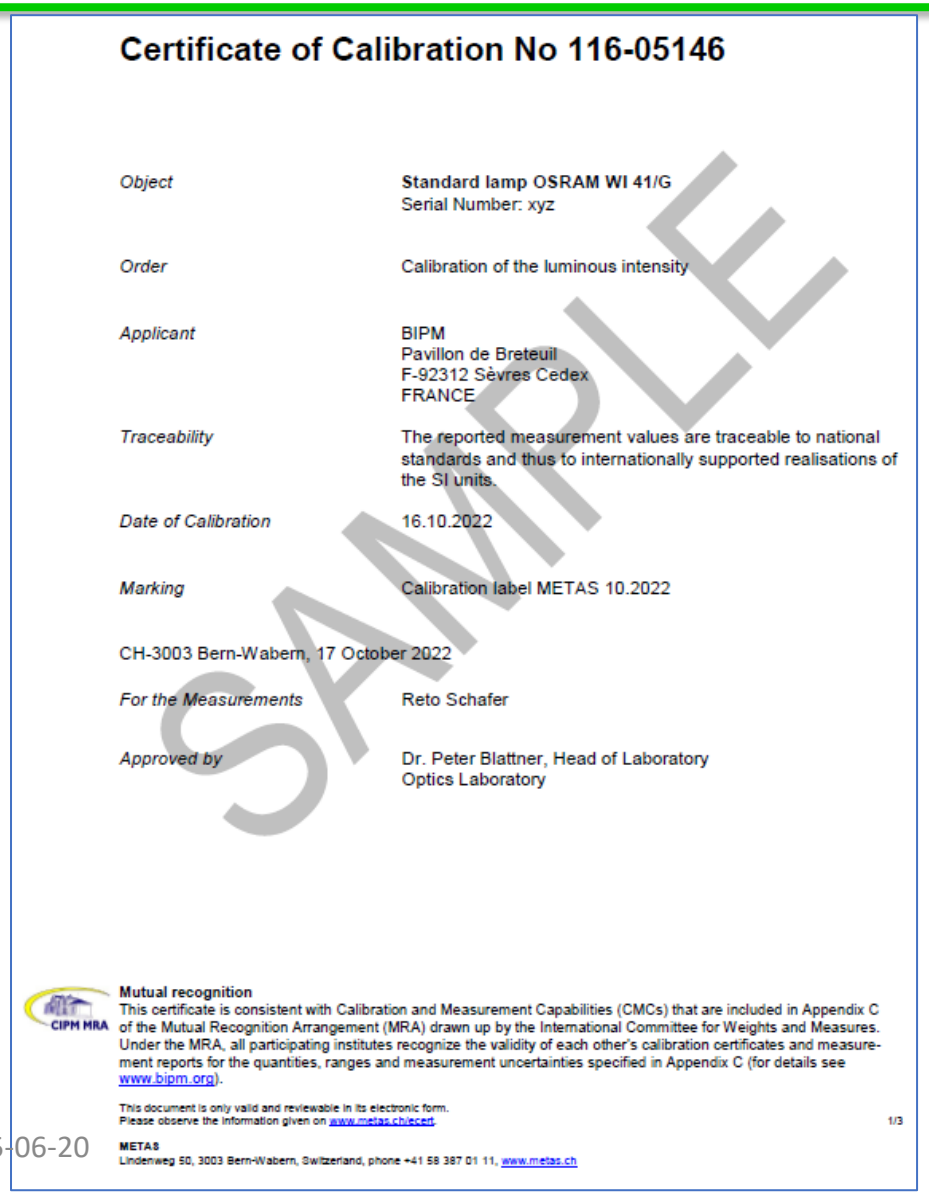
One- and two-port devices

Absolute expanded uncertainty : **0.9 degree to 1.1E1 degree**

Uncertainty table

Connector	abs(Sxx)	9 kHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 20 GHz	20 GHz to 33 GHz	33 GHz to 45 GHz
BNC 50 Ohm	0	-	-	-	-	-	-

Potential applications: Calibration Certificate



Certificate of Calibration No 116-05146

Object	**Standard lamp OSRAM WI 41/G** Serial Number: xyz
Order	Calibration of the luminous intensity
Applicant	BIPM Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE
Traceability	The reported measurement values are traceable to national standards and thus to internationally supported realisations of the SI units.
Date of Calibration	16.10.2022
Marking	Calibration label METAS 10.2022

CH-3003 Bern-Wabern, 17 October 2022

For the Measurements	Reto Schafer
Approved by	Dr. Peter Blattner, Head of Laboratory Optics Laboratory

SAMPLE

Mutual recognition
This certificate is consistent with Calibration and Measurement Capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee for Weights and Measures. Under the MRA, all participating institutes recognize the validity of each other's calibration certificates and measurement reports for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see www.bipm.org).

This document is only valid and reviewable in its electronic form.
Please observe the information given on www.metas.ch/lecert.

1/3

METAS
Lindenweg 50, 3003 Bern-Wabern, Switzerland, phone +41 58 387 01 11, www.metas.ch

Link to CMC entries in Calibration Certificate

QR-Tag in Calibration Certificate

Digital Calibration Certificate (https://www.ptb.de/dcc)

```
<dcc:statement refType="basic_isInCMC">
    <dcc:reference>EURAMET-M-CH-00000CHL-2</dcc:reference>
    <dcc:declaration>
        <dcc:content lang="en">This certificate is consiste
    </dcc:declaration>
    <dcc:valid>true</dcc:valid>
    <dcc:respAuthority>
        <dcc:name>
            <dcc:content>METAS</dcc:content>
        </dcc:name>
        <dcc:location>
            <dcc:city>Bern-Wabern</dcc:city>
```

“Machine” access to SI Digital Framework

«browser»

SI Digital Framework

KCDB CMC RECORDS

Version: 1.0 Beta , last update: 2025-03-11

CMC Identifier: EURAMET-EM-CH-00000GF9-5

Published in the KCDB

Approved on 04 January 2022

KCDB Service Category: EM/RF-11.3.2

Switzerland, METAS (Federal Institute of Metrology)

Institute service identifier : 217.01.02

Radio frequency measurements , Scattering parameters: reflection coefficient (Sii) in waveguide, phase : **-18(**

Passive device

Absolute expanded uncertainty : **0.9 degree to 1.1E1 degree**

Uncertainty table

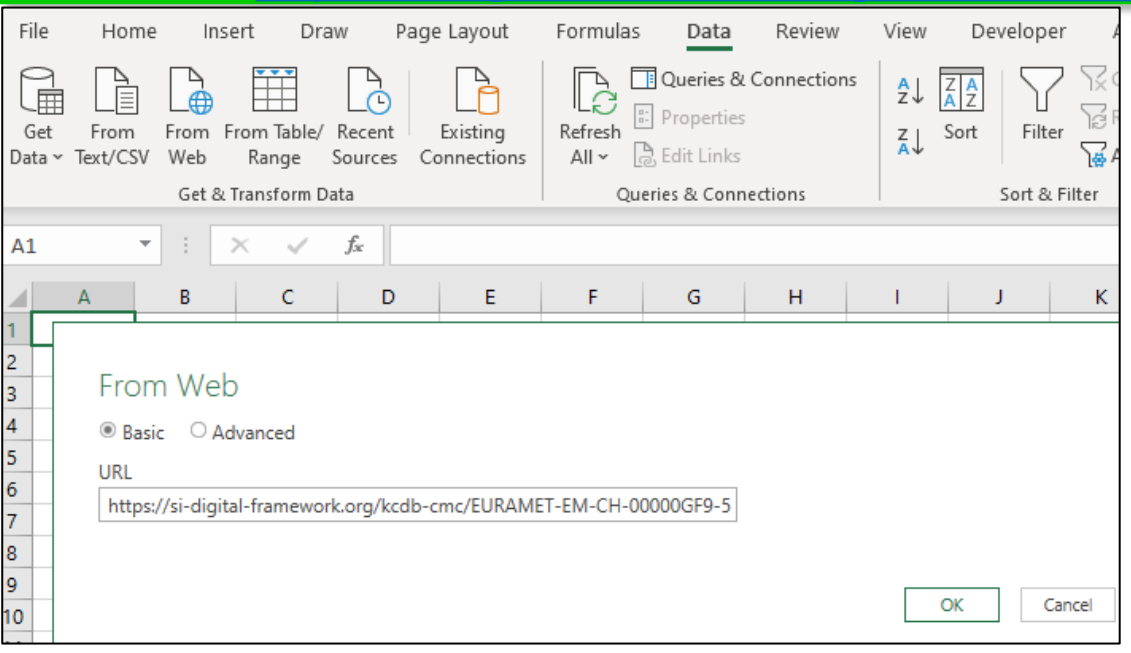
Connector	abs(Sxx)	67 GHz to 75 GHz	75 GHz to 90 GHz	90 GHz to 110 GHz	110 GHz to 116.5 GHz
WR10	0	-	-	-	-
WR10	0.1	11.1 deg to 6.6 deg	6.6 deg to 4.7 deg	4.7 deg to 4.2 deg	4.2 deg to 4.3 deg
WR10	0.2	4.9 deg to 3.2 deg	3.2 deg to 2.5 deg	2.5 deg to 2.2 deg	2.2 deg
WR10	0.3	2.9 deg to 2.1 deg	2.1 deg to 1.8 deg	1.8 deg to 1.5 deg	1.5 deg to 1.6 deg
WR10	0.4	2.0 deg to 1.6 deg	1.6 deg to 1.4 deg	1.4 deg to 1.2 deg	1.2 deg to 1.3 deg

«python-script, …»

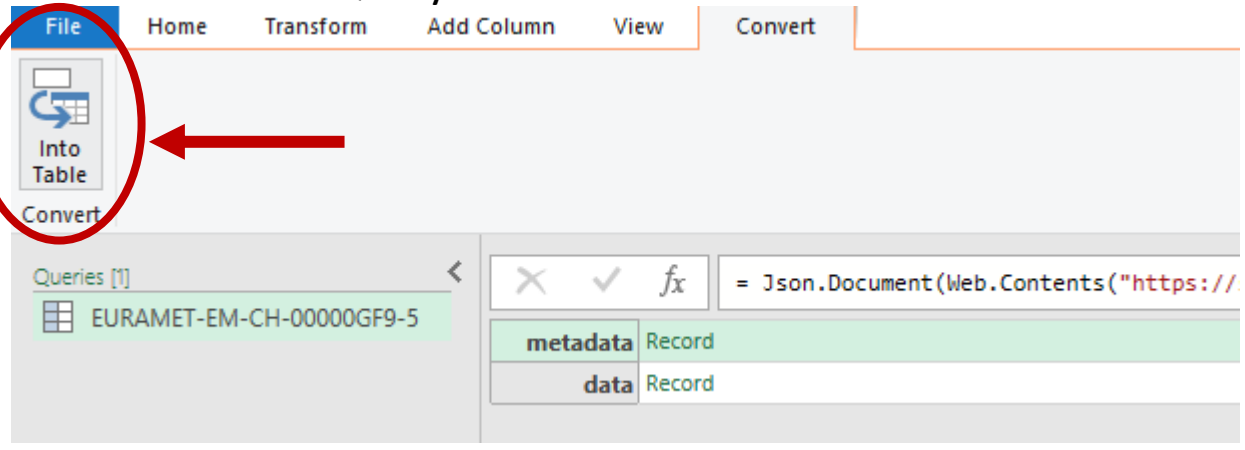

```
metadata:
    queryDate:              "09 March 2024"
data:
    kcdbCode:               "EURAMET-EM-CH-00000GF9-5"
    status:                 "Published"
    publicationDate:        "2022-01-04"
    approvalDate:           "2022-01-04"
    kcdbServiceCategory:    "EM/RF-11.3.2"
    branchValue:            "Radio frequency measurements"
    serviceValue:           "Radio frequency measurements"
    subServiceValue:        "Scattering parameters (vectors)"
    individualServiceValue: "Reflection coefficient in waveguide (real and imaginary)"
    instrument:             "Passive device"
    instrumentMethod:       "Vector network analyser"
    parameters:
        0:
            parameterName:  "Frequency"
            parameterValue: "67 GHz to 116.5 GHz"
        1:
            parameterName:  "Connector"
            parameterValue: "WR10"
        2:
            parameterName:  "S11 and S22"
            parameterValue: "0.1 to 1.0"
    id:                     35080
    statusDate:             "2022-01-04"
    domainCode:             "PHYSICS"
```

Intermezzo 1: Using Excel® to access the SIDF (1)

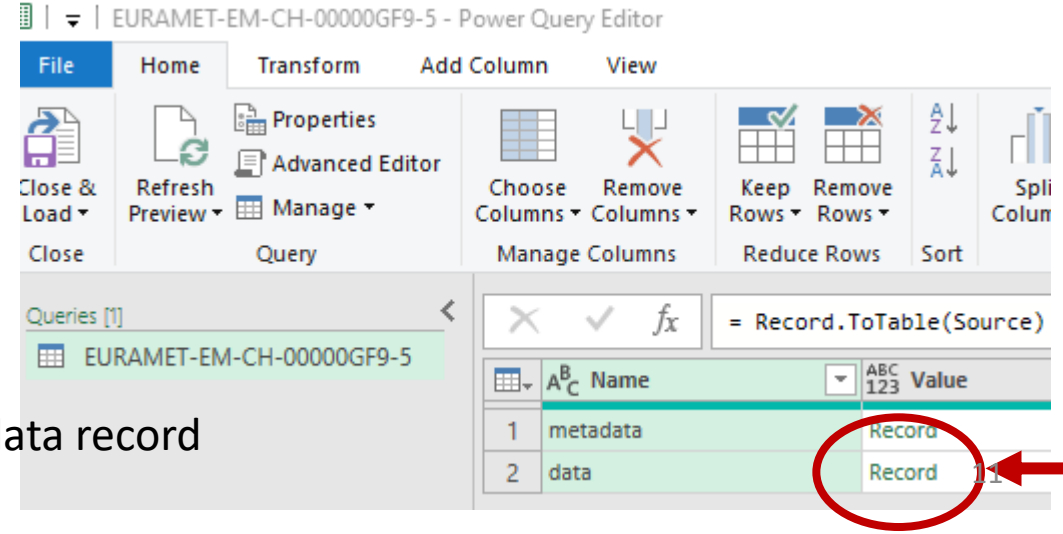
https://si-digital-framework.org/kcdb-cmc/EURAMET-EM-CH-00000GF9



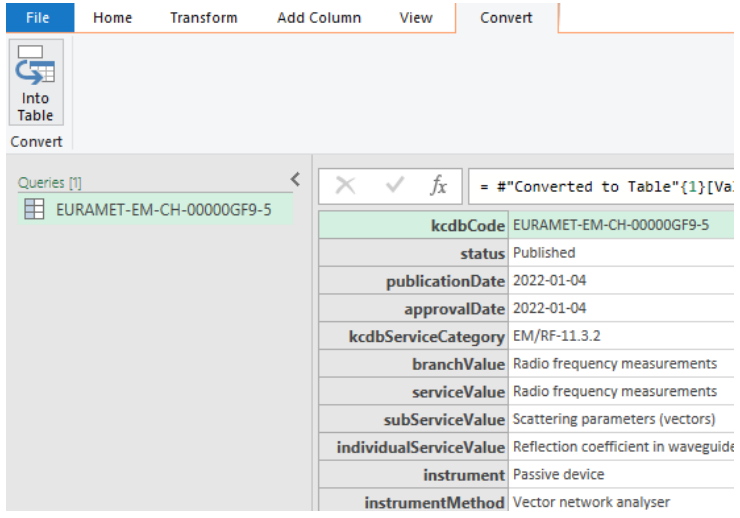
PowerQuery - Editor



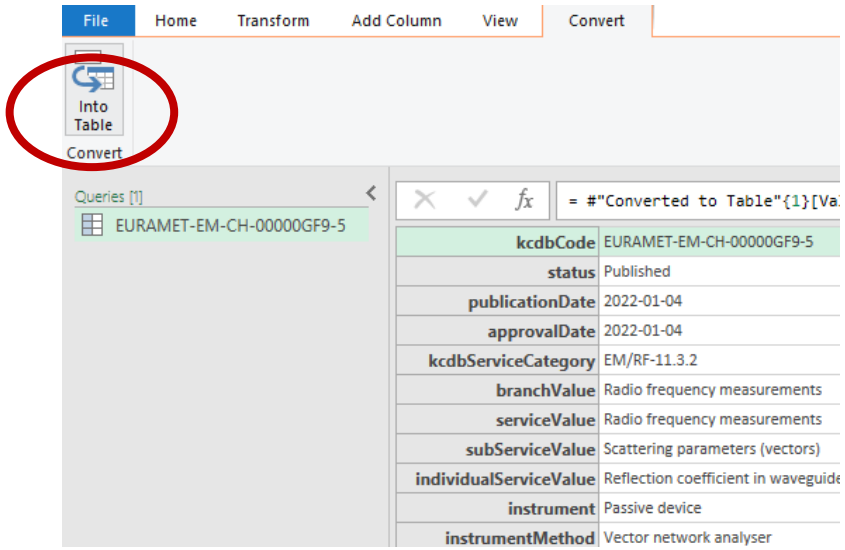
Convert into table



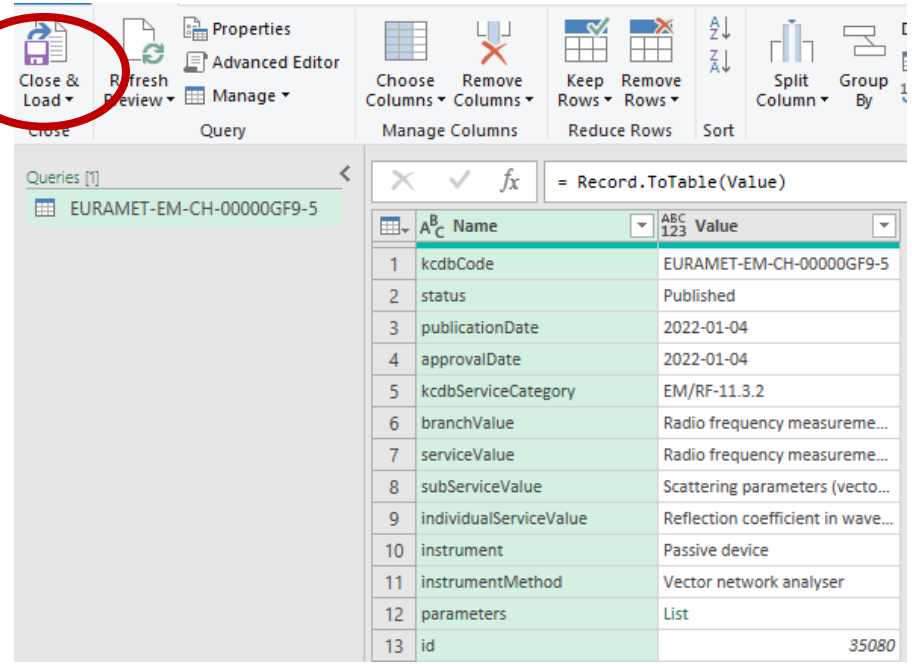
Expand data record



Intermezzo 1: Using Excel® to access the SIDF (2)



Convert into table



close and load

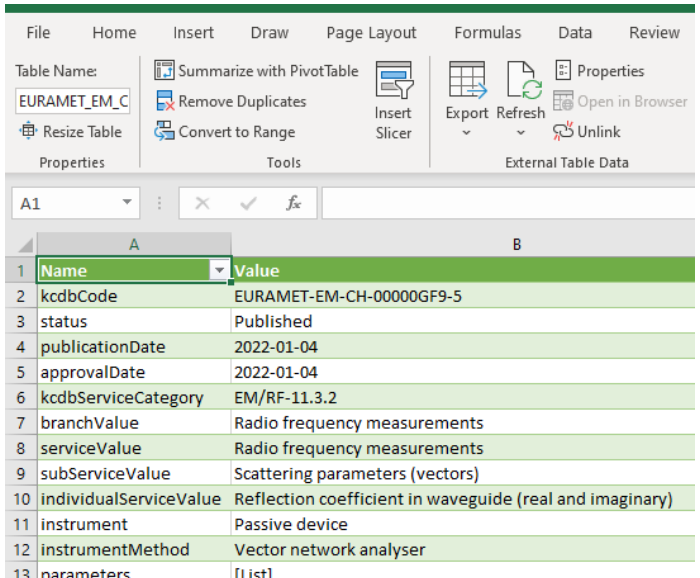


Table is linked to the SIDF: «refresh» will grap the latest information from the SIDF

Application example of accessing the KCDB-API: Up-to-date list of CMCs

KCDB API CMC COUNTRY QUERY

purpose: allows to extract all the CMCs of specific country and metrology area

documentation of the API can be found here:

https://www.bipm.org/api/kcdb/swagger-ui.html#/

Tested for versionApiKcdb 1.0.7

peter.blattner@metas.ch

Version: 3

	Parameter	Value
metrologyArea->	metrologyArea	Photometry and Radiometry
select country->	country	Czechia
select elements/page (def:200)	totalElements	200
select a page (def:0)	page	0

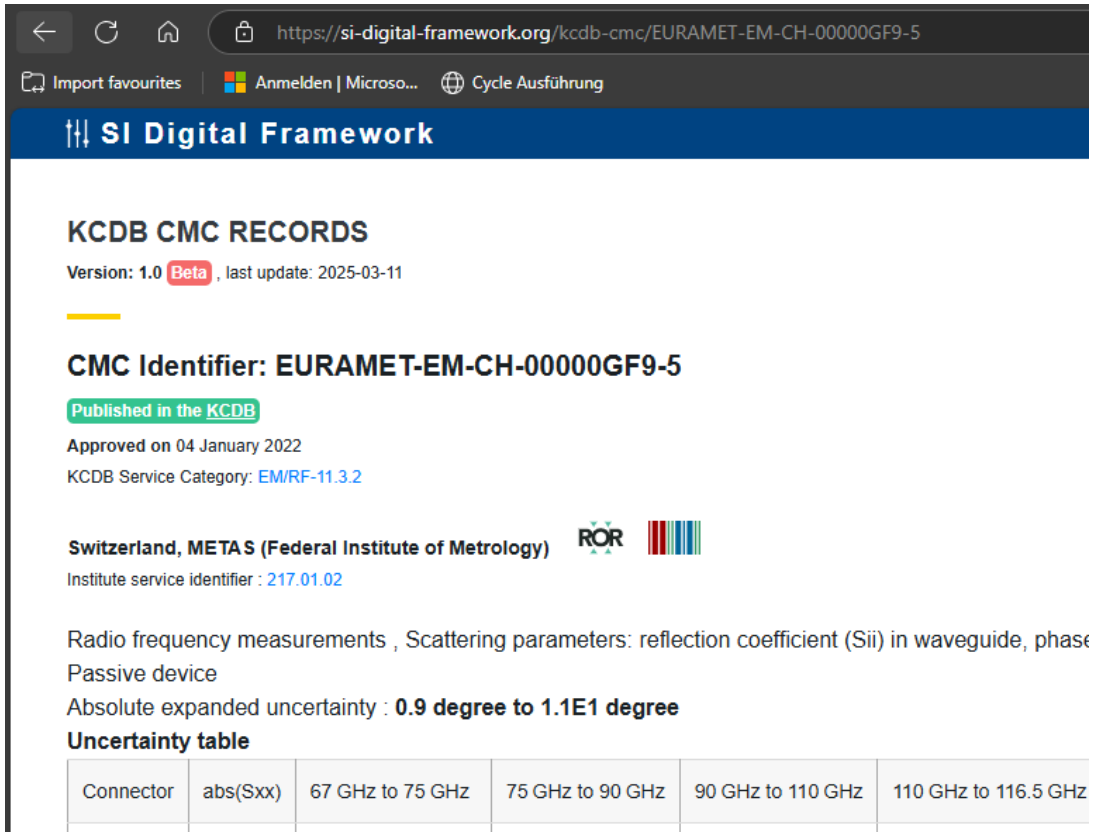
Excel® tool available on request (peter.blattner@metas.ch)

id	status	statusDate	kcdbCode	domainCode	ologyAr	rmo	countryVa	nmiCode	nmiName	nmiServiceCo	nmiServic	quantityValue
11238	Published	2019-10-22	EURAMET-PR-CZ-000008O6-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11239	Published	2019-10-22	EURAMET-PR-CZ-000008O7-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11240	Published	2019-10-22	EURAMET-PR-CZ-000008O8-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11241	Published	2019-10-22	EURAMET-PR-CZ-000008O9-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11242	Published	2019-10-22	EURAMET-PR-CZ-000008OA-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11243	Published	2019-10-22	EURAMET-PR-CZ-000008OB-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11244	Published	2019-10-22	EURAMET-PR-CZ-000008OC-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11245	Published	2019-10-22	EURAMET-PR-CZ-000008OD-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Transmittance, regular, spectral
11246	Published	2019-10-22	EURAMET-PR-CZ-000008OE-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Absorbance, regular, spectral
11247	Published	2019-10-22	EURAMET-PR-CZ-000008OF-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Absorbance, regular, spectral
11248	Published	2019-10-22	EURAMET-PR-CZ-000008OG-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Absorbance, regular, spectral
11249	Published	2019-10-22	EURAMET-PR-CZ-000008OH-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Absorbance, regular, spectral
11250	Published	2019-10-22	EURAMET-PR-CZ-000008OI-1	PHYSICS	PR	EURAMET	Czechia	CMI	Czech Metrology Institute			Absorbance, regular, spectral

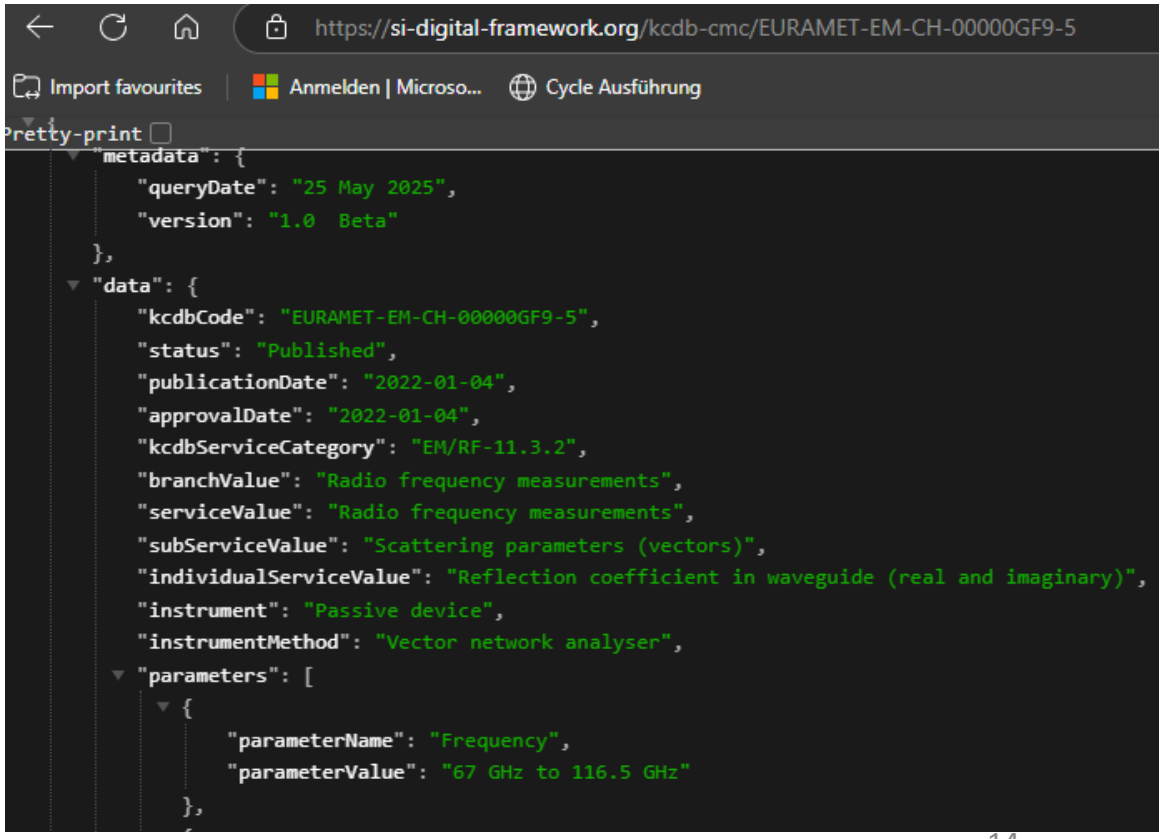
Intermezzo 2 – browser

https://si-digital-framework.org/kcdb-cmc/EURAMET-EM-CH-00000GF9

The content returned by a website can differ based on the requesting client. For example, a browser may receive a fully rendered HTML page with dynamic content, while a Python script or other non-browser client might receive raw data, a simplified response, or no content at all—depending on how the server interprets the request.



Same browser but with «ModHeader» extension



https://si-digital-framework.org/kcdb-cmc/EURAMET-RI-FR-00000L1E-1

KCDB CMC RECORDS

Version: 1.0 Beta , last update: 2024-11-14

CMC Identifier: EURAMET-RI-FR-00000L1E-1

Published in the KCDB

Approved on 21 September 2016

KCDB Service Category: RI/RAD-1.3.1

Nuclide(s): Ag-110m

https://si-digital-framework.org/quantities/ARRN [1]

https://si-digital-framework.org/SI/units/becquerel

France, LNE-LNHB (Commissariat à l'énergie atomique / Laboratoire National Henri Becquerel)

Institute service identifier : EUR-RAD-LNE-LNHB-2002

Activity , Single nuclide solution : **5.00E4 Bq to 5.00E7 Bq**

Relative expanded uncertainty **1.5 %**

Secondary standard ionisation chamber, balance

Ag-110m, glass ampoule

Reference standard : 4πβγ-coincidence counting

Source of traceability : LNE-LNHB

Service provided by the LNE-LNHB

SI Digital Framework : SI-Reference-Point

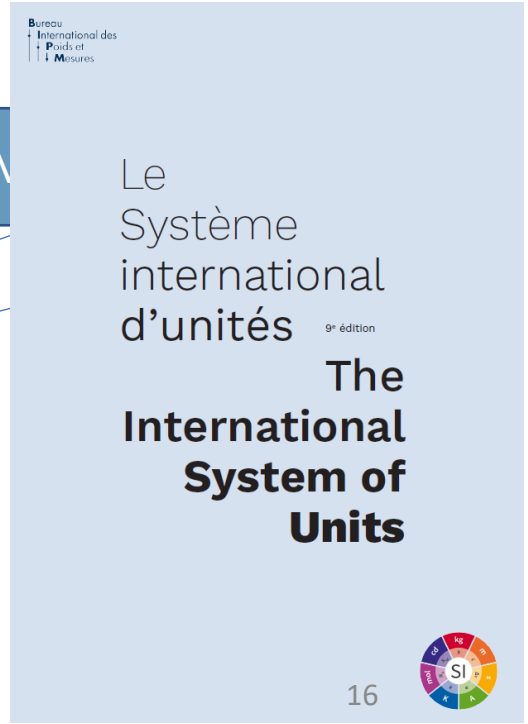
Findable
Accessible
Interoperable
Reusable

Units | Constants | Prefixes | Decisions

CMCs | KC | SI-Reference-Point | UTC database | CM

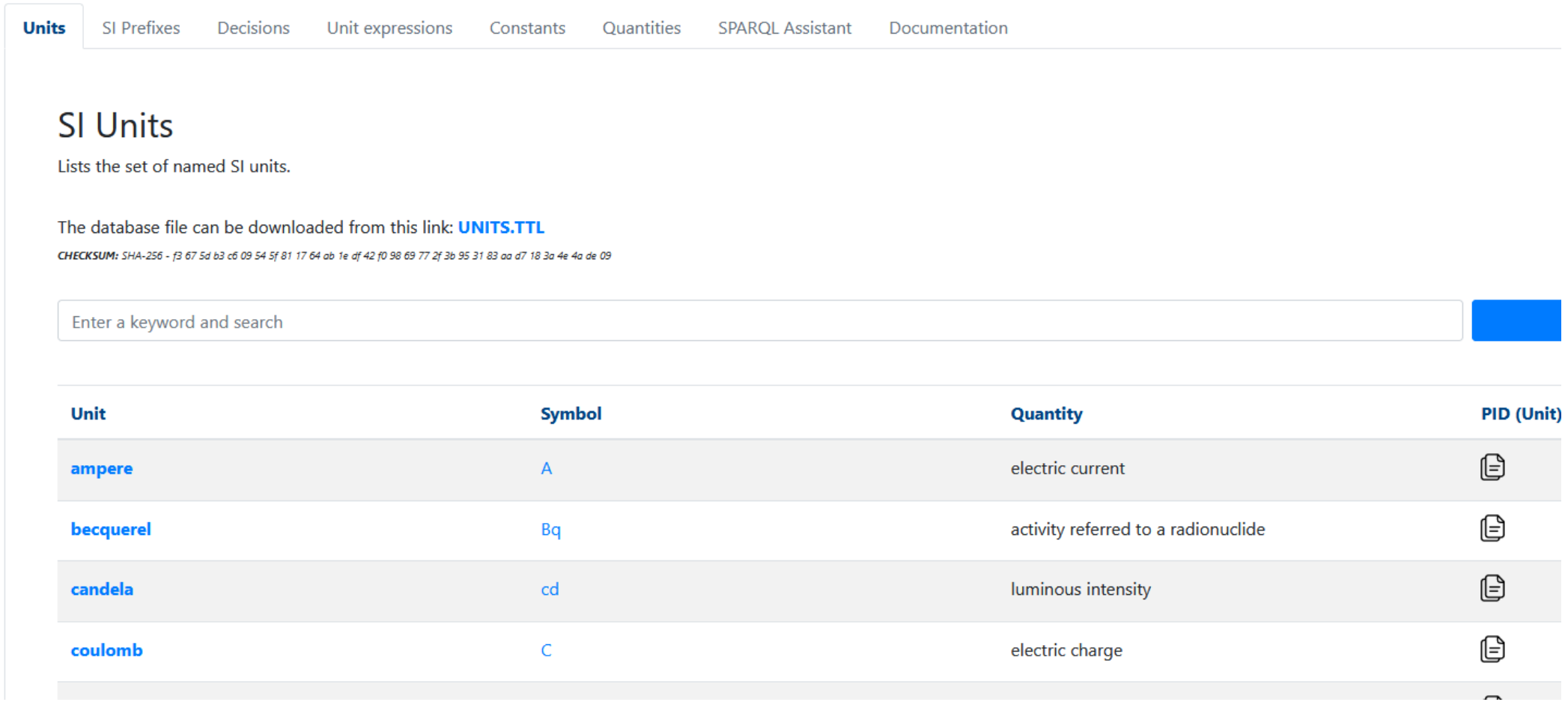
https://www.si-digital-framework.org/

Digital representation of the SI-Brochure



SI-Reference-Point

https://si-digital-framework.org/SI/units



Example: unit lx

- https://si-digital-framework.org/SI/units/lux

lux

Back to list

Unit	**lux**
Symbol	**lx**
Quantity	illuminance
Defining Resolution	CGPM Resolution 12 (1960)
Unit Type	Named SI derived unit
Unit expressed in terms of SI base units	$\mathrm{cd\ sr\ m^{-2}}$
Unit expressed in terms of other SI units	$\mathrm{lm\ m^{-2}}$

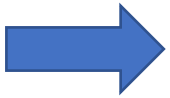
Name	Value
label	lux
symbol	lx
qLabel	illuminance
pid	http://si-digital-framework.org/SI/units/lux
unitId	lux
definingResolution	CGPM11-Res12
resolutionLink	https://doi.org/10.59161/cgpm1960res12e
qCode	ILLU
unitType	Named SI derived unit
unitTypeId	http://si-digital-framework.org/SI#SISpecialNamedUnit
eventName	11th meeting of the CGPM
eventDate	1960-10-20
resNbr	12
resolutionBody	CGPM
resolutionType	Resolution
hasPreviousDefinition	FALSCH
prefixRestriction	FALSCH
strExpressionInBaseSIUnits	cd . sr . m^-2
strExpressionInOtherSIUnits	lm . m^-2

Intermezzo 3: Using Python to access SIDF

```
import requests
url = "https://si-digital-framework.org/constants"
response = requests.get(url)

# Parse the JSON response
data = response.json()
constants = data.get("constants", [])

# Print the name, value string, and unit
for constant in constants:
    label = constant.get("label")
    value_str = constant.get("valueStr")
    unit = constant.get("strExpression")
    print(f"{label}: {value_str} {unit}")
```



```
Avogadro constant: 6.022 140 76 x 10²³ mol^-1
Boltzmann constant: 1.380 649 x 10⁻²³ J . K^-1
Planck constant: 6.626 070 15 x 10⁻³⁴ J . s
elementary charge: 1.602 176 634 x 10⁻¹⁹ C
hyperfine transition frequency of Cs-133: 9 192 631 770 Hz
luminous efficacy: 683 lm . W^-1
speed of light: 299 792 458 m . s^-1
```

There is more on the SI reference point: Identifiers for compounds units

Unit expressions

A parsing tool to provide the PID and semantic model for compound units.

Non-ASCII characters used for representation of prefix micro and units degree Celsius, ohm, degree, arcminute, arcsecond.

μ ℃ Ω ° ′ ″

kg.mm2.ns-2

Enter your unit expression using the syntax below:

Syntax: Enter your unit expression (without spaces) using the recommended symbols for units and prefixes. Use the buttons above to enter any special characters.
Indicate multiplication of units using a dot on the line (e.g. N.m for newton metre).
Indicate an exponent with a digit (e.g. mm2 for millimetre squared, mm^2); use a minus sign for negative exponents (e.g. ns-2 for per nanosecond squared, ns^{-2}).

PIDs for compound units

https://si-digital-framework.org/SI/units/kilogram.millimetre2.nanosecond-2

Expression analysis

Compound unit **kg.mm2.ns-2**

There is more on the SI reference point : ontology

RDF (Resource Description Framework)

Subject	→	Predicate	→	Object
:watt		si:hasSymbol		"W"
:watt		si:hasDefiningResolution		cgpm:CGPM11-Res12
:watt		si:isUnitOfQtyKind		quantities:POWR

-> SPARQL (query language)

->knowledge graph

SI Reference Point

This service constitutes the authoritative digital refe
constants, and a parsing tool for the PID and semanti

Turtle (Terse RDF Triple Language)-Files:

Knowledge base

SI.TTL

CHECKSUM: *SHA-256 - b8 11 05 c5 e9 30 d5 53 b1 ee 9b 4f e9 6e b7 2c e0 cd dd 06 05 ea 61 90 f9 40 c9 9a f1 a2 c3 e*

UNITS.TTL

CHECKSUM: *SHA-256 - 90 ac 02 33 2a 65 08 fd 08 63 5f 6e ad 9f a1 09 62 19 33 b2 19 e3 77 97 5f d1 e9 5b 64 03 76*

PREFIXES.TTL

CHECKSUM: *SHA-256 - a4 b4 08 1f 80 55 54 32 7a aa 08 1a e4 5b a4 63 ae 05 76 ae e1 b9 d0 7d ec 5f ab 29 65 4a 7c*

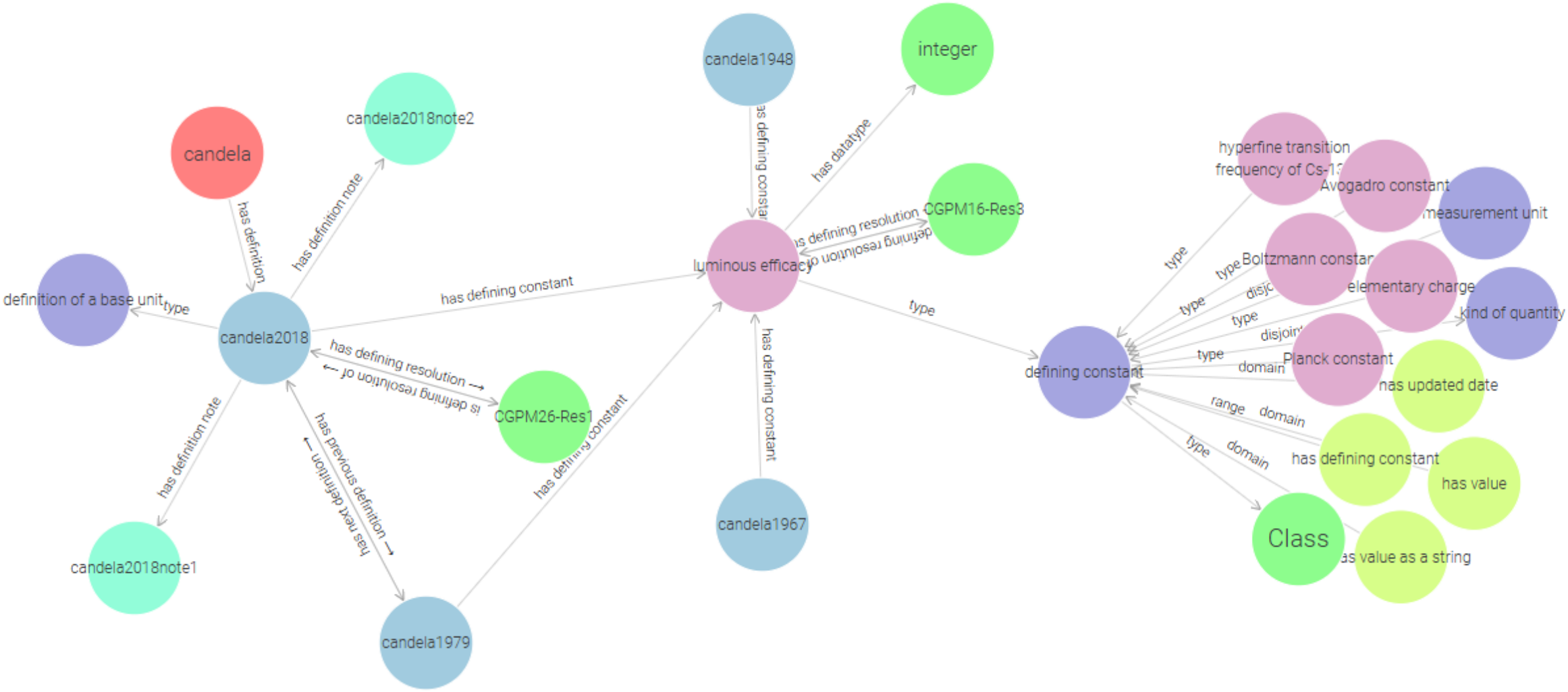
DECISIONS.TTL

CHECKSUM: *SHA-256 - fc e0 4c 42 a1 e5 4e b6 5e f6 d7 d8 87 02 49 fe 1e 12 ca 2b 89 cf 90 a7 34 d1 ce ec 73 ad 93 25*

CONSTANTS.TTL

CHECKSUM: *SHA-256 - 15 99 e7 51 fa 16 33 91 89 93 f5 c8 28 d2 74 f1 f9 b9 43 63 80 69 46 45 d1 c1 d7 71 27 e8 8c 4*

Exploring the ontology (GraphDB)



Conclusions

Resolution 2

"On the global digital transformation and International System of Units"

Encourages

the CIPM to undertake the development and promotion of an SI Digital Framework, that will include the following features:

- a globally accepted digital representation of the SI, compatible with, and useable within, digital data exchange standards and protocols, whilst maintaining compatibility with existing non-digital solutions,
- facilitating use of digital certificates in the existing robust infrastructure for the world-wide recognition and acceptance of calibration and measurement capabilities,
- the adoption of the FAIR principles (Findable, Accessible, Interoperable, and Reusable) for digital metrological data and metadata, ensuring that other communities recognize the critical importance of metrological traceability for measurement data, the latter being an established requisite for building trust.

(mostly) ready to be used